THE SOCIETY FOR INTEGRATIVE AND COMPARATIVE BIOLOGY

Society for Integrative and Comparative Biology

with the

Animal Behavior Society

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The Crustacean Society

2012 SICB

Annual Meeting

3-7 January

Charleston, South Carolina

Abstract Book

Oral Abstracts

59.4 ABBOTT, EM*; AZIZI, M; ROBERTS, TJ; Univ. of California, Irvine, Brown University; *emily.m.abbott@gmail.com*
Extrinsic loading in Cuban tree frog jumping
It is common for locomoting animals to bear additional loads. It may occur naturally, as with gravidity or large feeding events, or artificially, such as with any weight lifting activity. Jumping with external loads has been studied in humans to determine maximal performance, develop efficient training programs and define muscular properties. However, loading effects in animals specialized for saltatory locomotion have not been thoroughly studied. We examined the force-load relationship of Cuban tree frog (*Osteopilus septentrionalis*) jumping to assess whether the mechanics of extrinsically loaded jumping are indicative of either a muscular or an elastic spring model. It was assumed that in jumps powered solely by muscle, the forces produced during a jump would increase with increased extrinsic load (F=ma). On the other hand, in jumps utilizing an elastic mechanism, forces produced during jumping would not increase with extrinsic load and would be a function of the constant elastic properties of the spring (F=kx=ma). Five individuals (body mass 15.1-32.2g) were jumped from a force plate to quantify peak power, work, peak force, takeoff velocity and jump duration. The frogs were loaded with removable custom made nylon backpacks placed near the center of mass and filled with measured amounts of lead shot. Each individual was jumped with six different external loads equivalent to 0%, 30%, 60%, 90%, 120% and 150% of body weight. We found that these frogs maintain consistent work and peak force performance across all loads. Therefore, we conclude that even under substantial loading conditions, Cuban tree frogs are utilizing elastic mechanisms during their jumps. Supported by NSF grant 642428 to TJR.

14.1 ABZHANOV, A; Harvard University, Cambridge; *abzhanov@fas.harvard.edu*
Pecking at the Origin of Morphological Diversity: Insights from Darwin's Finches and Other Birds
The faces of vertebrates display a number of species-specific and adaptive characteristics, which they acquired during evolution by natural selection. The classic textbook example of adaptive radiation, natural selection and niche partitioning in animals is the fifteen closely related species of Darwin's finches (Thraupidae, Passeriformes), whose primary diversity is in the size and shape of their beaks. This natural morphological diversity is associated with the exploitation of various ecological resources and its developmental basis is not fully understood. It is likely that this stunning diversity of beaks in Darwin's finches and cranial morphology in vertebrates more generally was produced by alterations in their craniofacial developmental genetics. We continue to discover high degree of modularity in the developing finch beaks. For example, we recently discovered that two distinct regulatory and tissue modules regulate beak shapes. Such levels of modularity help to explain the levels of morphological variation observed in Darwin's finches. Moreover, we began analyzing beak shapes using mathematical approaches followed by developmental studies in both Darwin's finches as well as other groups of songbirds. These studies allow us better understand developmental mechanisms for morphological evolution in animals. Finally, we are using a combination of morphometrics, comparative and functional approaches to study evolution of the avian-specific cranial features during their evolution from more basal archosaurs and theropod dinosaurs. Our analyses reveal novel patterns and mechanisms of the origin and diversification of avians on both micro- and macro-evolutionary levels.

63.5 ACOSTA, Wendy*; MEEK, Tom H.; SCHUTZ, Heidi; DLUGOSZ, Elizabeth M.; VU, Kim T.; GARLAND, Theodore Jr.; Univ. of California, Riverside; *wacos001@ucr.edu*
Effects of early-onset voluntary exercise on adult physical activity in mice selectively bred for high voluntary wheel running
Decreased physical activity is thought to be one factor contributing to the increase in both childhood and adult obesity, which are associated with numerous adverse health consequences. Moreover, recent budget cuts threaten physical education programs in K-12 schools. Longitudinal studies of humans indicate that high childhood physical activity increases the probability of adults being physically active (Telama et al 2005 Am J Prev Med). Although rodents are commonly used as models to study the biology of physical activity (Garland et al. 2011 J Exp Biol), the effects of early-age exercise on adult propensity to exercise have not been investigated. We used mice from lines that have been selectively bred for high voluntary running on wheels (1.12 m circum.) attached to standard cages (Swallow et al. 1998 Behav Genet), termed high runner (HR) lines, and their non-selected control (C) lines to investigate whether early exposure to a wheel affects activity levels as adults. Half of the mice were given wheel access shortly after weaning for 21 consecutive days. Wheel access was then removed for 54 days, followed by 16 days of access for all mice. Early-life wheel access significantly increased voluntary exercise on wheels during the first week of the second period of wheel access for all mice, with the effect tending to be greater in HR than in C. During this same time period, spontaneous physical activity inside the home cages was not affected by early-age wheel access, and did not differ between HR and C mice. These results support the hypothesis that early-age exercise can have beneficial effects on adult levels of voluntary exercise, and have implications for public policy. Supported by NSF grant IOS-1121273 to TG.

36.2 ADAMS, D.K.*; SEWELL, M.A.; NOWAKOWSKI, N.M.; ANGERER, L.M.; National Institutes of Health, Bethesda, MD, University of Auckland, NZ, American University, Washington, DC; *adamsdi@mail.nih.gov*
Mechanism underlying developmental plasticity in echinoid larval form
A mechanistic understanding of developmental plasticity is a key component to determining how phenotypic plasticity alters ecological and evolutionary processes. A clear example of developmental plasticity occurs in prefeeding sea urchin larvae, in which arm length varies when food densities change. As we show here, increases in the size of this feeding structure improve food acquisition rates. Although this plasticity has been thought to have been selected to improve resource acquisition, here we show that the mechanism regulating it works in the opposite direction. We demonstrate that sensation of food activates dopamine signaling through a type-D_2 receptor, which *reduces* the size of the feeding structure and subsequent feeding. These results indicate that the developmental program combined with maternal provisioning predetermines the maximum feeding rate, independent of the environment. The food-dependent reduction in feeding structure size also decreases the expenditure of maternal lipids, providing a potential energy store to buffer future challenges or to invest in development towards the juvenile form. Thus, selective pressures on maternal inputs and/or the developmental program for increased feeding capacity must balance those operating on the food-induced dopamine-signaling mechanism for conserving lipids that hasten development. The use of dopamine in developmental plasticity in sea urchin larvae may have been co-opted from the use of food-induced dopamine signaling in behavioral responses of diverse organisms from worms to humans. Preliminary results surveying Echinoidea suggest that the putative co-option was an innovation of the regular urchins (Echinacea).

S6-1.3 ADAMS, N.L.*; CAMPANALE, J.P.; FOLTZ, K.R.; California Polytechnic State University, San Luis Obispo, CA, Scripps Institution of Oceanography, University of California, San Diego, CA, University of California, Santa Barbara, CA; *nadams@calpoly.edu*

Damage or defenses: An examination of how the sea urchin proteome changes in response to ultraviolet radiation

Anthropogenically induced ozone depletion and climate change have increased the importance in understanding how marine organisms, especially planktonic embryos and larvae that float in surface waters, respond to and protect themselves from abiotic stress. Marine organisms living in shallow waters are most vulnerable to damaging levels of ultraviolet radiation (UVR), which may act synergistically with other stressors including temperature, lower pH and changes in salinity. Over a century of research has demonstrated that echinoids, especially sea urchins, embryos and larvae are a powerful model organisms for studying effects of UVR on development, cellular targets, protein regulation, effects on whole organisms, and protection against damage. In addition to providing a large number of synchronously developing embryos amenable to cellular, biochemical, molecular, and single cell analyses, the purple sea urchin, *Strongylocentrotus purpuratus*, also offers an annotated genome, making it an excellent model for studying proteome dynamics and identifying protein biomarkers of stress. Our studies have highlighted some ways the proteome of *S. purpuratus* changes during development and in response to UV-induced stress. These changes include variation in protein levels as well as many post-translational modifications, such as phosphorylation, glycosylation, ubiquitination, and acetylation. Post-translational modifications may provide embryos with a fine-tuned, rapid-response to stress during early stages, especially during pre-blastula stages that rely on maternally derived defenses rather than responses through gene transcription.

57.2 ADDIS, E.A.*; SCHWARTZ, T.S; REDING, D.M.; PALACIOS, M.G.; BRONIKOWSKI, A.M.; Iowa State University; *addis@iastate.edu*

The insulin-like growth factor axis as a mediator of life history trade-offs

Classic life-history theory predicts trade-offs between the lifetime fecundity and lifespan of an individual. However, little is know about the mechanisms that control these trade-offs. Two genetically divergent ecotypes of *Thamnophis elegans*, the Western garter snake, provide a natural experiment to explore genetic and hormonal mechanisms that are involved in these trade-offs. Populations of the fast-living ecotype live along rocky outcrops of Eagle Lake, in the Sierra Nevada Mountains. This ecotype has on average eight young each year, and has an average life span of four years. In contrast, the slow-living ecotype lives in the mountain meadows above Eagle Lake, has an average lifespan of eight years and average litter sizes of four, but reproduction is dependent upon food availability. One proposed mechanism involved in these trade-offs is the regulation of the insulin-like-growth-factor (IGF) axis. The IGF axis is involved in a broad spectrum of cellular functions, particularly those of cell proliferation, cell differentiation, and the inhibition of programmed cell death. At the organismal level, these genes affect an organism's physiological processes, including those of aging and reproduction. In this study, we explored sequence and expression variation in the genes IGF-1, IGF-2, IGF-1R, and IGF-2R. We found little variation in gene sequences between ecotypes. However, expression of IGF-2, IGF-1R, and IGF-2R mRNA was several fold higher in the fast-living ecotype than the slow-living. No difference was observed in expression of IGF-1 mRNA between ecotypes. We discuss the significance of these results in the context of variation in both life-history strategies between the two ecotypes and in environmental conditions between the two habitats.

9.1 ADELMAN, JS*; HAWLEY, DM; Virginia Tech; *adelmanj@vt.edu*

Variation in immune responsiveness and tolerance of Mycoplasma infection between house finch populations

Revealing how population differences in immune defenses impact pathogen load and shedding will greatly improve predictive models of disease spread. However, such links remain poorly understood in natural systems. Here, we present population differences in host immune responses, disease pathology, and pathogen load in a naturally occurring host-pathogen system, house finches (*Carpodacus mexicanus*) infected with *Mycoplasma gallisepticum* (MG). This bacterial pathogen causes severe conjunctivitis and, since emerging in 1993, has spread rapidly across North America. In this study, wild-caught birds from two populations with different histories of pathogen co-evolution were experimentally infected in the same captive environment. MG arrived in the exposed population (Alabama) in the mid-1990s, but, as of capture, had not been detected in the naïve population (Arizona). While the Red Queen Hypothesis predicts that an exposed population should evolve increased resistance (the ability to reduce pathogen load more rapidly/completely), the populations displayed similar pathogen loads. However, early disease pathology (mass loss and conjunctival lesions) was less pronounced in the exposed population. This result suggests that tolerance of infection (reduced pathology per unit parasite), rather than resistance, may have evolved in the exposed population. Immunologically, the initial, inflammatory response (fever) began later in the exposed population, while subsequent, MG-specific antibody levels tended to be higher in that population. These data suggest that prioritization of different types of immune defense may help drive population differences in tolerance. We will discuss potential consequences of such differences in tolerance, rather than resistance, for disease spread and the evolution of virulence.

68.1 ADRIAENS, D.*; NEUTENS, C.; CHRISTIAENS, J.; VAN LOO, D.; DE KEGEL, B.; BOISTEL, R.; VAN HOOREBEKE, L.; Ghent University, Belgium, UniversitÃ© de Poitiers, France; *dominique.adriaens@ugent.be*

Evolutionary morphology of the caudal musculoskeletal system in syngnathid fish: from swimming to prehension ... in different ways

Seahorses and pipehorses possess the unique characteristic of extensive tail bending, allowing them to grasp onto the substrate. Current phylogenetic hypotheses suggest that grasping performance evolved more than once, as it seems to have arisen independently in pipehorses and seahorses. Pipehorse species with prehensile tail are nested within pipefish species (that lack this prehensile tail), hence are not sister group to the seahorses. Considering the different evolutionary strategies giving rise to a prehensile tail (starting from a rigid one), it is hypothesised that some crucial (and hence shared) structural modifications occurred at the level of (1) body armour organisation, (2) vertebra organisation, (3) interaction between plates en vertebra and (4) muscle organisation. To test these hypotheses, the caudal system in pipefish (ancestral condition), pipehorse and seahorse are compared, using histological and micro-CT data. The results confirm some hypotheses, but not all. As such, body armour organisation in pipehorse proved to be different from that of seahorses, providing both an increased capacity for flexibility between consecutive segmented plates (overall to partial plate reduction). Modifications in the musculature are also extensive, where seahorses represent a unique organisation of the muscle-tendon complexes for syngnathids (plate-like versus ancestral conical myoseptal organisation, and muscle fiber extension). This study thus confirms that within a single clade (syngnathids), at least two different evolutionary strategies have independently yielded an adaptive solution for a novel function, i.e. tail prehension.

112.4 AIELLO, B.R.*; BLOB, R.W.; BUTCHER, M.T.; Youngstown State University, Clemson University; *brettronaldaiello@gmail.com*

Correlation of bone loading and muscle function in the hindlimb of the river cooter turtle (Pseudemys concinna)

Limb muscles have important roles during locomotion, such as counteracting ground reaction forces (GRF) and generating propulsive mechanical work and power. Depending on the magnitude and direction of the GRF or the performance demands of locomotion, limb muscles may produce high forces that impose substantial loads on limb bones. While bone loading has been studied over a relatively broad phylogenetic and functional range of tetrapod lineages, much less is known about how muscle contractile function directly influences patterns and magnitudes of bone loading. To better understand mechanisms of limb bone loading in terrestrial locomotion, we correlated direct measurements of *in vivo* bone strain with muscle strain (via sonomicrometry) and EMG activation in a major hip extensor (Flexor tibialis internus) muscle of river cooter turtles (*Pseudemys concinna*) during treadmill walking. EMG recordings indicate activity prior to footfall that continues through approximately 60-70% of the stance phase. Large EMG bursts occur just after footfall when the muscle has reached its maximum length and is beginning to actively shorten, which it does through the first half of stance. At the time of peak bone strains (both principal and axial), the muscle fascicles are active but are no longer shortening, and remain isometric until late in stance when they passively lengthen occurs as the foot is preparing to be lifted from the tread. Peak bone loads therefore can be correlated directly with the action of limb muscles. Supported by URC #3-11.

45.1 ALBERGOTTI, L.C.*; HAMLIN, H.J.; MCCOY, M.W.; KOHNO, S.; GUILLETTE, JR., L.J.; University of Florida, Gainesville, FL, University of Maine, Orono, ME, Medical University of South Carolina, Charleston, SC; *lalberg@ufl.edu*

Steroidogenesis and Steroid Hormone Signaling in the Chorioallantoic Membrane of the Domestic Chicken (Gallus gallus), the American Alligator (Alligator mississippiensis), and the Florida Red-belly Slider Turtle (Pseudemys nelsoni)

As amniotes, mammals, reptiles, and birds share common extraembryonic membranes, which function in nutrient and gas exchange, waste removal and protection, and are critical for embryonic survival. In viviparous amniotes, extraembryonic membranes and maternal uterine tissues alike contribute to the placenta, an endocrine organ that synthesizes, transports and metabolizes hormones essential for embryonic development. Surprisingly, the endocrine role of extraembryonic membranes has not been investigated in oviparous amniotes despite similarities in their basic structure, function and shared evolutionary ancestry. To address this question, we examined steroidogenesis and steroid hormone signaling in the chorioallantoic membrane (CAM) of the chicken, American alligator and Florida red-belly slider turtle, representing three major amniote lineages that reproduce strictly by oviparity. We quantified mRNA expression of steroidogenic enzymes and steroid receptors in the CAM by quantitative PCR. In addition, protein expression of the progesterone receptor in the CAM was confirmed by immunohistochemistry. Furthermore, we found that the CAM could synthesize progesterone *in vitro* in the presence of a steroid precursor. Our data indicate that the oviparous CAM is steroidogenic and suggests that endocrine activity of extraembryonic membranes is not a novel characteristic of placental amniotes. Further, we hypothesize that endocrine activity of extraembryonic membranes might be an evolutionarily conserved characteristic of amniotes.

S7-1.2 ALBEN, S.*; WITT, C.; BAKER, T.V.; ANDERSON, E.; LAUDER, G.V.; Georgia Tech, Grove City College, Harvard Univ.; *alben@math.gatech.edu*

Resonances in fish fin models

When a flexible appendage such as a fish fin is flapped in a fluid, resonances can occur at certain combinations of flapping frequency and internal elastic parameters. Resonances correspond to peaks in propulsive force, but also input power supplied to the fin. We use mathematical and computational models to study resonances in thin foils and fin rays, both fixed and freely swimming in a flow. In many cases we can find simple approximate solutions that describe how thrust force and swimming speed scale with the length and elastic properties of the fins. We compare some results with recent experiments from the Lauder lab.

41.5 ALBRITTON-FORD, Aaron/C*; HARPER, Benjamin/T; Valdosta State University; *acalbrittonford@valdosta.edu*

The Influence of Salinity on Acute Toxicity to the Euryhaline Fish, Kryptolebias marmoratus

The Influence of Salinity on Acute Toxicity to the Euryhaline Fish, *Kryptolebias marmoratus*, A. Albritton-Ford, B.T. Harper, G.K. Bielmyer Valdosta State University, Valdosta, GA, 31698 Abstract Aquatic systems are commonly polluted with metals, due to a myriad of anthropogenic inputs. Cadmium (Cd) is a nonessential metal which may be toxic at elevated concentrations to many aquatic organisms. Although the mechanism of Cd toxicity has been well characterized in fish inhabiting freshwaters, fewer studies have examined the toxic effects of Cd in saltwater environments. Salinity is highly variable in estuarine systems and may influence the behavior and thus the toxicity of metals. In this study, the euryhaline fish, *Kryptolebias marmoratus* (7-9 d old), was exposed to Cd in waters with salinities ranging from 0.1-12 ppt for 96 h and mortality was recorded. Median lethal concentrations causing 50% mortality (LC50s) were calculated for each water type. The LC50 values ranged from 6.43 µg/L Cd in freshwater to 8.41 mg/L Cd in 12 ppt saltwater. Results demonstrated a reduction in Cd toxicity in these fish with increasing salinity. Further, we are investigating the influence of magnesium and calcium on Cd toxicity to *K. marmoratus*. Experiments are being performed in freshwater supplemented with the individual salts to determine which components of saltwater were protective against acute Cd toxicity to *K. marmoratus*.

47.4 ALDREDGE, R.A.*; SOCKMAN, K.W.; Univ. of North Carolina at Chapel Hill; *aldredge@live.unc.edu*

Egg pigmentation varies with laying order and differs in populations at different latitudes

Development time can vary widely both within and among organisms. In birds the incubation period is shorter for open-cup than cavity nesting birds, decreases as the season progresses and is shorter for temperate than for tropical breeding birds. Recent evidence suggests that photoperiod might partially explain why incubation periods are shorter for nests exposed to more hours of light per day (longer photophases). Females may be able to regulate this photoacceleration by altering certain egg properties, such as eggshell thickness or degree of pigmentation. We investigated 1) whether egg pigmentation differs between three populations of house sparrows (*Passer domesticus*) at different latitudes and 2) whether egg pigmentation varies over the laying sequence of the clutch. Pigmentation was greatest at our high latitude site, which experiences the longest photophases, declined at our geographically intermediate site, and was lowest at our tropical site, where photophases are the shortest. Additionally, the density of egg pigmentation decreased in last-laid eggs relative to earlier-laid eggs, regardless of site. Although we do not know the functional significance of these results, they raise the hypothesis that egg pigmentation increases the similarity in incubation periods across populations, a pattern that is unexpected given the latitudinal difference in avian incubation periods and increases the similarity in hatching synchrony within clutches.

65.2 ALFARO, ME*; FAIRCLOTH, B; SORENSON, L; CHANG, J; SANTINI, F; UCLA; *michaelalfaro@ucla.edu*

A 500-locus phylogenomic study of ray-finned fishes

Genomic approaches have helped resolve some of higher-level relationships on the fish tree of life. One key challenge that remains is to create phylogenomic techniques that easily, efficiently, and universally generate large data sets from fishes. Massively parallel sequencing (MPS) offers tremendous potential in this area, yet it has proven difficult to efficiently scale DNA inputs to the output of MPS platforms. For example, the amplification of hundreds of orthologous gene regions across deeply diverging taxa remains an inefficient step compared to sequencing these amplicons in multiplex. To overcome these barriers we developed a technique to universally collect data from over 500 loci across bony fishes. The method uses sequence capture probes to enrich organismal DNA for hundreds to thousands of ultra-conserved nuclear DNA regions and the sequence flanking these regions. Following enrichment, we use MPS to sequence captured loci and programmatic tools to align, analyze, and generate species trees from these sequence data. We tested this approach by enriching loci from DNA libraries prepared from 18 species of fish distributed across bony fishes. We sequenced enriched DNA using an Illumina GAIIx, and we developed a bioinformatic pipeline to assemble, align, and integrate these data with extant genome sequence data from seven fishes prior to phylogenetic analysis. From these alignments, we generated a concatenated matrix composed of 25 species and 160,000 characters. Bayesian analysis (MrBayes 3.1) of the data reveals a robustly supported tree (posterior probabilities for all nodes >0.99) that is largely consistent with studies based upon other molecular data sets while providing new evidence for the position of the elopomorphs as sister to other teleosts. This highlights the power of a very large number of UCE regions to resolve phylogenetic relationships at both broad and shallow scales.

70.2 ALLISON, Amanda/L*; FITZPATRICK, Benjamin/M; University of Tennessee, Knoxville; *aalliso4@utk.edu*

Distinctiveness and diversity of bacteria associated with salamander skin

The extent of co-evolution of microbial communities with animals and plants is largely unknown and it is uncertain how common specific mutualisms are or how important they may be in influencing the evolution and ecology of macro-organisms. Amphibian skin appears to be a selective medium allowing and perhaps promoting growth of certain bacteria. Some have hypothesized that certain bacteria are mutualists, helping defend the host from harmful microbes in the environment. The evolution of mutualism depends, among other things, on the consistency and specificity of associations. Almost nothing is known about the consistency and specificity of bacteria-salamander associations. The objectives of this study are to (1) confirm that the bacterial microflora associated with salamanders comprise a distinct community relative to the free-living bacteria in the immediate environment, (2) evaluate the consistency of bacteria-salamander associations across populations in various environments, and (3) test whether similarities between bacterial communities can be predicted by evolutionary relatedness of different salamanders. Microbial communities were collected from both salamander skin and their immediate environment and high-throughput pyrosequencing techniques will be used to assay microbial communities. Preliminary results will be presented.

MOORE.1 ALTERS, Brian; Chapman University; *alters@chapman.edu*

Evolution Education and Creationism Through the Decades

We will take an edutaining exploration of creationism from the roots of “scientific” creationism on this continent to current evolution issues in the Islamic world.

S1-2.2 ALTSHULER, D.L.*; SEGRE, P.S.; STRAW, A.D.; University of British Columbia, Institute for Molecular Pathology; *doug@zoology.ubc.ca*
Computational analysis of hummingbird flight
A central challenge to the study of maneuverability is complexity because animal movement occurs with coordination of multiple rotational and translational degrees of freedom, each with complicated time histories. One solution is to break down extended periods of motion into a hierarchy of movement at different temporal scales. For example, the decomposition of movement into simpler building blocks has been used in robotic control applications and to describe kinematic and neural control features in both humans and animals. Recent work in flying insects suggests that specific combinations of rotation and translation form discrete units of movement that are then assembled to form more complex motion trajectories. We tested the generality of this model for flying animals by examining Anna's hummingbirds (*Calype anna*) during periods of solitary and paired (competitive) flight in a large arena. The three dimensional positions and orientations were determined using a custom-designed automated tracking system capable of high temporal and spatial resolution. Unlike the previous description of insect flight modes, hummingbirds varied axial and torsional velocities continuously and no discrete units of movement were detected. However, the range of motions was constrained for both pure velocity components and for combinations of torsional and axial velocities. Comparing solitary to competitive flights across multiple days further revealed that the limits on movement vary by individual, behavioral manipulation and day of measurement. This suggests that a computational framework for describing free flight maneuvers can be used to study the limits to maneuvering performance.

7.4 ALWARD, B.A.*; ROUSE, M.L.; STEVENSON, T.J.; BALL, G.F.; The Johns Hopkins Univeristy ; *balward1@jhu.edu*
Photoperiodic and Social Regulation of Song Rate and Structure in Male Border Canaries (Serinus canaria)
Songbird species exhibit marked variability in the types and quality of song produced across the seasons. Here, we investigated the effects of photoperiod and social milieu on variation in both song output and structure. We conducted our studies in Border canaries (*Serinus canaria*), a strain that is very responsive to changes in photoperiod. We housed male canaries alone on short days (SD) or alone on long days (LD) for fourteen days. Furthermore, an additional group of LD males were paired with a female for fourteen days. We analyzed: 1) number of songs, 2) number of special syllables that are attractive to females, 3) duration of song, 4) latency to sing, 5) amplitude, 6) energy (a measure of amplitude), and 7) entropy variance (an inverse measure of the uniformity of a signal). LD-Alone birds sang more songs throughout the experiment and tended to sing earlier in the day than the other groups. LD-Alone birds also exhibited increases over time in the energy of their songs. By day 7, these birds were singing with more energy than the other groups. LD-Alone birds also increased the number of special syllables sung over time in a near-linear fashion, while the other groups did not. Another feature that distinguished LD-Alone birds is that they sang with higher entropy variance than the other two groups. Therefore, photoperiod and the social environment differentially regulate song output and structure in Border canaries: LD-Alone birds sang more songs and earlier than SD and LD-Paired birds and they sang louder and with less uniformity. We hypothesize that LD-Alone birds emphasize these changes in order to broadcast a complex signal to attract a potential mate.

S8-2.2 AMDAM, GV; Arizona State University; *Gro.Amdam@asu.edu*
The making of a social insect - Genetics of Social Design
How do complex social systems evolve? What are the evolutionary and developmental building blocks of division of labor and specialization, the hallmarks of insect societies? In solitary insects, shifts during life history between reproductively active and inactive states are associated with widespread changes in physiology and behavior. In advanced social honey bees, variation in similar physiology is linked to behavioral variation between workers, which are functionally sterile helper females. We suggest that worker behaviors evolved via modifications of gene and hormonal networks that can control reproductive states. This view is summarized in our reproductive ground plan hypothesis of social evolution, which explains how worker division of labor and behavioral specialization can emerge from solitary regulatory networks.

51.4 AMIEL, Aldine; HENRY, Jonathan Q.; SEAVER, Elaine C.*; University of Hawaii, University of Illinios; *seaver@hawaii.edu*
Blastomere deletions reveal organizing activity in the polychaete annelid Capitella teleta
The formation of a transient structure in the embryo called the organizer is crucial for establishment of the body axes. The vertebrate organizer is a specialized group of cells that orchestrates the formation of entire animal via cell-cell signaling and morphogenetic movements during gastrulation. In spiralian animals, organizing activity is localized to 1 -2 cells in the early cleavage stage embryo, namely 3D in the mollusks *L. obsoleta* and *C. fornicata*, and 2d plus 4d in the oligochaete annelid *T. tubifex*. The purpose of the present study is to investigate whether a similar organizing activity is found in the polychaete annelid *Capitella teleta*, a model well-suited for embryological approaches. The identity of organizer activity has not been characterized in polychaetes. The stereotypic spiralian cleavage program in *Capitella* and its known cell lineage allows for identification of each cell and its resulting larval fate. Over 12 uniquely identifiable individual blastomeres were ablated in *Capitella* using a laser ablation system and resulting larval phenotypes analyzed. For many of the blastomere ablations, resulting larvae lacked structures that normally arise from the ablated cell, but were otherwise normal. Our results show that organizer activity in *Capitella* arises from a cell in the D quadrant, although not the same cell as in molluscs (3D), and its activity occurs at an earlier stage of development. Furthermore, only the D/V axis is disrupted following D quadrant cell ablations. These results highlight variation among spiralians, and may ultimately give insight into how changes in the highly conserved spiralian developmental program generate the enormous diversity of body plans in the Lophotrochozoa.

89.4 ANDERSON, P*; RAYFIELD, EJ; RENAUD, S; Univ. Bristol, UK, Univ. Lyon, France; *phil.anderson@bristol.ac.uk*

Diet-Based Biomechanical Plasticity in Mouse Mandibles

The functional consequences of morphological variation is a major field of inquiry in modern biology. The relationship between form and function can be complex, and this is especially true in situations of phenotypic plasticity, where morphology is altered during development based on environmental stresses. Do environmental pressures (such as mechanical loading related to diet) affect morphology through bone remodeling in a functionally adaptable manner? We utilize a data set of lab mice, reared on mechanically distinct diets to test hypotheses related to morphological plasticity and its effects on mechanical function. We used 39 3-week old female mice from inbred strain C56BL/6J. Twenty of the mice were raised on a soft food diet and 19 on a hard food diet. We used morphometric analyses to compare the general shape between dietary groups using both left and right mandibles. We measured four different mechanical advantage metrics from each mandible based on the masseter and temporalis muscles and bite points on the incisors and molars. Landmark based morphometrics show significant difference in shape between mice raised on hard food and soft food diets. However, there are also significant differences between right and left mandibles across dietary groups, indicating potential directional asymmetry within these mice. Functional analyses based on lever mechanics illustrate that these shape differences have functional consequences. Hard food eaters have higher mechanical advantage measures than soft food eaters when left mandibles are compared. Differences are more limited when regarding right mandibles. Hence, there are strong mechanical signals in the phenotypic plasticity of mice raised on diets with different mechanical requirements.

45.6 ANDERSON, EM*; NAVARA, KJ; University of Georgia, Athens; *erinma@uga.edu*

Hormone Content of Rooster Seminal Plasma and Effects on Sperm Quality and Fertility

It has been demonstrated that female birds adaptively allocate hormones to eggs to enhance offspring quality and survival, but the hormone content of fluids contributed with gametes by the male has received less attention. First, we measured the concentrations of four reproductive steroid hormones, including progesterone, testosterone, dihydrotestosterone, and estrogen, in seminal and blood plasma collected from White Leghorn roosters. Progesterone was the most abundant hormone in seminal plasma. To determine the effect of progesterone in seminal plasma on fertility, we then inseminated hens with semen samples that were supplemented with either a high physiological dose of progesterone or a control vehicle, and fertility was evaluated using a perivitelline sperm hole penetration assay. Progesterone exhibited an inhibitory effect on fertilization of the egg. Finally, to determine the mechanism by which progesterone inhibited fertility, we then explored how concentrations of progesterone related to sperm mobility, concentration, and viability. Progesterone concentrations in blood and plasma were inversely related to sperm mobility, indicating that males producing more progesterone have poorer quality sperm, which would likely impair the ability of sperm to reach and penetrate the egg. The implications of this work and potential adaptive value of steroid hormones in seminal plasma will be discussed.

74.2 ANDERSON, J.M.*; HARDER, A.M.; HAND, S.C.; TONER, M.; CHAKRABORTY, N.; MENZE, M.A.; Eastern Illinois University, Dept. Biol. Sci., Charleston, IL, Louisiana State University, Dept. Biol. Sci., Baton Roughe, LA, Center for Engineering in Medicine Harvard Medical School, Boston, MA; *mmenze@eiu.edu*

Protective Mechanisms Against Water Stress Evaluated in Insect Cells

We utilized three different water-stress models (controlled-rate freezing, spin-drying, and osmotic dehydration) to investigate the impact of intracellular trehalose or transgenic expression of a group 1 LEA protein (ACX81198 variant) on membrane integrity in cell lines from *Spodoptera frugiperda* (Sf-21) and *Drosophila melanogaster* (Kc167), respectively. Neither species is tolerant to severe desiccation. Kc167 cells were challenged with 100mM sucrose in standard culture medium. Expression of LEA1 protein increased the number of cells with intact membranes by 25±3.5% (*n*=3,±SE) after 48h of incubation compared to controls. To facilitate trehalose uptake a nucleotide sequence (trehalose transporter BT003466) was stably transfected into Sf-21 cells (Sf-21-BT). Cells were incubated for 3h at 27 °C in a buffer containing 200mM trehalose. After incubation 43±3.7% (*n*=5,±SE) of control Sf-21 cells showed compromised membranes while Sf-21-BT cells maintained higher numbers of cells with intact membranes [76±5.4%(*n*=5,±SE, P<0.05)]. However, Sf-21 and Sf-21-BT cells frozen in this buffer at 1°C•min^{-1} showed no significant difference in membrane integrity after thawing (60±3.3% control vs. 60±2.8% Sf-21-RHO; *n*=3;±SE). After incubation in culture media with 400mM trehalose for 3h, severe water stress was applied in the form of spin-drying. Spin-drying caused 100% loss of membrane integrity in control Sf-21 cells, whereas membrane integrity in Sf-21-BT cells 48h after rehydration was comparable to non-dried control cells. Trehalose and LEA proteins appear to aid in maintenance of membrane integrity during water stress. (NSF-IOS-0920254, CFR-EIU-2010).

30.3 ANDERSON, R A*; KARASOV, W H; NAGY, K A; Western Washington Univ., Univ. Wisconsin, Madison, Univ. California, Los Angeles; *Roger.Anderson@wwu.edu*

Ecological cost of growth in a free-ranging lizard

The doubly labeled water (DLW) method can be used to measure respiration, compare metabolizable energy intake among individuals with different growth rates, and estimate ecological cost of growth in free-living animals. We used DLW to study field energetics of adults and juveniles in the wide foraging desert lizard, *Aspidoscelis tigris*. The cost for these insectivores to secure the extra food that powers growth was predicted to result in a cost of growth that is substantially higher than the consensus estimate for cost of growth (0.33 J respired per J deposited) in constrained animals. Positive correlations were predicted for respiration v. growth rate and for growth rate v. metabolizable energy intake. Daily rates of metabolism, feeding and growth were expected to be higher in *A. tigris* than in syntopic ambush predators. Juveniles had longer daily activity periods, adults moved more, juveniles and adults had similar time proportions in locomotion during the activity period, and their diets were similar. All juveniles and most adults increased in body mass during the 3 week study. There were no significant differences among groups in mass-corrected FMR, but mass-corrected water influxes in juveniles and adult females were higher than in adult males. Analysis of mass residuals of mass gain, FMR, and food water influx for all lizards with positive mass gains yielded significant positive correlations for FMR v. mass gain and for mass gain v. food water influx. There were no significant differences in slopes or intercepts of these relationships with sex or age when analyzed by ANCOVA. The ecological cost of growth was high in this wide forager (> 2.6 J/J), and it did have higher rates than syntopic ambushers in the parameters predicted.

75.4 ANDERSON, Christopher V.*; LARGHI, Nicholas P.; CREEMERS, Shelby; DEBAN, Stephen M.; University of South Florida, Tampa; *cvanders@mail.usf.edu*

Thermal effects on the performance, motor control, and muscle dynamics of tongue projection in a plethodontid salamander

Temperature has a strong effect on muscle contractile velocity and thus movement performance. Elastically powered tongue projection of *Chamaeleo*, *Bufo* and *Hydromantes* have been shown to be less thermally dependent than their associated muscle-powered retraction. We hypothesize that the low thermal sensitivity of elastically powered ballistic tongue projection is generalized to other ballistic movements and that the low thermal sensitivity of tongue projection occurs despite profound effects of temperature on muscle dynamics and motor control, due to rapid elastic recoil. We examined the thermal effects on kinematics, motor control, and muscle dynamics associated with both tongue projection and retraction in a plethodontid salamander with a convergent ballistic tongue projection mechanism, *Eurycea guttolineata*. Specimens were imaged feeding at 5-25°C, while simultaneously recording electromyographic activity of the tongue projector (SAR) and retractor (RCP) muscles. We examined the muscle dynamics of both muscles across the same thermal range. We found that elastically powered tongue projection maintains a significantly higher degree of performance at low temperature than retraction, which experiences a significant performance loss with decreasing temperature and has higher Q_{10} values than projection. Similarly, muscle activity durations and latencies show a 5-25°C Q_{10} >1.4 for both the SAR and RCP muscles. Further, contraction of the SAR muscle showed a larger effect of temperature on dynamic properties than on static properties. These results fail to support the alternative hypothesis that *Eurycea* maintain tongue projection performance by maintaining muscle contractile rate performance at low temperature and support the generality of low thermal sensitivity in ballistic movements utilizing elastic recoil.

96.2 ANGELIER, F*; CHASTEL, O; CEBC, CNRS, France; *angelier@cebc.cnrs.fr*

Prolactin as a mediator of the stress response in parent birds: an underappreciated mechanism

In birds, an emergency life-history stage (ELS) is expressed when the immediate survival is threatened by stressful events. This ELS redirects the individual away from the breeding stage so that it can cope with the perturbation and survive in the best condition possible. At the proximate level, this ELS is promoted by an increased secretion of corticosterone and, during the last two decades, most studies have been focusing on this stress hormone. However, other underappreciated endocrine mechanisms may be involved in the activation of ELS. Thus, prolactin probably deserves attention when focusing on the parental phase because this hormone is involved in the regulation of parental cares in vertebrates. Despite this potential, almost no study had examined how stressful events can affect prolactin levels in birds. Over the past 6 years, we investigated the inter-relationships between stress, prolactin, parental cares and fitness in bird species. We reported that stress-related decreases of prolactin levels are a general pattern during the parental phase. In addition, we showed that stress-related decreases of prolactin levels are rapid (within 30 min), and associated with a reduction of parental cares and with a low reproductive success. This demonstrates therefore that prolactin can be involved in the activation of an ELS during the parental phase. Interestingly, we also reported a large inter-individual variability in the prolactin stress-response, suggesting that all parents are not similarly sensitive to stress. Indeed, we found that several factors can affect prolactin levels and explain this inter-individual variability (age, experience, condition, etc.). Finally, we illustrated that the modulation of the prolactin stress response is appropriate to study life-history trade-offs and parental strategies in an evolutionary context.

102.6 ANGIELCZYK, K. D.*; MELSTROM, K. M.; Field Museum of Natural History, Univ. of Michigan; *kangielczyk@fieldmuseum.org*

Are the plastral scutes and plastral lobes of turtle shells modules? A geometric morphometric perspective

The turtle plastron (ventral shell) is covered by a series of keratinous scutes. Each scute is derived from one tissue condensation; therefore we might expect the scutes to be separate developmental modules. Similarly, the anterior and posterior plastral lobes of turtles with a hinged plastron may be separate modules because each lobe has to articulate with different parts of the carapace. To test these hypotheses, we used Klingenberg's application of the *RV* coefficient to geometric morphometric data to examine patterns of integration in the plastra of 884 specimens belonging to 12 emydid and kinosternid species. When the fluctuating asymmetry component of shape variation was considered, *RV* scores for configurations that were divided into modules representing individual scutes were consistently in the left tail of the distribution of possible *RV* scores. *RV* scores for configurations divided into modules representing the anterior and posterior lobes also were low, although some akinetic species had slightly higher scores. When the among-individuals component of shape variation was considered, *RV* scores for the emydid species were all near the high ends of their distributions when the configurations were divided into scutes, whereas the scores for kinosternids were low. *RV* scores for configurations divided into anterior and posterior lobes spanned a wide range, and there was not a consistent difference between kinetic and akinetic species. Together, these results are consistent with the individual scutes and the plastral lobes being independent developmental modules within individuals. However, the factors that affect shape variation among individuals seem to influence the plastron in a much more integrated way, at least for the species we sampled.

90.5 APPLEBY, L.R.; Univ. of Houston; *lrappleby@uh.edu*

Resource availability and colony founding in harvester ants

In many organisms, the riskiest life stage is the beginning. Some species deal with this by producing well-provisioned individuals who do not need to forage for some time. In harvester ants of the genus *Pogonomyrmex*, the highest mortality rates are at the beginning of colony life, when queens start colonies without workers. Some species like *P. barbatus* start colonies claustrally, without foraging, while others like some populations of *P. occidentalis*, regularly gather food while first brood develops (semi-claustral founding). It is thought that species have adapted their colony founding strategies to the resource availability of their native habitats. I hypothesized that a normally claustral queen would be handicapped relative to queens of a naturally semi-claustral species in use of exogenous food. I fed newly mated *barbatus* and *occidentalis* queens no food, low food, or high food and measured the queen's mass lost during production of the first clutch, the size of the first clutch, and the size of the first worker. In both species, unfed queens lost the most mass. In the claustral species, fed queens lost more mass when they were fed less (low food) rather than more (high food). Fed semi-claustral queens, on the other hand, lost equal mass regardless of the level of food provided. Food availability did not affect offspring size or clutch size in the claustral species, but the semi-claustral species produced larger offspring and clutches when exogenous food was provided. Low and high food queens of both species produced similar sized clutches and first workers. In conclusion, both claustral and semi-claustral queens can use exogenous food to maintain themselves during colony founding, but semi-claustral queens may be better than claustral queens at using exogenous food.

71.2 ARELLANO, Shawn M.*; MULLINEAUX, Lauren; ANDERSON, Erik J.; HELFRICH, Karl; MCGANN, Brenna J.; WHEELER, Jeanette D.; Woods Hole Oceanographic Institution, Grove City College, Grove City College; *sarellano@whoi.edu*
Can waterborne settlement cues trigger the larval transition from the plankton to the seafloor?
In marine benthic species, populations are connected via transport of their swimming larvae. The swimming behaviors that trigger the larval transition back to the seafloor are not understood well. One possibility is that waterborne cues originating from a settlement surface may mix up into the water column where swimming larvae can respond to them. Substratum-bound and waterborne chemical cues that induce larval settlement in late-stage barnacle larvae (cyprids) are characterized well. While substratum searching behaviors and settlement selection in response to these cues have been described, experiments examining the effects of waterborne cues on larval swimming behaviors under natural flow conditions are rare. We are using digital video observations, larval tracking, and flow characterizations to examine how cyprids respond to waterborne cues in field-relevant turbulent conditions. Preliminary experiments in still-water containers suggest that the average cyprid vertical swimming velocity switched from upward to downward when a homogenously dissolved waterborne cue was present. Subsequent experiments in a large racetrack flume examining changes in vertical swimming behaviors (e.g., velocity, tortuosity, sinking rate) as larvae come into contact with filaments of cue in turbulent flow will also be presented.

59.3 ASTLEY, H.C.*; HARUTA, A.; ROBERTS, T.J>; Brown University; *henry_astley@brown.edu*
The Effects of Substrate Compliance on Jump Performance in the Cuban Tree Frog (Osteopilus septentrionalis).
Animals locomoting in arboreal habitats face a variety of challenges, including moving on compliant substrates such as terminal branches. Compliant substrates yield when subjected to locomotor forces, altering the position and magnitude of the reaction force while simultaneously absorbing mechanical work. Substrate compliance may reduce jumping performance due to the loss of mechanical energy to the perch, as well as causing challenges to balance during locomotion. We compared the performance of six Cuban tree frogs (*Osteopilus septentrionalis*) jumping from a force plate and from perches with four levels of compliance, including rigid. The motion of the frog and perch were recorded via two high-speed cameras and digitized to measure jump performance metrics including kinetic, potential and total energy and takeoff velocity. In order to determine the energy absorbed by the perch during the jump, we quantified the relationship between perch displacement, displacement angle and force from a uniaxial force sensor and simultaneous kinematics. While up to 50% of total jump energy was absorbed by the perch, neither work done during the jump nor takeoff velocity was affected by compliance. This was largely due to recoil of the perch prior to takeoff, which allowed the animal to recover some or all of the energy previously stored as elastic strain energy in the perch. Although there were large movements of the substrate, all frogs were able to maintain balance throughout the jump. Thus, in spite of the mechanical difficulties of jumping off a compliance substrate, Cuban tree frogs show no significant reduction in jump performance. Supported by NSF grant IOS0642428.

59.1 AZIZI, E; Univ. of California, Irvine; *eazizi@uci.edu*
Muscle properties are tuned to mechanical function: lessons from hopping toads
Variation in the basic properties of muscles has likely been shaped by the mechanical tasks muscles perform. However, most muscles cannot be easily fit into a functional category and often perform a range of mechanically diverse tasks. Therefore, the relationship between the basic properties of muscles and the mechanical conditions in which they are used remains tenuous. Moreover, comparisons of functionally distinct muscles from distantly related species are limited by the confounding effect of phylogenic history. We use hopping in toads as a model system for comparing muscles that primarily produce mechanical energy with muscles that primarily dissipate mechanical energy. In this system the hindlimb muscles undergo active shortening to produce the mechanical energy used to propel the animal into the air whereas the forelimb muscles undergo active lengthening to dissipate mechanical energy during landing. Therefore, we observe distinct mechanical tasks performed by different muscles of the same individual, during the same locomotor task. We hypothesize that in order to avoid muscle damage common to energy dissipation, forelimb muscles will have higher passive stiffness and therefore operate over significantly shorter lengths. We use a combination of *in vivo* measurements during hopping and *in vitro* measurements of isolated muscles to compare the plantaris muscle, an ankle extensor, to that of the anconeus muscle, an elbow extensor. We find that the anconeus muscle has significantly higher passive stiffness and operates at much shorter lengths than the planataris. These results show that variation in passive elasticity is an important determinant of a muscle's operating length and that such variation is likely driven by a muscle's mechanical function. Funded by NSF IOS grant #1051691.

28.3 BABBITT, C. C.*; PFEFFERLE, L. W.; FEDRIGO, O.; WRAY, G. A.; Duke University; *courtney.babbitt@duke.edu*
Conservation and function of noncoding RNAs in primate evolution
Changes in the expression of genes play an important role in the evolution of phenotypes, however, protein-coding DNA is not the only DNA to be transcribed. Yet, it is currently unclear what fraction of noncoding transcripts are biologically relevant. Evolutionary conservation at the level of sequence, position, and expression is one approach for understanding transcript functionality. Here, we use directional paired-end RNA-Seq data to assess changes in global transcript abundance in five tissues of humans, chimpanzees, and rhesus macaques. We assay expression in noncoding intergenic regions, including both sense and antisense (relative to nearby genes) noncoding transcripts. We find that an abundance of noncoding transcripts, including many never previously annotated, are conserved in both location and expression level between species, suggesting a possible functional role for the broader category of conserved transcripts. We find a significant enrichment of intergenic RNA expression in regions flanking both the 5' and 3' regions of protein-coding genes. While the expression of noncoding RNAs are more conserved than expected by chance, expression levels can change rapidly over evolutionary time, with sense transcripts more conserved than antisense noncoding RNAs. We also find a negative correlation between 5'flanking antisense transcripts and the expression of the downstream gene, suggesting that these antisense transcripts are playing a regulatory, possibly repressive, role for nearby genes. Looking more broadly over multiple tissues, we find that many of these noncoding transcripts are playing tissue-specific roles. Comparative approaches may provide important insights into genes responsible for differences in metabolic functions between humans and non-human primates, as well as highlighting new candidate noncoding transcripts for further functional studies.

51.1 BABONIS, L.S.*; MARTINDALE, M.Q.; Univ of Hawaii/Kewalo Marine Laboratory; *babonis@hawaii.edu*
Cnidocyte development in Nematostella vectensis: a model for terminal cell differentiation
Cnidocytes, the stinging cells and nominal synapomorphy of Cnidarians, are an emerging model for understanding the genetic events that control the terminal differentiation of cells across animal taxa. Because they are replaced throughout the lifetime of the animal, these cells provide a highly tractable system in which to examine the signals responsible for directing the acquisition of a specific fate from an unspecified precursor. We induced cnidocyte firing in the model sea anemone, *Nematostella vectensis*, and then used morphological and molecular techniques to describe the genetic events regulating their replacement. Specifically, we examine the timing and distribution of cnidocyte development using markers of cell proliferation and capsule formation at various intervals after firing was triggered. Further, we compare the abundance and distribution of specific markers of cnidocyte identity in both control individuals (undergoing normal cnidocyte replacement) as well as individuals treated with DAPT, a &gamma-secretase inhibitor known to specifically inhibit the terminal differentiation of this cell type. Together, we used the combined results of these studies to begin characterizing the regulatory network underlying cnidocyte differentiation in *N. vectensis* and to make comparisons with terminal differentiation in other metazoan taxa.

S5-1.5 BABONIS, L.S.*; BRISCHOUX, F.; Univ of Hawaii/Kewalo Marine Laboratory, CEBC-CNRS, 79360 Villiers en Bois, France; *babonis@hawaii.edu*
Perspectives on salt gland evolution in marine snakes
Throughout the evolution of vertebrates, invasion of desiccating environments (e.g., marine and desert environments) has occurred numerous times. Because most vertebrates maintain dilute body fluids, the invasion of these desiccating environments was likely associated with the development of physiological features that permit the maintenance of low plasma osmolality. The diversity of specialized salt-secreting glands across vertebrate lineages suggests that this tissue has evolved numerous times, independently, throughout the evolution of vertebrates. Though the form and function of vertebrate salt glands have been studied for decades, there have been few hypotheses regarding the potential mechanisms that led to the convergent evolution of these glands across taxa. Here, we review the distribution of salt glands across tetrapod taxa to develop hypotheses about the number of convergent events that must have occurred to give rise to the modern diversity of these glands in marine taxa. Further, we review the anatomy and physiology of these specialized glands in comparison with glands that are not specialized for salt-secretion, using marine snakes as a model. Finally, we use these comparative data to propose potential mechanisms by which salt glands may have evolved independently from the repeated co-option of unspecialized precursors.

97.2 BACHMANN, Thomas; Technische UniversitÃ¤t Darmstadt, Germany; *bachmann@sla.tu-darmstadt.de*
The silent flight of owls
Barn owls are nocturnal birds of prey that detect prey mainly by using acoustic information. To improve the localization of prey owls evolved a slow and silent flight. Here, anatomical adaptations of barn owl wings to low speed and silent flight are presented. Three-dimensional surface scans and reconstructions of internal structures such as bones, skin and feather rachises were used to analyze aerodynamically relevant parameters. Fixed barn owl wings and artificially manufactured airfoil models were investigated in wind tunnel experiments to visualize the flow around the wing. Barn owl wings are huge in relation to their body mass leading to a low wing-loading. This enables the owl to fly slowly and increases the maneuverability. The skeleton elements of the wing appear elongated and narrow with little space for muscles. This observation suggests a rather steady flight with little movements within the wing. Since movements within the wing causes the feathers to rub against each other, wing movement produces sound emission. Barn owls reduced this noise during flight by a low wing-beat frequency. Additionally, a velvet-like surface structure of the barn owl feathers decreases friction noise and stabilize the air flow around the wing. A serrated leading-edge enriches the boundary layer of the wing energetically by which the flow stays laminar. Fringes along the trailing edge of the wing allow a smooth transition of the different air flows of the upper and lower side. The interaction of these anatomical specializations and the specific flight behavior of owls result in a silent flight.

98.2 BAIER, D.B.*; GATESY, S.M.; DIAL, K.P.; JENKINS, F.A. Jr.; Providence College, Brown University, University of Montana, Harvard University; *dbaier@providence.edu*
A new look at the avian wishbone
The V-shaped avian furcula (fused clavicles) spans between the shoulders and is known to be capable of considerable bending in most species. Earlier studies of European starlings suggested that the furcula might act as a spring, because the ends of the furcula expand laterally during downstroke and then recoil during upstroke at their attachment to the distal coracoids. Thus, energy put into the spring during downstroke might be recaptured during upstroke. Herein, we present the first subsequent in vivo measurement of the furcula during flight in two species, pigeons (multiple speeds; windtunnel; single-fluoroscope) and chukar partridges (ascending; free-flight; biplanar fluoroscopy). We employ markerless XROMM (X-ray Reconstruction of Moving Morphology) to reconstruct 3-D skeletal motions using high-speed cinefluoroscopy. Consistent among all three species is pronounced lateral bending during the wingbeat cycle, however the phasic pattern in chukars and pigeons is opposite that of observed in starlings. Since bending of the furcula is driven by movements of the robust coracoid that articulates at the coracosternal joint, there is clearly need for further exploration of the complex forces affecting the shoulder girdle during flight.

73.2 BALDWIN, J.L.*; JOHSNEN, S; Duke University; *jlb54@duke.edu*

The use of chromatic and achromatic cues during mate choice in the male blue crab, Callinectes sapidus

Male blue crabs, *Callinectes sapidus*, rely in part on color cues to select appropriate mates. In previous experiments, we found that male blue crabs prefer females with red claws to those with claws modified to be white or dark grey. Our results demonstrating the blue crab's ability to discriminate red from an isoluminant grey suggest that blue crabs are capable of color vision. Here, we have extended our study to investigate how color vision may function in relation to natural female claw color variations. Female blue crab claws vary in color from pale orange to deep red and could function in tasks such as gender identification, sexual maturity, or individual quality. However, given the blue crab's dichromatic color vision system and limited range of spectral sensitivity, it is unclear if males are capable of discriminating between long-wavelength shades, such as red and orange. The behavioral trials presented here were intended to probe the ability of the blue crab, to choose between similar long-wavelength shades during mate choice. Overall, males show an innate preference for red clawed females to those with variations of orange claws. However, in tests between red and orange shades similar in both brightness and hue, male blue crabs did not show preference, suggesting that males are either not able or not motivated to discriminate between these shades. Further, our results suggest that male blue crabs may use a mixture of chromatic and achromatic cues to discriminate between long wavelength colors. The results are discussed in relation to blue crab color vision and possible function of claw coloration.

87.1 BARAZANDEH, M*; DAVIS, CS; NEUFELD, CJ; PALMER, RA; Univ. of Alberta, Edmonton, AB, Canada; Bamfield Marine Sciences Centre Bamfield, BC, Canada, Univ. of Alberta, Edmonton, AB, Canada; *barazand@ualberta.ca*

A third way: Spermcapture mating in barnacles

Most free-living barnacles are hermaphroditic and eggs are presumed to be fertilized by pseudo-copulation or self-fertilization. The Pacific gooseneck barnacle, *Pollicipes polymerus*, is believed to be a mandatory cross-fertilizer. Nonetheless, some isolated *P. polymerus*, well outside the range a penis could reach, have fertilized egg-masses. They must therefore either self-fertilize or obtain sperm from the water. This latter possibility occurs in other sessile marine organisms but has never been considered in barnacles. To test how eggs of isolated individuals were fertilized, we collected isolated *P. polymerus* individuals (more than 2 body lengths from their nearest neighbors) bearing egg-masses as well as isolated pairs (two adjacent individuals that were more than 2 body lengths away from any other barnacles) where at least one carried egg masses. Sixteen polymorphic Single Nucleotide Polymorphisms (SNP) were developed for *P. polymerus*. SNP genotypes of parents and embryo masses of 37 isolated individuals showed that egg masses of all of them had at least one locus with one allele that differed from the parent, and 40% of embryo masses had non-parent alleles at four or more loci. Remarkably, even in isolated pairs, where both partners were within penis range, individuals still obtained some sperm from the water. These observations reject the possibility of exclusive self-fertilization in *Pollicipes polymerus* and confirm spermcapture mating for the first time in any species of barnacle, even when an individual has a nearby potential mate. Moreover, preliminary evidence further suggests that spermcapture mating also happens in acorn barnacles.

61.10 BARBANO, D.L.*; NISHIKAWA, K.C.; UYENO, T.A.; Northern Arizona University, Valdosta State University; *db356@nau.edu*

Ultrastructure and function in accessory heart of squid

Trabeculae as a structural theme transcend the vast diversity of morphologies represented by both vertebrate and invertebrate hearts. Trabeculae are muscular ties that extend through the lumen to connect portions of the heart wall. Longer trabeculae result in a rougher inner wall and narrower occluded central lumen, whereas shorter trabeculae confer a smooth internal wall surface and a wide lumen. There are multiple functional hypotheses accounting for varying level of trabeculation in the heart wall: 1) trabeculae allow metabolically active muscle to be bathed in blood of the lumen; 2) the roughness of the heart wall reduces suction that impairs heart filling; and 3) muscles arranged as trabeculae resist tension to prevent heart valve prolapse. In our work, we hypothesized that trabeculae may function as tunable elastic elements capable of storing and then returning energy with each beat of the heart, thereby increasing pumping efficiency. We examined the paired accessory hearts of the Humboldt squid (*Dosidicus gigas*) because they may have evolved in response to low peripheral blood pressures and also exhibit relatively long trabeculae and fill and expand elastically. Here we describe the ultrastructure of the trabeculae in longitudinal and cross section through the use of transmission electron microscopy (TEM). We dissected three trabeculae from the heart wall and three from the lumen for TEM analysis. Samples were embedded in a polyethylene glycol wax and stained in lead citrate and uranyl acetate. We described the arrangement and orientation of sarcomeres in the trabeculae and measured the lengths of the myofilaments. Finally, given the cross sectional areas and lengths of the trabeculae we developed an elastic model of the trabeculae to compare to future force lever experiments.

S9-2.1 BARKER, MS; RUNDELL, RJ*; University of Arizona; *msbarker@email.arizona.edu*

Polyploidy in Plants and Animals

Polyploidy, or whole genome duplication, is recognized as an important feature of eukaryotic genome evolution. Among eukaryotes, polyploidy has arguably had the largest evolutionary impact on vascular plants where many contemporary species are of recent polyploid origin. Recent genomic analyses also demonstrate that most plants experienced at least one round of ancient polyploidy, or paleopolyploidy. Thus, polyploidy is clearly an important component of plant diversity. However, it is not clear if polyploidy uniquely contributes to plant diversity relative to diploids. Using comprehensive genomic, biogeographic, and chromosomal data sets I evaluate the relative contributions of polyploidy and diploidy to the evolutionary and ecological diversity of vascular plants. Genomic analyses indicate that nearly 60 ancient genome duplications have occurred in the history of green plants, and at surprisingly similar rate across seed plant evolution. Analyses of diversification indicate that although recent polyploidy species have high extinction rates relative to diploid congeners, ancient polyploids are significantly associated with outstanding increases in plant diversity. Overall, these results indicate that recent and ancient polyploidy are conspicuous features of plant genomes, and their frequency in plants may be a consequence of the high rate of polyploid production and rare successful species rather than outstanding features of polyploid biology in general relative to diploids.

86.1 BAUMGARNER, Bradley/L*; INEROWICZ, Dorota; BROWN, Paul/B; Univ. of North Carolina Wilmington; *baumgarnerb@uncw.edu*

Comparative Proteomic Analysis of Intestinal and Pyloric Ceca Mucosa from Fed vs. Starved of Rainbow Trout (Oncorhynchus mykiss)

The goal of this study was to use 2-D gel electrophoreses to conduct a comprehensive proteomic analysis of the mucosa from the anterior gut intestinal tract (GIT) and adjoining pyloric ceca (PC) from fed vs. 4 wk starved rainbow trout. A total of 68 proteins, 40 proteins from GIT and 28 proteins from PC, were found to be differentially expressed and subsequently picked for in-gel trypsin digestion and peptide mass fingerprint analysis. Nine of the 21 positively identified proteins were directly related to innate immunity. The expression of alpha-I-antiproteinase decreased in GIT of starved vs. fed fish. Similarly, the level of a single isomer of leukocyte elastase inhibitor (LEI) decreased in the mucosa of GIT and PC of starved fish. However, one isomer of LEI increased in GIT mucosa of starved trout. Additionally, the level of copper/zinc-superoxide dismutase was reduced in PC mucosa of starved vs. fed trout. Also, the level of novel immune-type receptor II decreased, while the level of p-glycopotein increased in GIT mucosa of starved vs. fed fish. Overall, our results seem to indicate a reduced capacity to combat enzymatic and oxidative stress in GIT and PC mucosa of starved trout. In addition starvation may have resulted in increased gut permeability as indicated by an overall reduction most isoforms of keratin 8, which has previously been linked to gut permeability and inflammation in mammals. However, increased expression of p-glycoprotein in GIT mucosa of starved fish may indicate an adaptive response to increased levels of xenobiotics and other harmful agents in the intestinal lumen or in circulation. In mammals, increased expression of p-glycoprotein in intestinal epithelia has proven to play a critical role in reducing cellular and plasma levels of potentially toxic compounds.

43.7 BEATUS, T.*; RISTROPH, L.G.; MOROZOVA, S.; IAMS, S.M.; WANG, Z.J.; GUCKENHEIMER, J.M.; COHEN, I.; Cornell University; *tb343@cornell.edu*

Rock and Roll - how do flies recover from aerial stumbles?

Flying insects manage to maintain aerodynamic stability despite the facts that flapping flight is inherently *unstable* and that they are constantly subject to mechanical perturbations, such as gusts of wind. To maintain stability against such perturbations, insects rely on fast and robust flight control mechanisms, which are poorly understood. Here, we directly study flight control in the fruit fly *D. melanogaster* by applying mechanical perturbations *in mid-air* and measuring the insects' correction maneuvers. We glue small magnets on the flies and use pulses of magnetic field to apply torque perturbations along the flies' roll axis, which is, as we show, an unstable degree-of-freedom. We then use high-speed filming and 3D hull-reconstruction to characterize the detailed kinematics of their correction maneuver and show how the flies fully recover from roll perturbations of up to 60 degrees within 7-8 wing beats (30-40ms), which is faster than the visual response time. Finally, we show that this correction maneuver can only be explained by a *nonlinear controller*. This control mechanism is qualitatively different from the linear controller used for correcting perturbation in yaw. These results have implications ranging from the neurobiological mechanisms that underlie flight control to the design of flapping robots.

114.4 BEBUS, S.E.*; SMALL, T.W.; ELDERBROCK, E.K.; HEISS, R.S.; SCHOECH, S.J.; University of Memphis; *sarabebus@gmail.com*

Corticosterone Responsiveness at Nutritional Independence Predicts Behavior Nine Months Later in the Florida Scrub-Jay (Aphelocoma coerulescens).

Early environment can shape the phenotype of an individual through modification of its genetic information. Pre- and post-natal exposure to the adrenal steroid hormone, corticosterone (CORT), has been shown to mediate environmental effects via epigenetic alteration of the hypothalamic-pituitary-adrenal (HPA) axis in a manner that results in long-term changes to the behavior and physiology of an organism. Both baseline and stress-induced CORT levels of Florida scrub-jays *(Aphelocoma coerulescens)* were measured at nutritional independence (~ 70 days post-hatch), some 7 – 8 months prior to behavioral tests. Then, we assessed the behavioral response of individuals presented with food (peanuts) near a novel object as a measure of personality. Two tests, each utilizing a different object, were conducted on free-living birds in their home territories at 10-11 months of age. In the 'harder' test, birds were required to cross a bright orange ring (60 cm diameter) to obtain peanuts. In the 'simpler' test, peanuts were placed at the base of a mirrored ball (8 cm diameter). A test was completed when an individual approached or crossed the novel object and took a peanut. Individuals were separated into three groups based on their responses. Group 1 completed both tests, group 2 completed the mirrored ball test but not the ring test, and group 3 did not complete either test. Corrected integrated CORT levels differed among groups, with the highest levels in group 3 and the lowest levels in group 1. The results indicate that stress responsiveness, as measured by stress-induced CORT levels, is predictive of personality along a shy-to-bold continuum in non-manipulated free-living birds.

S2-2.4 BECHLER, D.L.; Valdosta State University, Valdosta, Georgia; *dbechler@valdosta.edu*

Kryptolebias marmoratus, the mangrove rivulus, as a model organism for comparative research

Several species of fish, with more in development, are currently being used as models for the study of genetic and evolutionary processes as well as other aspects of biology and biomedical research. In this presentation, the genetics, evolutionary biology, reproductive biology, ecology and behavior of *Kryptolebias marmoratus* are contrasted with other model fish species that are phylogenetically close to *K. marmoratus*. From this review and comparison, it is shown that the unique reproductive biology involving self-fertilization resulting in the development of homozygous strains, its unique mating system involving androdioecy, and its ecology and behavior provide opportunities for the study of a wide range of biological questions. As such, comparative studies involving the phenotypic expression of a wide variety of traits using *K. marmoratus* and other related species will permit researchers to determine critical links between genomic structure and the resultant phenotypic expression.

99.5 BEDORE, CN*; HARRIS, LL; KAJIURA, SM; Florida Atlantic University; *bedorech@gmail.com*

Behavioral sensitivity of batoid elasmobranchs to prey-simulating electric fields

Elasmobranchs are renowned for their electrosensory capabilities and sensitivity to electric fields has been quantified for numerous species. However, tremendous diversity in morphology, behavior, and habitat is present throughout the group and may confer adaptations in sensory system function. We tested the electrosensitivity of two morphologically, behaviorally, and ecologically diverse batoids, the cownose ray, *Rhinoptera bonasus*, and the yellow stingray, *Urobatis jamaicensis* (order Myliobatiformes). We predicted that electrosensory morphology may impart differences in electrosensitivity. We measured bioelectric fields of prey items and generated biologically relevant stimuli that were employed in behavioral assays. The yellow stingray demonstrated greater electrosensitivity than the cownose ray. Although the cownose ray possessed a greater number of electrosensory pores than the yellow stingray, most pores were concentrated on the ventral surface of the head, near the mouth and cephalic lobes. Conversely, the yellow stingray lacks cephalic specialization and its pores were more widely distributed across the body. Behavioral differences between the two species, rather than morphology, likely explain much of the discrepancy in electrosensitivity. Cownose rays are bentho-pelagic and spend much of their time in schools at the water surface, but prey primarily on benthic molluscs and may rely on cues other than electroreception until the last moments of prey localization. In contrast, the yellow stingray is exclusively benthic and feeds opportunistically on cryptic invertebrate prey, which demand greater sensitivity for detection. This study demonstrates that dramatic differences in sensory systems exist and that generalizations about sensory function may be inadequate, even within a closely related group.

104.6 BERGMAN, D.A.*; PAGE, K.; GAUTHIER, S.; Grand Valley State University; *bergmand@gvsu.edu*

Alkyphenol Effect on Development, Growth, Reproductive Behavior, and Survival of Crayfish

Crayfish are an important invertebrate that is affected by chemical pollutants, such as pesticide/herbicide runoff and industrial waste effluents. Crayfish are considered keystone species because they are an important resource for other species and consequently influence diversity and abundance. For these reasons, it is critical that we understand the effects of pollution on the behavior and ultimate survival of crayfish. Alkylphenols are a group of chemicals often concentrated in the tissues of crayfish, fish, and birds when released into nature. They are used in various detergents and pesticide formulations, which makes them very common pollutants. Exposure can lead to contamination levels between ten to several thousand times greater than in the surrounding environment. They have notably adverse effects in fish and likely have similar harmful impacts for crayfish. We examined the effect of exposure to two alkylphenol pollutants (nonylphenol and octylphenol) on development, growth, reproductive behavior, and success finding food. We found numerous impacts on crayfish when exposed to alkylphenols.

102.4 BERGMANN, P.J.*; BERK, C.P.; Clark University, University of Arizona; *pbergmann@clarku.edu*

Evolution and integration of weapons in horned lizards (Phrynosoma)

Many animals posses weapons for defense, prey procurement, and competition for resources. Many of these structures, including horns, antlers, spines, and venom glands exhibit positive allometry, being disproportionately larger and more effective in larger animals. Lizards of the genus *Phrynosoma* have multiple horns that they use in anti-predator defense. We show that all of these horns are positively allometric, as expected, and study the evolution of horn allometry and the morphological and ontogenetic integration among horns in this clade. The level of integration among horns will shape how horn morphology can evolve. We find that larger and adjacent horns are more integrated with one another morphologically, and in terms of their growth, supportive of both functional and developmental integration hypotheses. We also show that species with outlying horn morphologies also have odd horn allometries, suggesting that the evolution of horn morphology is mediated through the evolution of horn allometry.

43.2 BERGOU, AJ*; FRANCK, J; REIMNITZ, L; RISKIN, D; TAUBIN, G; SWARTZ, S; BREUER, K; Brown University; *attila_bergou@brown.edu*

Inertial and Fluid Forces during Bat Flight Maneuvers

Flying animals generate forces and torques to move through the air by coordinating the movement of their wings. Bats have evolved a particularly impressive capacity for flight control: with a very large number of wing joints, bats are able to extensively manipulate wing shape. By changing wing area, angle of attack, and camber, bat are able to control their flight through altering aerodynamic forces on their wings. The relative heaviness of bat wings compared to their total body mass, opens a second mode of control for these animals: by changing wing shape, bats are also able to control their flight through altering their overall mass distribution - generating apparent "inertial forces". Here, we use a model-based tracking framework to reconstruct detailed wing and body kinematics of maneuvering bats from high-speed video. Using this data, we extract simplified wing geometry and kinematics to estimate the aerodynamic forces on a bat's wings with numerical simulations. We use these forces with a low-order dynamical model of a bat to reconstruct how bats can adjust their wing motion to generate various flight maneuvers. Our reconstruction highlights the importance of both inertial and aerodynamic forces for flight control by bats.

34.3 BERKE, Sarah K*; JABLONSKI, David; KRUG, Andrew Z.; University of Chicago; *skberke@gmail.com*

Do clams of a feather arise together? Evolutionary dynamics, latitudinal gradients, and the global deployment of bivalve life habits

Functional diversity (i.e. the variety of life habits) is a critical component of overall biodiversity, with important implications for ecosystem function and the nature of adaptive radiations. Here we investigate the macroecological patterns in functional diversity for marine bivalves worldwide, using a database of occurrences for >5,000 species worldwide. We define functional groups by trophic mode, exposure on the seafloor, locomotory mode, and body size, using counts of trait combinations as well as distance-based metrics to assess latitudinal trends in functional diversity. Unsurprisingly, functional richness is a saturating function of taxon richness. However, we find an inverse latitudinal diversity gradient (LDG) for functional evenness (the distribution of taxa in niche space), even when taxon richness is controlled for. Thus, clustering in functional space increases at lower latitudes. This trend is likely driven by different origination rates among functional groups, working in concert with an LDG in origination rates. Younger genera, reflecting high origination rates, are disproportionately represented in the tropics. Functional groups with a greater proportion of young genera consequently come to represent a larger fraction of low-latitude faunas, increasing the uneven distribution of taxa among functional groups there. Surprisingly, originations do not show a recent downturn, and thus provide no evidence of saturation in any functional traits, despite the fact that the area of tropical habitats has shrunk over the past 5 my. Crowding of taxa into spatial bins and functional categories has evidently not impeded continued diversification for the most prolific bivalve clades and modes of life.

S1-1.4 BERMAN, Gordon J*; BIALEK, William; SHAEVITZ, Joshua W; Princeton University; *gberman@princeton.edu*

A data-driven methodology for analyzing the behavior of terrestrial fruit flies

The last decades have seen an explosion in our ability to characterize the molecular, cellular and genetic building blocks of life; the ingredients out of which we try to explain the rich and compelling behavior of living organisms. Our characterization of behavior itself, however, has advanced more slowly. Since modern ethology was founded over a century ago, behavioral experiments have focused largely on a restricted set of behaviors within the scope of a limited environment. Moreover, the set of behaviors to be examined is often user-defined, creating the potential for human bias and anthropomorphism. The research presented here describes a data-driven methodology for analyzing animal behavior, focusing on the fruit fly, *Drosophila melanogaster*, as a model system. Towards this end, we have built an imaging system that can track single flies as they move about a relatively unencumbered environment. Utilizing this capacity to generate large data sets of animal behavior, we have developed a method for automatically identifying behavioral states using techniques from image analysis, machine learning, and nonlinear dynamics. Identifying these states provides the starting point for many analyses and creates the possibility for automatic phenotyping of subtle behavioral traits.

41.6 BERNHARDT, L.*; BECHLER, D.L.; RING, B.C.; ELDER, J.F.; Valdosta State University; *lbernhardt@valdosta.edu*

The impact of color on egg laying rates and outcrossing of Kryptolebias marmoratus

Kryptolebias marmoratus participates in a reproductive system involving androdioecy in which populations are composed of hermaphrodites and males where self-fertilization or outcrossing can occur. As result of self-fertilization, it is possible to develop nearly 100% homozygous strains or reestablish heterozygosity via outcrossing between a hermaphrodite and a male. Because these fish are widely used in many aspects of research, the need for eggs is great. My research examines background color and its relationship to movement patterns, egg laying and outcrossing. Prior to beginning this research, I assessed lag time of untested strains to determine position on a shy/bold continuum. From this, five strains (R2, HON 7, SSRHL, SLC8E, and VOL) were selected to cover differing geographical origins and levels of shyness and boldness. All five strains have been tested for activity and movements as a function of color preference. The rate of movement patterns matched the shy/bold order previously established. Color preference tests showed black was most preferred and white least preferred. The results of egg production using black and white backgrounds with the five strains have revealed a daily cyclical pattern of egg laying and sudden bursts of egg laying upon changing background color. Currently, experiments are being conducted to see if color influences outcrossing rates. This work is important because it will increase our knowledge so as to better understand the impact of color on egg laying and its potential to establish heterozygosity via outcrossing of *K. marmoratus*.

49.1 BERTRAM, JEA*; HASANEINI, SJ; University of Calgary; *jbertram@ucalgary.ca*

What are walking and running, and why? Modeling optimization tested against gravity manipulation

Simulated reduced gravity studies indicate a fundamental difference between human walking and running. The metabolic cost of running decreases directly with decrease in gravity and kinematic patterns change substantially and systematically. In contrast, only relatively minor changes occur in walking when gravity is changed. Although numerous hypotheses have been put forward to explain these differences, no clear evidence of the root of these differences exists. Here we test the gait predictions of a simple but comprehensive model of bipedal locomotion under varying gravity levels. The model is able to predict optimum actuation patterns, mechanical cost and the resultant movement patterns that provide the most effective locomotion under the circumstances encountered. We then evaluate the response of human subjects to the same locomotion conditions and find that their response parallels that of the model's predictions. Since the behavior of the model can be analyzed in detail, we can conclude that these gaits are optimized largely for the trade-off between momentum loss resulting from strut-like contact of the supporting limb and the cost of leg work required to limit those losses. The decreased cost of running in reduced gravity is largely due to the low cost of the non-contact 'flight' phase of this gait. The cost of walking is largely determined by momentum loss, a function of mass and velocity that is little influenced by gravity level. There appears no reason why the results found for human locomotion mechanics would not apply to the fundamentals of quadrupedal gait as well.

42.7 BIELECKI, Jan*; GARM, Anders; University of Copenhagen; *jbielecki@bio.ku.dk*

Swim pacemaker response to bath applied neurotransmitters in the box jellyfish Tripedalia cystophora rhopalium.

Here we present the first physiological evidence of neurotransmitters used in box jellyfish visual processing. Bath applied RFamides have a proven positive effect on photo tactic behavior in cnidarians but until now there has been no physiological evidence of the effect of any types of neurotransmitters. Extracellular electrophysiology was performed on the rhopalial swimming pacemaker of the box jellyfish *Tripedalia cystophora* and showed a marked decrease in pacemaker output in the presence of bath applied FMRFamide and serotonin-like neurotransmitters. Other neurotransmitter species commonly associated with cnidarians (taurine, GABA, acetylcholine, glycine and glutamate) had no detectable effect. The inhibitory effect on swim pacemaker cells observed in this work is seemingly in direct contradiction to the positive photo taxis behavioral studies performed on other cnidarians, however, a decrease in pacemaker frequency is not directly correlated to negative photo taxis, but is rather an indication of swimming strategy in the box jellyfish; turning around the passive side of the bell. An inhibitory signal on one side of the bell would thus cause the animal to turn around that axis. This effect can be correlated to new biomechanical research on box jellyfish bell contractions to explain the positive photo taxis observed in previous studies.

S2-1.4 BIELMYER, GK*; DECARLO, C; MORRIS, C; CARRIGAN, T; BULLINGTON, JB; Valdosta State University; *gkbielmyer@valdosta.edu*

The Influence of Salinity on Zinc and Nickel Toxicity to Two Euryhaline Fish Species

Salinity can rapidly change in estuarine systems on a daily and seasonal basis and these changes may influence the bioavailability and thus toxicity of metals to estuarine organisms. Despite this concern, few studies have characterized the influence of salinity on metal toxicity, particularly using the same fish species. In recent years, there has been increasing interest in the effects of zinc (Zn) and nickel (Ni) on aquatic organisms in environments with varying water chemistry. To address this issue, 96 h toxicity experiments were performed with two euryhaline fish species, *Fundulus heteroclitus* and *Kryptolebias marmoratus*. Median lethal concentrations (LC50s) for Zn and Ni were determined for 7-9 d old larvae of each species at six different salinities. For both *F. heteroclitus* and *K. marmoratus*, metal toxicity generally decreased with increasing salinity. The LC50 values for both metals were similar between the two species at salinity extremes (0 and 36 ppt); however, at intermediate salinities *K. marmoratus* was more sensitive than *F. heteroclitus*. Additional experiments were performed in freshwater supplemented with individual salts to determine which components of saltwater (magnesium, calcium, sodium, and/or chloride) were protective against acute Zn and Ni toxicity to *F. heteroclitus*. Among the ions tested, calcium was most protective against Zn toxicity, likely due to cation competition for binding sites on the gill. Alternatively, chloride concentration was most protective against acute Ni toxicity likely resulting from increased complexation of the metal. These results provide new data concerning effects of water chemistry on metal toxicity in euryhaline fish and could be useful for development of site-specific water quality criteria.

S4-1.6 BIRD, Christopher E*; TIMMERS, Molly A.; SMOUSE, Peter E.; TOONEN, Robert J.; University of Hawaii at Manoa, NOAA Honolulu, Rutgers, The State University of New Jersey; *cbird@hawaii.edu*

Haplotypes, genetic distance and the inference of dispersal patterns using analysis of molecular variance

Tracking the dispersal routes of marine organisms is a major conservation challenge in the study of ecology, evolution, and conservation biology. The PCR revolution and subsequent widespread use of molecular techniques to infer dispersal patterns has produced large amounts of data; however, interpretation is not always straightforward. Here, we investigate the dispersal patterns of the destructive coral-eating crown of thorns sea star, *Acanthaster planci*, using both haplotype-based and genetic distance-based analysis of molecular variance (AMOVA). While it is often assumed that accounting for the evolutionary relationships among haplotypes (distance-based AMOVA) add resolution to an analysis, we demonstrate that under commonly occurring circumstances, haplotype-based AMOVA provides better resolution. We present a unique method of determining the utility of distance-based and haplotype-based AMOVA. In the case of *A. planci*, distance-based AMOVA is informative at large spatial scales, where there is a strong association between molecular similarity and spatial distribution. Counter to popular intuition, haplotype-based AMOVA is more informative at fine spatial scales where migration rate is outstripping the mutation rate of our marker (mitochondrial control region). Armed with this information, we conclude that the dispersal patterns of *A. planci* are even more spatially restricted than we have previously proposed, and it is difficult for outbreaks of the sea star to propagate across deep ocean channels. These techniques and results are broadly applicable to all taxa, especially given the movement towards genome-wide surveys of single nucleotide polymorphism (SNP) haplotypes.

19.3 BIRN-JEFFERY, A.V.*; DALEY, M.A.; Royal Veterinary College, UK; *abirnjeffery@rvc.ac.uk*

The effects of posture and body mass on uneven terrain locomotion in Galliformes and Struthio camelus

Galliformes are a diverse group of ground dwelling birds, which are capable runners and span a 50-fold body size range (0.085-5kg). This order is ideal for investigating neuro-mechanical, stability and energy management mechanisms used over uneven terrain. In contrast, ostriches (*Struthio*) are the largest extant bipedal runners, and possess a straight legged posture typical of large animals. We hypothesise that postural changes associated with body size will alter the strategies used to run in uneven terrain. Small body mass combined with a crouched posture will allow robust stability using passive energy mechanisms, reducing reliance on feedback information. We collected kinetic and kinematic data as galliforms ran across six terrain conditions of varying 'roughness', using level terrain as control. Obstacles were of a single height; from 10-50% leg length (L_{leg}), spaced 2 strides apart. Similar data were collected from ostriches through an ontogenetic series, with only a 10% L_{leg} height obstacles. Ostriches were only capable of negotiating a 10% L_{leg} obstacle, and struggled with this height at 9 months old. In contrast, quails were capable of negotiating an obstacle of the same absolute size (8cm), which amounted to 80% L_{leg}. All birds appeared to anticipate the obstacle by increasing their centre of mass height before encountering the obstacle. Interestingly, smaller birds used a lower leg retraction velocity; one strategy for greater robustness in uneven terrain. Birds appear to optimise for safety over stability, as they allow changes in body motion and energy but minimise changes in ground reaction force. Understanding the mechanisms used by birds for robust locomotion in uneven terrain will allow replication of their remarkable performance in legged robots and prosthetics.

120.5 BISCOCHO, D. *; LEISE, E.M.; University of North Carolina Greensboro; *esther_leise@uncg.edu*
Is GABA an Inhibitory Neurotransmitter in the Neural Circuit Regulating Metamorphosis in Ilyanassa obsoleta?
Metamorphosis in the marine mud snail, *Ilyanassa obsoleta*, is an irreversible biological event by which larvae metamorphose into sexually immature juveniles that reside on coastal mudflats. *I. obsoleta* undergoes transformations that include loss of the apical ganglion, reorganization of brain ganglia, and disappearance of the velar lobes that are essential in mobility and feeding. The neurotransmitter γ-aminobutyric acid (GABA) can induce metamorphosis in the abalone *Haliotis rufescens* (Morse, et al 1979. Science 204, 407-410), but results of our experiments with *I. obsoleta* have revealed an inhibitory action for this compound. Bath application of GABA to larval *I. obsoleta* does not elicit metamorphosis. Earlier work on *I. obsoleta* demonstrated that the neurotransmitters serotonin (5-HT) and nitric oxide function as a promoter and repressor of metamorphosis, respectively. GABA can inhibit serotonergically induced metamorphosis, suggesting that GABA acts either downstream of, or directly on serotonergic neurons. We are currently exploiting reagents that modify the function of GABA transport, synthesis and metabolism. In bath application, muscimol, a $GABA_A$ agonist, inhibits spontaneous metamorphosis for 48 hours. Bath application of isoguvacine, another $GABA_A$ agonist or aminooxyacetic acid (AOA), a major inhibitor of GABA-Transaminase can repress metamorphosis in 5-HT-induced larvae. Currently, experiments in which we inject reagents into competent larvae allow us to drastically decrease chances of interactions between neuroactive compounds and epidermal sensory receptors. These experiments should further support the idea that GABAergic activity occurs internally within the larval central nervous system, perhaps in the apical ganglion. Together, our data will help to elucidate the role of GABA in this molluscan metamorphic pathway.

56.1 BLEVINS, EL*; MACESIC, LM; MULVANEY, D; Harvard University, Cambridge, MA, Mount Holyoke College, South Hadley, MA, Florida Atlantic University, Boca Raton, FL; *eblevins@fas.harvard.edu*
Synchronized Swimming: Coordination of pelvic and pectoral fins during augmented punting in stingrays
Benthic animals live at a fluid-solid boundary, and therefore have access to multiple modes of aquatic locomotion—they can swim through the water, or use the nearby substrate to "walk." Aquatic walking and similar substrate-dependent forms of propulsion have evolved multiple times in vertebrates: in lungfish, teleosts, salamanders, sharks and batoids. Within batoids, skates are benthic locomotion specialists, using uniquely adapted pelvic fins to "punt" along the substrate, pushing the body forward while the pectoral disc is kept still. In contrast, benthic rays, close relatives of skates, exhibit "augmented punting," combining pelvic punting with pectoral undulations like those used during swimming. Studies of other benthic locomotors (e.g. frogfish, salamanders) have found both synchronous and asynchronous motions of fin/limb pairs depending on species and gait. In this study, we investigate how benthic rays coordinate fin pairs to combine benthic locomotion and swimming, hypothesizing that pelvic and pectoral fins are used synchronously during augmented punting to align the timing of thrust production. We used high-speed video to film dorsal and ventral views of freely-punting freshwater stingrays (*Potamotrygon hystrix*, n=5, disc length=9.10cm±0.224SD), and analyzed nine punting sequences per individual. We determined the timing of events in the pelvic punt cycle (thrust start, thrust end, and recovery phase), the time of the pectoral wave's maximum and minimum height, and the stingrays' distance-traveled and speed during pelvic and pectoral cycles. Pectoral wave maxima are tightly aligned to the end of the pelvic thrust cycle, confirming synchrony of fin pairs in pelvic-pectoral locomotion.

93.4 BLIER, Pierre U*; PICHAUD , Nicolas; BALLARD, J. William O.; TANGUAY, Robert M; UniversitÃ© du QuÃ©bec, Rimouski Qc, University of New South Wales, Australia., UniversitÃ© Laval, QuÃ©bec Qc; *pierre_blier@uqar.qc.ca*
Divergent mitochondrial haplotypes convey clear adjustments in metabolic phenotypes.
Linking the mitochondrial genotype and the organismal phenotype is of paramount importance in evolution of mitochondria. In this study, we determined the differences in catalytic properties of mitochondria dictated by divergences in the siII and siIII haplogroups of Drosophila simulans using introgressions of siII mtDNA type into the siIII nuclear background. Our results showed that the catalytic properties of the electron transport system are not impaired by introgressions, suggesting that the observed divergences in mitochondrial functions are mainly confered by mtDNA differences and not of nuclear DNA or mito-nuclear interactions. This is the first study in our knowledge that make a clear demonstration that one haplogroup observed in a natural population can confer phenotypic divergences in terms of functional properties of the mitochondrial metabolism.

33.3 BLOB, R.W.*; KAWANO, S.M.; MOODY, K.N.; BURCHFIELD, H.J.; MAIE, T.; PTACEK, M.P.; SCHOENFUSS, H.L.; Clemson Univ., St. Cloud State Univ.; *rblob@clemson.edu*
Environmentally Correlated Divergence in Morphology and Climbing Performance in Waterfall-climbing Fish from Hawai'i and Kaua'i
Depending on the island to which they return, postlarvae of the climbing gobiid fish, *Sicyopterus stimpsoni*, encounter different environments when they enter freshwater to migrate to upstream breeding habitats after their oceanic larval phase. Streams on Hawai'i have waterfalls nearshore, placing a premium on climbing performance; in contrast, streams on Kaua'i have long, low-gradient stretches below waterfalls, placing a premium on evading non-climbing predators. Our previous work showed that climbing and predation impose selection favoring contrasting body shapes (streamlined for climbing, tall for predator evasion). Also, fish returning to each island have shapes advantageous for the main pressure they encounter. Do such shape differences lead to performance differences that could form the basis for selection in nature? We filmed postlarvae from both islands to compare climbing kinematics, speed, and success rate. *S. stimpsoni* from Kaua'i are slower during single climbing cycles than *S. stimpsoni* from Hawai'i. However, longer (20 cm) trials that included rest periods showed no difference in net speed, because fish from Kaua'i rested less. One factor that may contribute to slower climbing movements in Kaua'i fish is that, with narrower heads, their oral sucker expands only one third as much as in Hawai'i fish, possibly limiting body advancement while this sucker is attached to the substrate. Such kinematic and performance differences may contribute to the lower success rate observed for Kaua'i (50%) versus Hawai'i fish (70%) in climbing trials over 2.4 m (100 BL) distances. NSF IOS-0817794, IOS-0817911.

60.4 BLUM, Y*; BIRN-JEFFERY, A; DALEY, MA; Royal Veterinary College; *yblum@rvc.ac.uk*

Perturbed bipedal running: How do touch down conditions affect stance dynamics?

Our goal is to identify control strategies used by birds to achieve stable and robust locomotion in uneven terrain. We want to investigate how touch down conditions, which are determined by swing leg control strategies, influence stance dynamics during both steady state running and in the presence of ground height disturbances (i.e. a step down). Avian running trials were conducted on a runway, and dynamics and kinematics of five birds (guinea fowl, *Numida meleagris*) were recorded. We had three experimental setups, consisting of a flat pathway, a ramp with a 4 cm drop and a ramp with a 6 cm drop. The results suggest that swing leg control, namely the time-dependent adjustment of leg angle and leg length in anticipation of ground contact, affects the initial conditions of the following stance phase, and therefore, controls the stance phase as well. Especially the horizontal impulse (i.e. speeding up or slowing down), and both the net center of mass work and the net leg work (i.e. energy production or absorption) seem to be strongly related to center of mass velocity, leg angle and leg length at the instant of touch down. While the flight phase might be controlled by a mainly feed-forward and time-dependant swing leg strategy with a triggered starting point, our results suggest that during stance phase the system's energy is regulated depending on the resulting leg conditions at the instant of touch down. Such a combination of control strategies, namely a "blind" flight control with a stance control that relies on its initial conditions, could work without feedback and might explain why running birds such as guinea fowl are such remarkable obstacle negotiators.

74.6 BODINIER, Charlotte*; MENG, Yanling; GALVEZ, Fernando; Louisiana State University, Baton Rouge; *cbodinier@lsu.edu*

Localization and expression of Na^+/K^+-ATPase, $Na^+/K^+/2Cl^-$ cotransporter, and CFTR during osmotic challenges to Fundulus grandis.

We investigated the role of Na^+/K^+-ATPase (NKA), $Na^+/K^+/2Cl^-$ cotransporter (NKCC), and cystic fibrosis transmembrane conductance regulator (CFTR) in transporting epithelia of the gulf killifish, *Fundulus grandis*, during osmotic challenges. Although NKA was always expressed on the basolateral membrane of epithelia regardless of salinity, the cellular distributions of NKCC and CFTR were salinity-dependent. During seawater acclimation, NKCC and CFTR were mainly co-localized to the apical membrane of the intestine, but were distributed to the basolateral and apical membranes of gills, respectively. Freshwater transfer resulted predominantly in apical NKCC and basolateral CFTR cellular distributions in the intestines and gills. Exposure of fish to intermediate salinities (1 or 5.0 ppt) resulted in mixed cellular distributions of NKCC and CFTR in the gills and intestines, suggesting the presence of mixed cell types in these tissues. We also found that the expression of transport proteins in the kidney varied extensively with salinity, but that these protein-distribution patterns depended on the localization along the kidney tubule. This presentation will describe the potential roles of these proteins in osmoregulation and acid-base regulation during osmotic challenges.

118.1 BOETTGER, SA*; TARASKA, NG; West Chester University of Pennsylvania; *sboettger@wcupa.edu*

Development of hemic neoplasia in Mya arenaria along the Atlantic coast of the United States.

Hemic neoplasia, a disease in bivalve mollusks, is characterized by highly mitotic hemocytes is one of the six most destructive molluscan diseases. Efforts to link the onset of this fatal disease to environmental factors have depended on data collected following episodic contamination events. Studies documenting chronic neoplasia development are needed due to increased contaminants, elevated temperatures and sediment changes in the marine environment. Here we examine the development of neoplasia in the soft shell clam, *Mya arenaria*, at 12 sites of know environmental, contaminant and sediment qualities between Maine and Maryland. Deployment of healthy, hatchery raised *Mya arenaria* for 12 months will allow us to document the highest frequency of neoplasia development and decrease of phagocytic ability (immune response) in relationship to environmental temperatures, sediment characteristics and contaminant. Sediment levels of heavy metals have previously been linked to neoplasia development and indicate vulnerability of juvenile clams to environmental stress induced by heavy metal contamination, which decreases their immune defenses. (NOAA Saltonstall/Kennedy NA08NMF4270215 to SAB)

95.5 BOGGS, Ashley S P*; LOWERS, Russell H; HAMLIN, Heather J; MCCOY, Jessica A; GUILLETTE, Louis J; Medical University of South Carolina / University of Florida, Innovative Health Applications, Kennedy Space Center, NASA, University of Maine / Medical University of South Carolina, Medical University of South Carolina; *boggsas@musc.edu*

The role of plasma iodide and endocrine disrupting chemicals in predictive adaptive responses of Alligator mississippiensis

Alterations to thyroid hormones during development could reset the hypothalamic-pituitary-thyroid (HPT) axis in a manner indicative of a predictive adaptive response. Endocrine disrupting chemicals (EDCs) such as PCBs and PBDEs have been shown to alter the regulation of thyroid hormones. However, the influence of these chemicals could be altered by iodide concentrations. American alligator eggs from an estuarine environment with high iodide availability, a freshwater environment contaminated with EDCs, and a reference freshwater environment were incubated under identical conditions. Hormone concentrations, thyroid histology, thyroid gene expression, and growth were recorded at hatch and after 10 months of ad libitum food and freshwater. Neonates from the estuarine site were hyperthyroid while those from the contaminated freshwater site were hypothyroid despite similar concentrations of PCBs and PBDEs in juveniles from both sites. Increased plasma iodide concentrations were correlated with increased thyroid hormone concentrations among the estuarine neonates. After 10 months, thyroid hormone concentrations returned to normal but thyroidal histology and gene expression, and somatic growth remained altered. This suggests a resetting of the HPT axis to compensate for EDCs or elevated iodide exposure through a predictive adaptive response.

84.2 BOK, M.J.*; PORTER, M.L.; CRONIN, T.W.; University of Maryland, Baltimore County; *mikebok@gmail.com*
Ultraviolet vision in mantis shrimp
Stomatopod crustaceans, or mantis shrimp, possess some of the most notable visual systems known to biology. Their visual ecology has been characterized in great detail, showing that many species of this order are capable of advanced color and polarization discrimination. The photoreceptors of stomatopod compound eyes are maximally sensitive to at least ten separate wavelengths of light in the human visible range, from 400 to 700 nm. Stomatopod photoreceptors have also been shown to be maximally sensitive to at least five discrete wavelengths of ultraviolet (UV) light, between 310 and 380 nm, as well as orthogonal polarization angles of UV light. Little is known about the visual pigments or spectral tuning mechanisms at work in these UV-sensitive photoreceptors. Here we report on preliminary molecular investigations of short wavelength-sensitive opsin transcripts in the retina, and spectroscopic measurements from the optical components of the eye. These findings suggest that multiple UV-absorbing visual pigments and novel optical filters are responsible for the surprising diversity of spectral sensitivities observed in stomatopod UV photoreceptors. Furthermore, comparative analysis of these tuning mechanisms alongside preliminary behavioral experiments may indicate a variety of UV spectral tuning mechanisms, and UV visual capabilities, across different species of stomatopods.

107.2 BOMPHREY, R.J.*; HENNINGSSON, P.; MICHAELIS, D.; HORSTMANN, T.; HOLLIS, D.; University of Oxford; *richard.bomphrey@zoo.ox.ac.uk*
Desert locust aerodynamics: instantaneous wake volumes using tomographic particle image velocimetry (tomo-PIV)
Tomographic Particle Image Velocimetry (tomo-PIV) is becoming increasingly established in the experimental fluid mechanics community as a volumetric method for the analysis of complex flows, but has yet to be applied to animal flight despite the major advances in the field made possible by its planar predecessors. The technique captures a volume of instantaneous flow velocity vectors with equal resolution along each axis rather than the more limited experimental sampling plane of stereo-PIV. From the three-dimensional flow fields, a portrait of the flow features can be visualized and quantified. We recorded the wake of desert locusts flying tethered in a wind tunnel using broad sheet laser illumination operating at 1kHz (pulse pairs) and a four-camera data acquisition system. This resulted in overlapping, near-wake volumes forming a time-resolved representation of the vortex wake. Here we present novel, Tomo-PIV data revealing, for the first time, wake components of a flying animal that have been hitherto undetectable using existing techniques. The wake is complex, due primarily to the existence of out of plane vortex elements of variable strength and significant wake deformation is apparent. To compliment the tomo-PIV study, we have characterised some of the most important parameters concerning wake deformation relevant to animal flight using fixed-wing model flow visualization.

S5-2.1 BONNET, X; CNRS CEBC France; *bonnet@cebc.cnrs.fr*
Long term field study of sea kraits in New Caledonia: fundamental and conservation issues
A long term field study focusing on two sea krait species was set up in New Caledonia in 2002. More than 30 sites were sampled, and in most places mark-recapture procedure was implemented. The initial objectives were oriented toward fundamental issues and aimed to examine the adaptations to the amphibious life style of the sea kraits and the associated trade-offs to cope with terrestrial and aquatic environments. Rapidly however, the potential of the sea kraits as useful bio-indicators of marine biodiversity, of contamination by human activities (nickel mining for instance), and of the general trophic functioning of reef ecosystems became obvious. With more than 12,000 individuals marked and thousands of recaptures, the population functioning was assessed at large scale and revealed novel patterns. Notably, sea kraits tend exhibit fish like meta-population functioning despite the fact that their life style is clearly similar to those of other air breathing top predators (seabirds, seals, marine iguanas). Finally, several anecdotic events (rain falls...) provided unsuspected physiological insights of general importance to better understand both fundamental and conservation problems. One of the lessons of this long term study is that key results emerged in an unexpected way, but all were dependent from intensive field work.

31.3 BORCHERT, JD*; RUSCH, T; ANGILLETTA, M; Arizona State University; *jdborche@asu.edu*
Variation in assimilation rate among populations of Sceloporus lizards at constant and fluctuating temperatures
We examined the assimilation rates of *Sceloporus tristichus* from Utah and Arizona and *Sceloporus consobrinus* from Nebraska and Texas. Two separate experiments were conducted: one in which lizards were held at constant temperatures (30, 33, or 36°C) and a second in which lizards were exposed to different diel cycles of temperature (either 6, 10, or 14 h at 33°C and the remainder at 20°C). During each experiment, we measured food intake and waste production. At constant temperatures, feeding rate increased as temperatures increased. At fluctuating temperatures, feeding rates at 10 and 14 h of high temperature were nearly double that at 6 h of high temperature. However, feeding at 10 and 14 h of high temperature were similar. This result contradicts recent mechanistic models, which assume that energy intake increases linearly with the time available for thermoregulation.

71.5 BORDA, Elizabeth*; KUDENOV, Jerry D.; BLAKE, James A.; ALVARADO, Jaime R.; CHEVALDONNé, Pierre; DESBRUYèRES, Daniel; FABRI, Marie-Claire; HOURDEZ, Stephane; PLEIJEL, Fredrik; SCHULZE, Anja; SHANK, Timothy M.; ROUSE, Greg W.; Texas A&M University at Galveston, University of Alaska Anchorage, AECOM, Centre de Brest de l IFREMER, Centre d'OcÃ©anologie de Marseille, Ifremer MÃ©diterranÃ©e , Station Biologique de Roscoff, TjÃ¤rnÃ¶ Marine Biological Laboratory, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography; *bordae@tamug.edu*

Cryptic species of Archinome (Annelida: Amphinomida) from hydrothermal vents and cold seeps.

Since its description from the Galapagos Rift in the late 1980's, the amphinomid *Archinome rosacea* (Annelida: Amphinomida) has been recorded from hydrothermal vents in the Pacific, Atlantic and Indian Oceans. In general, specimens are morphologically uniform and thus *A. rosacea* has been thought to have a cosmopolitan distribution. However, the recent description of a second species and new records from cold methane seeps suggests the need to re-evaluate *Archinome* from a taxonomic and evolutionary standpoint. This study examines the phylogenetic relationships of specimens identified as *Archinome* on a broad scale, including samples from the type localities of *A. rosacea* (Galapagos Rift) and *A. storchi* (Pacific Antarctic Ridge), as well as specimens from the Costa Rica Margin, Guaymas Basin, East Pacific Rise, Lau and North Fiji Basins, Mid Atlantic and Central Indian Ridges. Our results show that *Archinome* is monophyletic and includes at least six species, four of which are new to science. In the absence of clear morphological differences among species, the geographic distributions and diagnoses of species are re-delineated on the basis of both nuclear and mitochondrial DNA sequence data and High-Resolution Melting Analysis. Distributional data of *Archinome* species indicate the potential for long-distance dispersal leading to broad distributions and the ability for larvae to cross a wide bathymetric depth range. Biogeographic connections between vents and seeps are highlighted, as are potential connectivity between populations from vent fields located in the northern Atlantic and Indian Oceans.

107.1 BOUROUIBA, Lydia; Massachusetts Institute of Technology ; *lydia.bourouiba@math.mit.edu*

Disease transmission: insights from fluid dynamics

Following the infiltration of a pathogen in a population of susceptible hosts, the nature of the "contact" between infected and non-infected members of the population becomes critical in shaping the outcome of the epidemics. This is true whether one considers a human, an animal, or a vegetal population; nevertheless, the mechanisms leading to contact and prescribing the spread of common infectious diseases remain poorly understood. Here, we discuss how a combination of theoretical and experimental biofluid dynamics approaches can help shed light on the dynamics of contact. Particular attention is given to respiratory and foliar diseases.

43.5 BOWLIN, M.S.*; ENSTROM, D.A.; COCHRAN, W.W.; COCHRAN, J.; Univ. of Michgan-Dearborn, Illinois Natural History Survey, JDJC Corp.; *melissabowlin@gmail.com*

Migration in three dimensions: Flight altitudes of small migratory birds

Small migratory birds use approximately one third of their energy budget during migration on flight; most of the mortality that these animals experience may also be concentrated in this phase of the annual cycle. Yet, we know very little about the behavioral ecology of small migrants during their nocturnal flights. Here, we present data we have gathered from ~35g Swainson's Thrushes (*Catharus ustulatus*) carrying newly-developed 1g altitude transmitters. With altitude readings every 30s during the migratory flights of birds followed from takeoff to landing, our tracks represent the most complete data set about the flight altitudes of individual passerine birds collected to date. Surprisingly, the birds did not all adopt an energetically efficient strategy of ascending, leveling off, and then descending; instead, some repeatedly gained and lost over 60% of their maximum altitude. We will present these data and discuss our initial efforts to correlate this intra-individual variation in flight altitude with variables such as light pollution and wingbeat frequency.

100.1 BOYLE, W.A.*; WINKLER, D.W.; GUGLIELMO, C.G.; Univ. Western Ontario; *aboyle7@uwo.ca*

Female Tree Swallows modulate fat and lean mass in anticipation of increased foraging costs of chick rearing

Birds often lose body mass during nesting. Determining if this mass loss represents an energetic cost of reproduction (energetic stress hypothesis), serves an adaptive function (flight efficiency hypothesis), or results from physiological processes that are neutral with respect to fitness (e.g. gonadal regression hypothesis) is important to interpreting variation in body mass and energy stores in the context of life-history theory. New QMR technology enables precise, repeated measurements of body composition on the same individuals, and we used this to test predictions distinguishing among hypotheses for mass loss in female Tree Swallows (*Tachycineta bicolor*). Swallows lost mass abruptly in anticipation of the peak foraging demands of feeding chicks. Lean mass and fat mass losses varied independently, with small and gradual losses in lean mass during incubation, and dramatic losses of fat immediately prior to and following hatching. The period of greatest parental foraging costs was not associated with any significant changes in total body mass, lean mass, fat mass, or water. Net change in body mass from early incubation until mid-way through chick rearing was associated strongly with initial body mass and to a lesser degree, brood size. These findings are consistent with females facultatively modulating endogenous energy stores to maximize insurance against bad weather and poor foraging opportunities during incubation, but then lowering body mass to maximize flight efficiency once chicks hatch, thereby reducing their costs of feeding nestlings. This study corroborates results of a growing number of studies suggesting that increases in mass in anticipation of reproduction (and the subsequent loss of that mass) are likely best viewed as part of an adaptive suite of interrelated reproductive decisions made by females each year.

26.5 BOYLE, M. J.*; RICE, M. E.; Smithsonian Marine Station at Fort Pierce, Florida; *boylem@si.edu*

Life History Evolution: Insights from Comparative Development and Gene Expression in Sipuncula

Marine invertebrate animals develop through some of the most diverse life history patterns on earth, but how those patterns evolve is a mystery. We are in search of evidence that may reveal how direct, lecithotrophic and planktotrophic developmental modes diverged in Sipuncula, a clade of non-segmented, coelomate marine worms with a unique larval form, the pelagosphera. Our models include: *Phascolion cryptum*, which develops directly from an embryo to the vermiform stage, *Themiste alutacea*, which develops indirectly through lecithotrophic trochophore and pelagosphera larvae, and *Nephasoma pellucidum*, which develops indirectly through a lecithotrophic trochophore and a planktotrophic pelagosphera larva. Confocal laser scanning micrographs reveal variation between these species in the position and timing of organ system formation, including the presence or absence of a buccal organ, terminal organ, trochal bands or functional gut. Molecular evidence across Metazoa suggests that such variation is regulated by the expression of transcription factors and cell signaling pathways. We isolated fragments of developmental regulatory genes (*foxA, blimp-1, brachyury, wingless*), including three Parahox genes (*gsx, xlox, cdx*) from each sipunculan species. The *foxA* gene is expressed in the developing esophagus and endoderm of *N. pellucidum* and *P. cryptum*, and the *wingless* gene is expressed in ectoderm of the digestive system, posterior pole, and transition between the introvert and trunk of the pre-vermiform stage of *P. cryptum*. The Parahox genes are expressed in the developing gut of *N. pellucidum*, and both the nervous system and gut during development of *P. cryptum*. Additional patterns for all three species are in progress, and they will be presented in the context of life history evolution.

10.3 BOYLES, J.G.*; VERANT, M.L; WALDREP, JR., W.; WIBBELT, G.; BLEHERT, D.S.; Univ. of Tennessee, Knoxville, Univ. of Wisc, Madison, Univ. of Chicago, Leibniz Institute for Zoo and Wildlife Research, Berlin, Germany, USGS National WIldlife Health Center, Madison, Wisconsin; *jgboyles@utk.edu*

Temperature-dependent growth performance of Geomyces destructans>, the fungus associated with white-nose syndrome in bats

White-nose syndrome (WNS) has devastated populations of cavernicolous bats in eastern North America. The fungus *Geomyces destructans* (*Gd*) is the likely causative agent, but gaps remain in our knowledge of the basic biology of *Gd*. As a psychrophilic microorganism, temperature restrictions limit active growth of *Gd* to cold environments, but only cursory examinations of temperature-dependent growth have been completed to date. Infection with *Gd* causes high mortality in North American bats, but does not apparently negatively impact European bats. Thus, we grew two isolates of *Gd*, one North American and one European, on Sabouraud Dextrose agar at nine temperatures from 0 to 22°C. For each temperature tested, we measured the area of each of 21 colonies weekly for 6 weeks. We then described the performance curve of each isolate using an information-theoretic approach to distinguish among a set of seven candidate functions. Analyses indicated two curves, one for each isolate, better describe the data than does a single curve for all data, suggesting important differences in the temperature-dependent growth of the two isolates. The optimal temperature for growth was estimated at 13-14°C for both isolates, but the North American isolate grew 1.5 to 35 times faster across the range of temperatures measured. Visual examination of the colonies indicated that morphologies varied across temperatures with the colonies grown at temperatures ≥12 °C exhibiting properties indicative of stress (e.g. fragmentation of hyphae and production of chlamydospores).

99.2 BRANDLEY, N. C.*; JOHNSEN, S.; Duke University; *ncb9@duke.edu*

The black widow's hourglass: a covert aposematic signal?

While culturally iconic, the hourglass of the American black widows (*Latrodectus hesperus*, *L. mactans*, and *L. variolus*) is scientifically unstudied. The hourglass' color and orientation suggest that it is an aposematic signal to avian predators. However it appears that the American widow species have been under selection for reduced coloration; adult females of *L. hesperus*, *L. mactans*, and *L. variolus* lack the yellow and white patterning found in their younger morphs and other *Latrodectus* species. Here we examine the hourglass of the black widow in two ways. First, to test the aposematic hypothesis, we used 3-D printing to create model black widows that were either all black or possessed a typical red hourglass. These models were then presented to wild songbirds in a series of feeder experiments, where preliminary data indicates that songbirds are about 3 times more likely to peck a widow that lacks an hourglass. Secondly, we also model how the loss of coloration may benefit the widow by functioning as a covert signal. While a red hourglass is conspicuous to humans and avian predators, a typical insect prey -- which lacks the LWS photoreceptors used in red vision -- has an achromatic contrast of the hourglass that is about 40% lower. This may help black widows balance the differing selective pressures of being both aposematic and a sit-and-wait predator.

111.3 BRAZEAL, KR*; HAHN, TP; UC Davis; *krbrazeal@ucdavis.edu*

Carryover or compensation? The effect of delayed plumage molt in House Finches (Carpodacus mexicanus)

Most animals need to time their annual cycle stages to appropriately correspond with optimal environmental conditions. In seasonally-breeding birds, the timing of the transition between breeding and molt represents an important life-history trade-off between the benefits of extended current reproduction and the costs of delayed molt, which can impair survival. Another consequence of delayed molt could be a carryover effect, causing delayed molt in subsequent years. Conversely, proximate mechanisms controlling molt may allow for animals to make appropriate timing adjustments. This study examined whether such a carryover effect exists. House finches captured in June 2010 were given either control or testosterone implants prior to the start of molt. The implants were replaced every 2 months and then removed in December. Testosterone treatment delayed the beginning of molt by 2-3 months in most birds and completely prevented molt until implant removal in a few birds. Despite the lengthy delay of molt in 2010, the timing of molt in 2011 did not significantly differ between the control and previously T-treated groups. Those birds that did not molt until after implant removal therefore completed two molt cycles within the same calendar year. Molt start date in 2010 and 2011 was significantly correlated among control birds but not among T-treated birds. These results suggest that the timing of molt can carryover from year to year on a small scale, but extremely late-molting birds are able to compensate in subsequent years and still regain a normal molt schedule.

21.1 BRICKNER-BRAUN, I*; PINSHOW, B; Ben-Gurion University of the Negev, Jacob Blaustein Institutes for Desert Research; *inbalbr@bgu.ac.il*

Burrowing rodents are not necessarily tolerant of hypercapnia

Burrow geometry, coupled with low permeability of soils to gases, and the respiration of its tenant(s), are assumed to generate fractional concentrations of CO_2 (FCO_2) and O_2 (FO_2), respectively above and below those in the free atmosphere. In mammals, breathing air containing high FCO_2 is likely to cause respiratory acidosis. Thus, burrow-dwelling rodents are generally presumed to be adapted to hypercapnic and/or hypoxic conditions. Assuming that burrowing rodents are in fact hypercapnia-tolerant, we examined the physiological responses of a semi-fossorial rodent, *Meriones crassus* to changes in inspired FCO_2. First, we measured O_2 uptake (VO_2) of 6 female *M. crassus* that were exposed to gradually changing FCO_2, from 0.04% CO_2 (atmospheric) to 1, 2, 4 and 7%, and again to 0.04%. Then, VO_2 was measured while *M. crassus* were exposed to a step change, from 0.04% CO_2 to 7%, and back to 0.04%. Second, blood samples of 13 *M. crassus* were equilibrated in a tonometer to each of 4 humidified gas mixtures, simulating arterial and venous blood in animals breathing fresh or high FCO_2 air, and blood $[H^+]$ was determined. We found that *M. crassus* pay a significant energetic price if FCO_2 rises above that of atmospheric air; VO_2 of *M. crassus* breathing 7% CO_2 averaged 23% higher than when breathing fresh air. The $[H^+]$ of mixed venous and arterial blood equilibrated to high FCO_2 were respectively 26.73 ± 4.95 and 27.27 ± 7.04 nmol/l higher than the $[H^+]$ of mixed venous and arterial blood equilibrated to "normal" (5%) PCO_2 ($p < 0.01$). Since *M. crassus* are apparently not especially adapted to breathing air with high FCO_2, we question the assumption that burrowing rodents are generally hypercapnia-tolerant.

S5-1.4 BRISCHOUX, F*; TINGLEY, R; SHINE, R; LILLYWHITE, HB; CEBC-CNRS, France, University of Sydney, Australia, University of Florida, USA; *francois.brischoux@gmail.com*

Distributional data helps to identify evolutionary challenges: Oceanic salinity as a major constraint during the transition to marine life in snakes

Secondary transitions from terrestrial to marine life provide remarkable examples of evolutionary change. Maintenance of osmotic balance poses a particular challenge for secondarily marine vertebrates. However, its role during such evolutionary transition has not previously been assessed. Using large scale biogeographical analyses on the four independent lineages of marine snakes, we found that salinity significantly constrains their current distribution, and does so more profoundly in species which are presumably analogous to the early transitional forms between the land and the sea. Fine scale analyses at the species level suggest that a more efficient salt-secreting gland allows a species to exploit more saline, and hence larger, oceanic areas. These results, as well as the current ranges of marine snakes suggest that the Indonesian Basin has been a centre of origin for the four independent lineages of marine snakes. We emphasise that both the low salinity and high seasonal variation in salinity of the Indonesian Basin might have provided a favourable context for the evolutionary transition to marine life in snakes. More generally, salinity may have been an overlooked parameter in ecological and evolutionary studies of secondarily marine vertebrates (including turtles, birds and mammals) and should be incorporated into models assessing the impact of climate change on marine vertebrates. Supported by NSF IOS–0926802 to HB Lillywhite.

118.2 BROCK, J.R.*; BIELMYER, G.K.; Valdosta State University; *jrbrock@valdosta.edu*

Metal Accumulation and Sublethal Effects in the Sea Anemone, Aiptasia pallida>, After Waterborne Exposure to Metal Mixtures

Metal contamination frequently occurs in marine environments, mainly due to anthropogenic inputs, yet the effects of metals on symbiotic cnidarians are largely understudied. To address this issue and to further understand the impact of elevated metal concentrations on marine symbiotic organisms, a toxicity study was performed using the model sea anemone, *Aiptasia pallida*. *A. pallida* were exposed to a control or a metal mixture (Cu, Zn, Ni, and Cd) at three exposure levels (10, 50, and 100 µg/L) for 7 d. Anemones were then transferred to clean seawater for an additional 7 d after the metal exposure to assess metal depuration and recovery. Accumulation of copper, zinc, nickel, and cadmium and the corresponding effects on enzyme activity (catalase, glutathione reductase, and carbonic anhydrase), protein concentration, and algal cell density were measured at 0, 1, 3, 5, 7, and 14 d. Metal accumulation in *A. pallida* occurred in a time and concentration dependent manner throughout the experiment. Additionally, enzyme activity and algal cell density were significantly affected and corresponded to the accumulated metal. Metal depuration and physiological recovery was dependent on both the metal and the exposure concentration. Understanding how *A. pallida* and their symbionts respond to mixed metal exposures in the laboratory may allow better understanding about how symbiotic cnidarians respond in metal polluted aquatic environments.

S9-1.6 BROWN, C.T.*; LOWE, E; PAVANGADKAR, K; MALISKA, M.E.; SWALLA, B.J.; Michigan State University, University of Washington, Seattle; *ctb@msu.edu*

Tail loss: investigating the Molgula

The Molgulid clade of ascidians contains multiple species that have at least three times independently lost tails during their larval stage. While the vast majority of the 3,000+ described species of ascidians develop swimming tails, replete with muscles and notochord, fifteen of the one hundred and fifty Molgulid species have lost a larval tail, suggesting that there is some genomic preadaptation for tail loss. Extensive prior investigation of two Molgula, M. occulta (tailless) and M. oculata (tailed), and their hybrids, has demonstrated that the loss of the tail in M. occulta is most likely due to loss of function mutations. We have used deep sequencing (Illumina mRNAseq) to quantitatively investigate the transcriptomes of embryo-stage M. occulta and M. oculata. Quantitative sequencing of hybrids and subsequent allelotyping analysis has also enabled us to begin inferring potential cis-mutations responsible for the loss of the tail developmental program.

35.3 BROWN, A.*; THATJE, S.; University of Southampton; *alastair.brown@noc.soton.ac.uk*

Respiratory response of the deep-sea amphipod Stephonyx biscayensis indicates bathymetric range limitation by temperature and hydrostatic pressure

Depth zonation of fauna on continental margins is well documented. Whilst increasing hydrostatic pressure with depth has long been considered a factor contributing significantly to this pattern, discussion of the relative significance of decreasing temperature with depth has continued. This study investigates the physiological tolerances of fed and starved specimens of the bathyal lysianassoid amphipod *Stephonyx biscayensis* at varying temperature to acute pressure exposure by measuring the rate of oxygen consumption. Acclimation to atmospheric pressure is shown to have no significant interaction with temperature and/or pressure effects. Similarly, starvation is shown to have no significant effect on the interaction of temperature and pressure. Subsequently, the effect of pressure on respiration rate is revealed to be dependent on temperature: pressure equivalent to 2000 m depth was tolerated at 1 and 3°C; pressure equivalent to 2500 m depth was tolerated at 5.5°C; at 10°C pressure equivalent to 3000 m depth was tolerated. The variation in tolerance is consistent with the natural distribution range reported for this species. There are clear implications for hypotheses relating to the observed phenomenon of a biodiversity bottleneck between 2000 and 3000 metres, and for the potential for bathymetric range shifts in response to global climate change.

18.1 BROWN, M D*; HOLZMAN, R; BERG, O; MULLER, U K; California State University, Fresno, Tel Aviv University; *mdbrown@mail.fresnostate.edu*

Sub-millisecond flow fields induced by bladderwort, the fastest known suction feeder

Bladderwort *Utricularia gibba* is a carnivorous plant that captures zooplankton in underwater bladders. These modified leaf structures are highly specialized for suction feeding. However, their small size (1-2 mm) and fast action (*ca.* 1 ms) have obscured the underlying functional kinematics and flows. We have used high-speed digital video and flow visualization (Particle Image Velocimetry) to study *U. gibba* at frame rates up to 10 000 per second. A total of 34 suction events have been analyzed. At a distance 1/2 diameter from the typical gape of 200 µm, bladderwort generate peak flow speeds of up to 1.2 m/s (mean 0.2 m/s), corresponding to a Reynolds number of 200 (mean 30). Prey are ingested within 1 ms of triggering the bladder, at speeds up to 0.8 m/s. Time to peak flow speed from the beginning of suction is 0.6 ms, causing accelerations in the aspired water of up to 1300 m/s^2 (mean 400 m/s^2). The time course of the suction event has a distinctively steep onset, followed by a relatively constant-speed plateau. Adult fish, by contrast, accelerate water with a symmetric and smoothly varying time profile of longer duration. While the peak flow speeds generated by suction-feeding fish and bladderwort are similar, the accelerations observed in bladderwort are two orders of magnitude greater. This is a consequence of their smaller size, and the pre-stressed suction mechanism that minimizes time to peak flow speed. The spatial distribution of flow speed across the gape and along the gape agrees with flow speed distributions observed with adult fish. An analytical model of flow speed distributions, when applied to suction feeding in bladderwort, is in satisfactory agreement with the observed flow fields.

103.6 BROWN, Kevin A*; IRIARTE-DIAZ, Jose; TAKAHASHI, Kazutaka; HATSOPOULOS, Nicholas G.; ROSS, Callum F; University of Chicago; *kevbrown@uchicago.edu*

Kinematic and state representations by neuron population activity in MI orofacial cortex

The role of cortex in sensorimotor transformations during repeated iterations of voluntary arm and hand movements has been well studied, but its role in controlling ethologically relevant complex movement sequences is still poorly understood. The primate feeding system is well-suited to address this question, because feeding sequences include a rich combination of voluntary, semiautomatic, and reflexive jaw and tongue movements in response to continuously changing sensory feedback from food material properties. To investigate the role of motor cortex in regulating this complex convergence of information, we recorded activity from MIo neurons in three macaque subjects using Utah microarrays implanted in the orofacial region of primary motor cortex (MIo) while measuring tongue and jaw kinematics using videofluoroscopy and 3-d jaw tracking. Here we report that MIo neurons modulate their activity in response to natural categories of movement (ingestion, food manipulation, rhythmic chewing, swallowing), as well as continuous kinematic parameters. In particular, we show that both single neuron and population representations of movement include a nontrivial interplay between kinematic parameters and categorical state information. Using the generalized linear model framework in combination with dimensionality reduction techniques, we uncover aspects of this representation, including dynamic changes in network state as a function of movement context.

66.6 BROWNE, W.E.*; SCHNITZLER, C.E.; GILDEA, D.; NGUYEN, A.-D.; MAXWELL, E.; RYAN, J.F.; BAXEVANIS, A.D.; University of Miami, NHGRI/NIH; *wbrowne@bio.miami.edu*

The Early Embryo: Genomic analysis of gene expression in an early diverging lineage of metazoans, the Ctenophora

The defining characteristic of metazoans is the possession of distinct tissues, typically composed of multiple terminally differentiated cell types. However, biologists still grapple with understanding the molecular genetic underpinnings of how differential cell fates are established and maintained. The ctenophore *Mnemiopsis leidyi* has an early cleavage program particularly well suited for investigation by developmental and genetic studies, providing a unique window for the broader examination of early cell fate restriction in metazoans as the undifferentiated single-cell embryo becomes a collection of constrained and differentiated cell types. *Mnemiopsis leidyi* has become a powerful model system for understanding ctenophore development with the completion of the genome. Here, we present a comprehensive analysis of mRNA and miRNA expression data from the fertilized zygote. Our experimental approach takes advantage of next-gen RNAseq approaches to examine temporal and spatial changes in gene expression. Preliminary analysis highlights the presence of a complex transcriptome with a diverse developmental gene complement suggesting that maternal transcripts are playing an important role in early cell fate decisions. Our data reveal the presence of novel miRNAs and an absence of clear Drosha/Pasha homologs implicating a novel miRNA biogenesis pathway. Our genomics approach provides us with quantitative data that will shed light on transcriptional changes accompanying the transition from totipotency to restricted pluripotent states during early *Mnemiopsis* embryogenesis. Further, an improved understanding of embryonic gene expression dynamics in ctenophores is fundamentally important to identifying key developmental and molecular genetic events associated with early metazoan evolution.

19.2 BURNELL, Amy L*; YOUNG, Bruce A; Univ. of Massachusetts, Lowell; *amy.reichlen@gmail.com*
Tracking Reptilian Footprints
The few previous controlled studies on the influence of substrate on tetrapod locomotion have shown significant changes in locomotor cycles with changing substrate. We examined the relationship between substrate and the locomotion of a large sprawling lizard, the water monitor (*Varanus salvator*). Sub-adult to adult animals (lengths> 1.5meters) were initially filmed walking over a force plate. In subsequent experiments the animals were filmed locomoting over substrates of varying degrees of compactness (loose sand, compact sand, saturated sand, and submerged sand). For the trials over the substrate, dental stone was used to take impression of footprints; the casts were then digitized with a 3-D scanner and aspects of each footprint quantified using ImageJ. High-speed digital videography of individual footfalls on each substrate allowed quantification of both deformation of the foot as well as foot-substrate interactions (e.g., slippage, substrate ejection). Statistical analyses of the locomotor velocity and duty cycles, quantitative features of the footprints, and the foot-substrate interactions revealed significant differences by substrate type.

15.8 BURNETT, K*; WISE, R; PETTY, A; FIRE, S; HAYNES, B; WANG, Z; HARDY, K; BURNETT, L; College of Charleston, Biotoxins Program, NOAA/NOS, Medical University of South Carolina; *burnettk@cofc.edu*
Impacts of Hypoxia and Domoic Acid on Large Muscle Activity in the Shrimp Litopenaeus vannamei
Low oxygen (hypoxia=H) slows the rate at which crustaceans can replenish arginine phosphate which powers anaerobic muscle activity. H often follows or coincides with harmful algal blooms. Domoic acid (DA), a toxin produced by the diatom *Pseudo-nitzschia*, binds to glutamate receptors of the neuromuscular junction in crustacean muscles. We tested whether H and DA, individually or combined, alter anaerobic tail muscle activity and/or recovery from fatigue in *L. vannamei*. Muscle activity (initial tail-flips to fatigue) was not significantly altered by H (O_2=4.0 kPa, CO_2<0.06 kPa) vs. air-saturated water (normoxia=N). However, fatigued animals that recovered for 10 min in H performed fewer tail-flips than controls recovered in N (H=9.0±3.8 SEM; N=17.4±3.8, P<0.001). In a second study, shrimp immersed for 30 min in seawater (SW) or SW with 400 ug DA L^{-1} were transferred to H or N and tested for anaerobic muscle activity and recovery from fatigue. As before, H reduced recovery tail-flips (2W-ANOVA, P=0.034). In contrast, DA reduced initial tail-flips to fatigue (2W-ANOVA, P=0.006). Thus, shrimp exposed to DA and H performed fewer initial tail-flips to fatigue (DA/H=24.6±2.7 SEM; SW/N=33.3±3.8) and after recovery (DA/H=13.6±1.5; SW/N=20.0±1.6). DA and H show independent and additive effects on anaerobic muscle activity in crustaceans. If predator avoidance is similarly impaired, then crustaceans may be vectors of DA to higher trophic orders in the marine food web (NOAA OHH at HML; NSF DBI-1062990, IOS-0725245).

15.6 BURNETT, L.*; DANIELSON, M.; MCELROY, E.; STOVER, K.; BURNETT, K.; College of Charleston; *BurnettL@cofc.edu*
Performance in the Atlantic blue crab: Effects of anemia and hypoxia
The concentration of the respiratory pigment hemocyanin (Hc) in *Callinectes sapidus* can be quite variable and can depend on such factors as molting and oxygen levels in water. We tested the effects of anemia (crabs with Hc concentration < 3 g Hc/100 mL) on the ability of male crabs to walk on an underwater treadmill while assessing fatigue after each hour of walking. Treadmill speed was set at 8 m/min and water was either well-aerated or made hypoxic (4 kPa O_2). Fatigue was assessed using a "pull test" that measured the force crabs used to hold on to and then release a stationary mesh stage when pulled away, mimicking the way a male crab holds a female during mate guarding. Anemic crabs had a mean Hc concentration of 2.52 g/100 mL (N=8 ±0.05 SEM), while controls had 6.33 g/100 mL (N=7 ±0.7). Both anemic and control crabs were able to complete 4 hours of walking on the treadmill. Force generated by anemic crabs on the "pull test" decreased dramatically over 4 hours of walking to only 53% of the initial value tested before walking. This is in contrast to control crabs which showed no significant fatigue after 4 hours. In separate experiments, crabs made artificially anemic by removing hemolymph and replacing it with sterile saline (mean=1.92 g Hc/100 mL) revealed the same pattern as naturally anemic crabs. Non-anemic crabs with "control" levels of Hc were also exposed to hypoxia (O_2=4 kPa) during walking and were unable to walk more than 2 hours. "Pull test" measures after 2 h were 47% of the initial. Mean hemolymph lactate after 4 hours was 3.9 mmol/L in controls and 4.4 in anemic crabs; these were significantly different (P<0.001) from 18.7 in hypoxic crabs after only two hours. (NSF DBI-1062990, IOS-0725245).

23.3 BURNETTE, M.F.*; ASHLEY-ROSS, M.A.; Wake Forest University; *burnmf0@wfu.edu*
Group shooting behavior in archerfishes
The archerfish (Toxotidae) are a small family of brackish-water fish native to Asia and Australia. All seven species of archerfish demonstrate a unique hunting strategy: traveling in small groups, individuals forcibly shoot jets of water from their mouth at prey located above the surface of the water on twigs or leaves. These streams of water dislodge the prey and cause it to fall into the water where it is then consumed, either by the shooter or another member of the group. In order to aim this jet, the fish must rotate its body so that the tip of the mouth breaks the surface of the water. Researchers have demonstrated a wide range of body angles that individual archerfish use during spitting; it is thought that body rotation serves as a cue to group members who seek to steal prey from the shooter. A recent report indicates that as group size increases, archerfishes become less accurate when shooting. We sought to test the relationship between accuracy, body rotation and group size. We hypothesize that as group size increases, competition for the prey item as it impacts the water will lead shooting archerfishes to take less preferred shooting positions below the prey, choose shallower shooting angles and perform the rotation maneuver more rapidly. High-speed lateral and overhead video will be used to track the shooter during free-feeding on crickets suspended over the aquarium. Group sizes will vary from 1 to 4 individuals. Time to shooting position, time to maximum dorsal rotation, magnitude of dorsal rotation, horizontal distance to prey and time to ventral rotation after the shot will be quantified from video sequences. Individual variation in these parameters and the effect of group size will be determined.

104.1 BYERS, KJRP*; BRADSHAW, HD; RIFFELL, JA; University of Washington; *kjbyers@uw.edu*

Specific floral odorants contribute to differential pollinator attraction in monkeyflowers (Mimulus)

Floral diversity is immense, with more than 250,000 species of angiosperms known. The number of phylogenetically diverse floral species that share common characteristics implies a background pattern of selection acting on floral traits. Unique combinations of these floral traits, or "pollination syndromes," are hypothesized to reflect selective pressure imposed by certain classes of pollinators. One flower character in particular, scent, has been hypothesized to operate as an unseen signal to attract certain pollinators, particularly when combined with other signals such as color and shape. However, the contribution of scent in pollinator-mediated selection between sister taxa has nearly always been inferred and rarely directly tested. The genus *Mimulus* (Phyrmaceae) forms a developing model system for studying floral diversity and speciation using a combination of genetics and field ecology. Two sister species of *Mimulus*, *Mimulus cardinalis* and *Mimulus lewisii*, are pollinated by hummingbirds and bumblebees respectively, and in combination with readily available genetic tools present a unique system in which to examine the sensory mechanisms and signals that mediate pollinator-driven speciation. Using a combination of headspace collection, gas chromatograph-coupled multi-unit recording, and behavioral experimentation, we investigated the role of multiple *Mimulus* volatiles on bumblebees (*Bombus occidentalis*). Several key compounds are found at different concentrations in the two species, with notable effects on electrophysiology and behavioral responses by bumblebees. Together, these results suggest that scent alone may be a sufficient force to drive differential pollinator attraction to sister species, providing a mechanism for speciation and maintenance of reproductive isolation in angiosperm taxa.

2.5 BYRNES, Greg*; JAYNE, Bruce C; University of Cincinnati; *byrnesgt@ucmail.uc.edu*

The gripping forces and behavior of climbing snakes

Arboreal environments consist of a network of cylindrical branches inclined from the horizontal. On these substrates, animals lacking claws must use muscular force to generate sufficient normal force to prevent slipping to climb successfully. Unlike many arboreal mammals, including primates, that have discrete gripping regions on the hands and feet, the elongate bodies of snakes allow for modulation of both the size and orientation of the gripping region. We used a vertical perch instrumented with capacitive pressure sensors to study the gripping behavior of a diverse group of snake species during climbing to answer the following questions: (1) is there interspecific variation in the gripping behavior of snakes? (2) within individuals, are there differences in gripping performance in different body regions? and (3) do snakes climb using economical force production? Our sample consisted of 4 boid species and one colubrid, the brown tree snake (*Boiga irregularis*). We found a difference between the gripping behavior of the 4 boids and the brown tree snake. All boid species were capable of supporting their entire body with a single gripping loop, whereas the brown tree snakes required multiple simultaneous gripping regions. Further, among all snakes, we found no evidence of regionalization of gripping performance along the body length. Finally, across all species we studied, snakes produced an average of 3.5 times more normal force than required to support body weight on the vertical substrate. This suggests that despite the high cost of climbing, having a large safety margin to avoid slipping may be more important than locomotor economy.

7.3 BYWATER, C L*; WHITE, C; WILSON, R S; The University of Queensland; *c.bywater@uq.edu.au*

It's costly to be honest: the metabolic expense of maintaining a reliable signal of strength for crustaceans

Handicap costs are predicted to be one of the primary mechanisms for the maintenance of reliable signals that are used during intra-specific communication. However, separating the costs required to unambiguously communicate a message to a receiver (efficacy costs) from the actual costs of producing a reliable signal (handicap costs) is empirically very difficult. Displays of weaponry by crustaceans offer an opportunity to measure the costs directly associated with signal reliability. A unique feature of crustacean morphology is that their claw muscles, which influence their fighting capacity, are concealed beneath an exoskeleton. Thus, it is impossible for competitors to accurately assess the strength of their opponents without physical contact, which is potentially very costly. This feature allows us to separate the signal magnitude (claw size) from its reliability (strength). We quantified the metabolic costs of maintaining claw muscle for original- and regenerated-clawed fiddler crabs (*Uca vomeris*) and male and female slender crayfish (*Cherax dispar*). We found that the total metabolic costs of claw muscle for fiddler crabs with weak regenerated-claws represented 12% of their total metabolic rate, which was half of that for crabs with the stronger original-claws. Thus, male fiddler crabs with the weaker regenerated-claws save around 10% of their total resting metabolic demands by producing a claw with less muscle. Although male and female crayfish both had similar overall costs for claw muscle (approx. 30% of resting metabolic rate), claw muscle from male crayfish exhibited half the metabolic rate per gram of tissue than females. Thus, from our studies of crustacean claws, we found that the metabolic costs of maintaining claw muscle could be a powerful incentive for producing weak claws.

5.4 CAHILL, A.E.; Stony Brook University; *acahill@life.bio.sunysb.edu*

Response of Crepidula larvae to temperature as a function of geography and developmental mode: existence of local adaptation

Distributional changes are expected to become more common in the face of global climate change as species that cannot adapt to changing temperatures expand, contract, or shift their ranges. Marine invertebrate species with planktonic larvae are expected to show greater dispersal than those with direct development. In contrast, populations of directly developing species may show more potential for local adaptation due to low levels of gene flow from outside the population. Local adaptation to current water temperature may make a species more vulnerable to warming global temperatures. I use species in the genus *Crepidula* to examine the role of larval type in local adaptation to water temperature using a common-garden experiment. *C. convexa* is a direct developer, while *C. fornicata* and *C. plana* have a planktonic larval stage. *C. convexa* is known to have high levels of genetic structure compared to *C. fornicata*. However, it is unknown if such neutral genetic structure corresponds to ecologically relevant differentiation in growth and survival at different temperatures. To test for local adaptation to temperature in *Crepidula*, I studied the effects of temperature on growth and survival of larvae from populations from the northern, middle, and southern parts of the ranges of *C. fornicata*, *C. plana*, and *C. convexa*. I collected adults from all three species from populations along the east coast of the United States and raised them in common laboratory conditions in a factorial temperature*origin design at 12ºC, 20ºC, or 28ºC. There is no clear pattern of local adaptation in *C. fornicata*, but trends in survival in *C. plana* and *C. convexa* indicate potential local adaptation.

48.2 CALLIER, V; Arizona State University ;
vcallier@gmail.com
A mechanism for metabolic scaling in insects
In insect larvae, the tracheal system grows in discrete steps, increasing in size only at each molt. In contrast, the body increases in mass continuously, and metabolic demand increases in concert. This mode of growth makes insects particularly well suited to study the effects of growth on the changing relationship of metabolic supply and demand.

81.5 CAMERON, SF*; WYNN, ML; WILSON, RS; Univ. of Queensland, Australia; *s.cameron3@uq.edu.au*
Trade-offs and compensatory traits: bite force and sprint speed pose conflicting demands on the design of male geckos (Hemidactylus frenatus)
The evolution of exaggerated ornaments and armaments is driven by the benefits accrued to reproductive success and by the costs imposed on viability. Thus, when traits are required to perform multiple functions that are important to both reproduction and viability, trade-offs can result in a compromised phenotype. One of the more intuitive viability costs that can result from the possession of exaggerated male traits is increased predation pressure due to reduced locomotor capacity. Despite only mixed empirical support for such locomotor costs, recent studies suggest these costs may be masked as a result of the evolution of compensatory mechanisms that offset any detrimental effects. In this study, we provide a comprehensive assessment of the importance of potential locomotor costs that are associated with improved male-male competitive ability by simultaneously testing for locomotor trade-offs and compensatory mechanisms. For males of the Asian house gecko (*Hemidactylus frenatus*), both fighting capacity and escape performance are likely to place conflicting demands on an individual's phenotype. Males that are highly territorial and aggressive are more likely to require greater investment in jaw size/strength in order to compete with rival males, which may affect the overall manoeuvrability and speed of an individual. We found that males, exhibited a trade-off between maximum sprint speed and bite-force; where males that exhibited a larger bite force capacity had a reduced sprint speed. In addition, this performance trade-off was amplified for male *H. frenatus* with larger heads when sprinting up inclines. Larger males with stronger bites showed greater prey-capture and fighting capacity, but the poorer sprint speed. However, we found little evidence for compensatory mechanisms that off-set the functional trade-off between bite force and sprint speed.

94.4 CAMP, A.L.*; BRAINERD, E.L.; Brown University, Providence, RI; *ariel_camp@brown.edu*
Pectoral girdle motion and hypaxial muscle strain during suction feeding in largemouth bass, Micropterus salmoides
To capture food in an environment 900 times as dense as air, fish rely on suction: explosively expanding the mouth cavity to accelerate fluid and engulf prey. This wave of expansion originates dorsally with cranial elevation and ventrally with hyoid depression. Both mechanisms require substantial muscle power, but the cranial muscles are relatively small. Instead, power may come from the large body muscles, epaxialis (EP) and hypaxialis (HYP). The rostral EP is already known to power dorsal expansion. The HYP may be stabilizing the pectoral girdle while the sternohyoideus muscle retracts and depresses the hyoid. Alternatively, the HYP could power ventral expansion by retracting the pectoral girdle, which is connected to the hyoid by the sternohyoideus. We tested the role of the HYP in ventral expansion, and the rostrocaudal extent of shortening in EP and HYP during feeding. Using suction strikes of largemouth bass (*Micropterus salmoides*), we measured neurocranial and pectoral girdle kinematics with X-ray Reconstruction of Moving Morphology (XROMM). XROMM quantifies 3D skeletal motion from bone models and bi-planar high-speed fluoroscopy. From these x-ray videos, we also measured the distances between intramuscular markers to calculate muscle strain in the EP, HYP, and sternohyoideus. Surprisingly, HYP strain magnitudes are statistically significantly greater than EP (mean of 5.8% versus 3.7%; $p<0.01$). The HYP shortens a statistically significantly greater distance than sternohyoideus (mean of 5.7mm versus 0.66mm, $p<0.001$), and the pectoral girdle is retracted; both results support the HYP as powering ventral expansion. The EP and HYP show strain as far caudal as the second dorsal fin, suggesting these body muscles are powering suction feeding.

80.4 CAMPBELL, JC*; COBB , VA; Middle Tennessee State University; *jc3n@mtmail.mtsu.edu*
Are all snakes made equal: handling hypoxic conditions.
Fossorial animals are generally exposed to different environmental conditions than their terrestrial counterparts. Because of enclosed surroundings with little air space and reduced air flow, hypoxic and hypercapnic conditions (LO2/HCO2) would be expected, and animals that frequent such environments could exhibit physiological adaptations (e.g., reduced metabolic rates). As the early evolutionary history of snakes likely involved fossorial conditions but extant species exhibit great diversity in habitat selection and lifestyle, we hypothesized corresponding respiratory metabolic variation. We addressed this question by using closed-system respirometry to measure oxygen consumption on two fossorial and two terrestrial snake species under normal and simulated LO2/HCO2 environments at three temperatures(15, 25, 30 °C). Basal metabolic rate (BMR) was calculated by placing individuals in a respirometry chamber and measuring VO2 every hour for 24 hours using normoxic air; hypoxic/hypercapnic simulations were performed by flowing air from pre-filled gas tanks(15% O2 and 5% CO2) through the respirometry setup and measuring VO2 every hour for 12 hours. At normoxic conditions, the terrestrial species had higher BMRs than the fossorial species, particularly at the warmer temperature treatments. At LO2/HCO2 conditions, BMRs remained similar to normoxic conditions for the fossorial species, but there was a rapid increase in BMR for the terrestrial species associated with the highest temperature treatment. We suggest fossorial snakes may exhibit reduced metabolic rates as well as mechanisms to handle LO2/HCO2 conditions and that their more terrestrial species may have lost. Understanding such physiological variation may help strengthen the evolutionary lineages of snakes as well as provide insights into the plasticity of physiological systems.

102.1 CAPLINS, S. A.; NORENBURG, J. L.; TURBEVILLE, J. M.*; Virginia Commonwealth University, Richmond, VA, National Museum of Natural History, Washington, DC; *jmturbeville@vcu.edu*

Molecular and Morphological Variation in the Barnacle Predator Nemertopsis bivitatta (Nemertea, Hoplonemertea)

The nemertean *Nemertopsis bivitatta* is a suctorial barnacle feeder abundant in hard-bottom intertidal communities along the coasts of Europe, South America, and the Southeastern United States. Individuals of *N. bivitatta* are typically pale yellow to whitish in color with a pair of dorsally-situated dark greenish brown pigment bands that extend for nearly the entire length of the worm. In most individuals these stripes are separated anteriorly, but in some a transverse pigment bar connects them anteriorly. Variation in stripe configuration has been considered to reflect intraspecific variation. We sampled a population containing both morphs from Pawleys Island, SC, USA to assess the extent of variation at the morphological and molecular level. Our qualitative analysis of stylet basis morphology for 20 individuals of each morph revealed morph-specific variation; morphometric analyses are planned to quantify the differences. We sequenced the mitochondrial cytochrome-oxidase one gene (*cox1*, 500-650 bps) for 8 individuals exhibiting the anterior fusion of pigment bands and for 14 individuals without this feature. Sequences for the two morphs are mutually exclusive, with a minimum and an a maximum pair-wise difference of 13.6% and 19.9.%, respectively (average 15.8%). This lies within the range of variation observed between valid species in Hoplonemertea. A tree-based species delimitation analysis is consistent with sequence divergence and morphological data, placing the morphs in separate lineages with strong support. These preliminary findings suggest that the morphs represent separate species, and we are currently analyzing the nuclear gene fragment ITS2 to provide a more rigorous delimitation test.

90.4 CAPLINS, S.A.*; TURBEVILLE, J.M; Virginia Commonwealth University; *caplinssa@vcu.edu*

Reproduction and fecundity in the nemertean worm Prosorhochmus americanus (Nemertea, Hoplonemertea)

The nemertean worm *Prosorhochmus americanus* resides on rock jetties in coastal areas of the Southeastern United States and is uncommon among nemerteans in being hermaphroditic and viviparous. Early observations revealed that isolated individuals are able to reproduce in the absence of cross-fertilization. As part of a comprehensive investigation of reproduction in this species, individual fecundity was examined whereby worms were either placed in pairs, with the potential to cross-fertilize, or kept isolated, preventing cross-fertilization. Specifically, 120 adult worms (treatment 1; n=40 replicates) and 42 juvenile worms (treatment 2; n=14 replicates) were raised in pairs or in isolation and monitored for the development and emergence of offspring. Worms were examined every 24 hours for juvenile emergence and were fed amphipod crustaceans once weekly. Worms in treatment 2 were examined weekly for the development of gonads, eggs, and embryos. Experiments were carried out for 160 days, over which period a total of 2,863 juveniles were produced. Isolated individuals in treatment 1 produced slightly more juveniles (n, mean=21.3±3.8) than paired worms (n/2, mean=19.1±3.4; t-test, p=0.0102, α=0.05). In contrast, worms in treatment 2 produced approximately the same number of offspring regardless of being isolated or paired (p=0.26). Newly emerged juveniles averaged 2.5 mm in length, and produced gonads within 2 weeks of emergence. Developing juveniles appeared within 5 weeks and emerged approximately 3 weeks later, resulting in a two-month generation time (juvenile-to-juvenile). Microsatellite DNA markers are currently being developed to determine the degree at which cross-fertilization occurs between paired worms and will provide a starting point in determining potential fitness advantages that may be associated with differing modes of reproduction.

88.4 CARLSON, BE*; LANGKILDE, T; Penn State University; *bec169@psu.edu*

Personality across ontogeny in an amphibian

Animals often exhibit consistent individual differences in behavior (“personalities”) but the evolution of such diversity is poorly understood despite the importance of personality in behavioral ecology. Constrained behavioral flexibility across time may create tradeoffs that promote diverse strategies. Personalities may also be driven by variation in individual states or local selection pressures. We explored these factors in wood frogs (*Rana sylvatica*), characterizing behavioral consistency across time within and between life history stages, and assessing the effects of age, size, and population of origin on behavioral variation. In the laboratory, we individually reared 50 frogs representing four source populations and 13 sibling groups. At three tadpole and three frog stages, the behavior of each individual was analyzed in both familiar home and novel open field environments. We measured three personality traits: activity, exploration, and boldness. We assessed within-stage repeatability and between stage correlations of behaviors, and the effects of age, body mass, and source population on behavior. Preliminary results indicated significant within-stage repeatability and individual variation for some personality traits (activity and exploration) but not others (boldness), contrasting with previous findings. Correlations between stages were often weak, but exploration behavior was notably correlated between tadpole and frog stages. Age and size strongly affected exploration and boldness in some tadpole stages but not in frogs. Source population significantly influenced some traits in all stages. These results suggest that personality traits may be moderately correlated across ontogeny, allowing for evolutionary tradeoffs, but that variation in state and in selection history may also promote behavioral diversity.

54.2 CARNEY, Ryan M*; VINTHER, Jakob; SHAWKEY, Matthew D; D'ALBA, Liliana; ACKERMANN, Jörg; Brown University, University of Texas, Austin, University of Akron, University of Akron, Carl Zeiss NTS GmbH; *ryan_carney@brown.edu*

Back in black: new evidence on the color, ultrastructure, and nature of the isolated Archaeopteryx fossil feather

Archaeopteryx has been regarded as an icon of evolution ever since its discovery 150 years ago from the Late Jurassic limestone deposits of Solnhofen, Germany. The mosaic of plesiomorphic and derived anatomical traits in these fossils has inspired a rich scientific literature on *Archaeopteryx* and the origin of birds, yet the animal’s color, a diverse and multifunctional trait in modern birds, has remained only speculative. Here we report the first evidence of color from *Archaeopteryx*, based on scanning electron microscopy and energy-dispersive x-ray analyses that reveal the presence of fossilized color-imparting melanosomes in the isolated feather (MB.Av.100). Using a phylogenetically diverse database of 115 extant bird feathers (representing 87 taxa from 27 orders), quadratic discriminant analysis of five properties of melanosome morphology predicts that the original color of the *Archaeopteryx* feather was black, with 95% probability. Furthermore, reexamination of the feather’s morphology leads us to interpret it as an upper primary covert, contrary to previous interpretations. Additional findings reveal that the specimen is preserved as an organosulfur residue, and that barbule ultrastructure identical to that of modern bird feathers had evolved as early as the Jurassic. As in extant birds, the extensive melanization observed likely provided mechanical advantages to the *Archaeopteryx* wing feather during this early evolutionary stage of dinosaur flight. Our results demonstrate how modern microscopy techniques and statistical analysis can be coupled to reconstruct and further the understanding of plumage color and function in extinct dinosaurs.

60.5 CARRIER, David/R*; ANDERS, Christoph; SCHILLING, Nadja; University of Utah, Salt Lake City, University Hospital Jena, Jena, University of Veterinary Medicine Hannover, Hannover; *carrier@biology.utah.edu*

The musculoskeletal system of humans is not tuned to maximize the economy of locomotion.

Humans are known to have energetically optimal walking and running speeds at which the cost to travel a given distance is minimized. We hypothesized that "optimal" walking and running speeds would also exist at the level of individual locomotor muscles. Additionally, because humans are 60 to 70% more economical when they walk than when they run, we predicted that the different muscles would exhibit a greater degree of tuning to the energetically "optimal" speed during walking than during running. To test these hypotheses, we used electromyography to measure the activity of 13 muscles of the back and legs over a range of walking and running speeds in human subjects and calculated the cumulative activity required from each muscle to traverse a kilometer. We found that activity of each of these muscles was minimized at specific walking and running speeds but the different muscles were not tuned to a particular speed in either gait. Although humans are clearly highly specialized for terrestrial locomotion compared to other great apes, the results of this study indicate that our locomotor muscles are not tuned to specific walking or running speeds and, therefore, do not maximize the economy of locomotion. This pattern may have evolved in response to selection to broaden the range of sustainable running speeds, to improve performance in motor behaviors not related to endurance locomotion or in response to selection for both.

9.6 CARY, TL*; KARASOV, WH; University of Wisconsin, Madison, WI; *tcary@wisc.edu*

Immunotoxicity may be a more sensitive endpoint for sublethal polychlorinated biphenyl exposure in the northern leopard frog

Modulation of immune function due to contaminant exposure may be one way that amphibian populations are at increased risk to pathogens, as altered immune function may contribute to increased susceptibility. Additionally, at sublethal exposure levels, assessment of immune function may provide a more sensitive tool for determining toxicity. Polychlorinated biphenyls (PCBs) are a class of organochlorines that were used commercially in the mid-20th century as flame retardants, coolants and insulating fluids for transformers and capacitors. Due to the persistant nature of PCBs, they are still prevalent in the environment today and can be taken up by organisms and biomagnified through the food web. Beginning at the free-swimming stage, *Lithobates (Rana) pipiens* tadpoles were exposed to environmentally relevant dietary levels of PCB-126 (0, 0.37, 1.2, 5.0 ng PCB-126/g wet food) through metamorphic climax. Survivorship across all treatment levels ranged from 79.5 to 91.0%, with no significant treatment differences, supporting a sublethal exposure level. There were also no effects of dose level on growth and development of tadpoles, however, based on tissue residue levels and our earlier study of impacts of PCB-126 no major effects were expected for these endpoints. To assess how PCB-126 exposure affects the adaptive immune response, we used an enzyme-linked immunosorbent assay (ELISA) to measure specific-IgY production in post-metamorphic frogs following immunization with keyhole limpet hemacyanin (KLH). Results so far indicate that frogs exposed to PCB-126 at the highest dose had a lowered secondary antibody response compared to the controls, however, this result was not statistically significant. Supported by UW Sea Grant Institute (grant number NA16RG2257, project number R/EH-2).

23.1 CASTLE, Wendy; NISHIGUCHI, Michele K.*; New Mexico State University; *nish@nmsu.edu*

Language barriers among bacteria: Cooperation and cheating in a squid-Vibrio symbiosis

The sepiolid squid-*Vibrio fischeri* symbiosis is a well developed model for the study of mutualistic associations. Bioluminescent bacteria are housed in specialized light organs in the mantle cavity of the squid where light is used by for silhouette reduction. Previous data suggests that light production may cost *V. fischeri* as much as twenty-five percent of their energetic output. Given the shared nature of the benefit (increased host survival), individual cost to bacteria, and the cooperative nature of luminescence regulation, this system is vulnerable to invasion by non-cooperative "cheaters" either at initiation of the infection or through mutation. Recent theory papers have suggested this particular mutualism is maintained through "screening" of partners. However, we find evidence that strains of "bright" and "dim" *Vibrio* are consistently isolated from the same lobe of the light organ of the same individual host. We find evidence that relatedness among co-occurring bright and dim strains is inconsistent. Additionally, we find that the frequency of dim strains is higher than that of bright strains in all hosts examined (frequency dependent selection). A more complex hypothesis of social interactions among these mutualistic polyclonal bacterial communities is supported with the evidence that isolates from the same light organ have differential responses to quorum sensing signals (QS) which regulate the costly luminescence production. This leaves open the possibility that QS signals may act as a form of policing and may be vulnerable to manipulation. Understanding the social consequences of competing bacteria in this environmentally transmitted symbiosis can provide insight into the subtlties of alleopathic interactions among competing mutualistic vibrios.

S1-1.6 CENSI, Andrea*; STRAW, Andrew D. ; SAYAMAN, Ros; MURRAY, Richard M.; DICKINSON, Michael H.; California Institute of Technology, Research Institute of Molecular Pathology (IMP), Vienna, Austria, Department of Biology, University of Washington, Seattle, Washington; *andrea@cds.caltech.edu*

Dimensionality reduction to understand sensory influences on turning in large scale behavior in Drosophila

A prerequisite for the mechanistic understanding of how nervous systems orchestrate behavior is a phenomenological description of those behaviors, in terms of the relevant features of the external stimuli and the animal's internal state. This is particularly challenging in experiments where the animal experiences very rich stimuli and generates complex behaviors, as opposed to experiments where the stimulus and measured responses are highly constrained. Here we describe a new approach that models turn-making decision process of the fruit fly Drosophila using machine learning techniques applied to a large dataset of free-flight 3D movement trajectories through a large environment. Our technique reduces the dimensionality of a complex visual input stream to a single variable that best predicts the decision to turn and successfully much of the structure in turn statistics in the tested environment. This analysis places bounds on the relative importance of various factors contributing to the fly behavior. In particular, the statistics of searching behaviors have alternately been attributed as either reactions to exogenous stimuli or as the direct behavioral manifestation of an intrinsic stochastic source with statistical properties matched to the search task. Our analysis suggests that flies will predominantly use such sensory cues to guide search rather than relying predominantly on an endogenous stochastic source as an important behavioral mechanism. We argue that a similar relationship is likely to be found for any searching organism endowed with sensory abilities.

23.4 CHADWELL, B.A.*; HRISTOV, N.I.; ALLEN, L.C.; Guilford College, Greensboro, Center for Design Innovation/Winston-Salem State Univ., Salem College, Winston-Salem; *chadwellba@guilford.edu*

Methods for describing and analyzing group behavior in bats: A case study in the Brazilian free-tailed bat

The collective behavior of large groups of organisms has long attracted the interest of diverse disciplines of science. However, technical and computational limitations have minimized empirical work and previous studies have focused on computational modeling and simulation approaches. Advances in high-speed videography and thermal infrared imaging, spatial calibration and computational analysis have allowed the accurate recording and reconstruction of three-dimensional position of individuals in large groups. How does one make sense of these rich data? In particular, what is the appropriate method for calculating the position and movement of individuals relative to one another? Using the Brazilian free-tailed bat (*Tadarida brasiliensis*) as a model, the three-dimensional trajectories of free-tail bats during their emergence were reconstructed from videos captured by an array of time-synchronized, space-calibrated, high-speed thermal cameras. We propose alternate methods for describing the shape and dynamics of the flight formation as well as for calculating and analyzing the distances and relative orientation between specific bat-pairs. Furthermore, we present the effect of each approach on the overall analysis and interpretation. Empirical data and their analysis are important for validating previous computational work and for understanding the behavior and mechanism of grouping in large colonies of bats and collective movement in general.

74.4 CHAMPAGNE, AM*; ALLEN, HC; WILLIAMS, JB; The Ohio State University; *champagne.7@osu.edu*

Effects of lipid-lipid and lipid-water interactions on cutaneous water loss in the house sparrow (Passer domesticus) across temperature and humidity regimes

Cutaneous water loss (CWL) accounts for over half of total water loss in birds. The barrier to water loss through the skin is the stratum corneum (SC), the outermost layer of the epidermis. The SC is composed of corneocytes embedded in a lipid matrix of cholesterol esters, fatty acid methyl esters, triacylglycerides, free fatty acids, cholesterol, ceramides, and cerebrosides. The relative abundance of these lipid classes may affect the barrier properties of the lipid matrix by affecting the ability of the lipid molecules to pack together or interact with water molecules to prevent CWL. In this study, we acclimated House Sparrows (*Passer domesticus*) to different temperature and humidity regimes and measured their CWL at different ambient temperatures. We then used infrared (IR) spectroscopy to measure lipid-lipid and lipid-water interactions in extracted SC of these birds at different temperature and hydration levels. We found that as temperature increases, CWL increases and lipid chains become more disordered. These results suggest that a subset of lipids undergo a phase change from a solid to a liquid phase, which increases SC permeability. In addition, as the SC is hydrated, lipid chain order does not change, and water molecules take on an ordered structure. These results indicate that polar lipid headgroups may order water to slow its permeation through the lipid matrix.

S10-2.3 CHAN, B.K.K.*; TSANG, L.M.; NG, W.C.; WILLIAMS, G.A.; CHU, K.H.; Academia Sinica, Taiwan, The Chinese Univ. of Hong Kong, Hong Kong, Univ. of Hong Kong, Hong Kong, Univ. of Hong Kong, Hong Kong; *chankk@gate.sinica.edu.tw*

Biogeography of the widespread intertidal barnacle Chthamalus malayensis in Indo-Pacific waters: the interplay of geological history, contemporary ocean circulation patterns and habitat specificity

Chthamalus malayensis is a widespread rocky shore barnacle in the Indo-Pacific. To examine the possible factors affecting the distribution of *C. malayensis*, samples were collected from the South China Sea to the West Indian Ocean. In each location, distribution patterns were scored and at least 30 barnacles were collected. COI genes were sequenced, revealing four distinct clades. The South China Sea Clade (SC) is widely distributed and occurs in high abundance (70% cover) in the South China Sea. In Taiwan, the SC clade is sparse but there is an endemic Taiwan Clade (TC) which occurs at low densities (10% cover). In the Gulf of Thailand, Malacca Strait, N Borneo, Bay of Bengal and Arabian Sea, the Indo-Malay Clade (IM) is present (60% cover). In Christmas Island, there is a South Indian Ocean Clade (SI). Separation of the IM and SC clades in the Indian and Pacific Ocean, respectively, is probably due to isolation of the two oceans during the Pleistocene glaciations. The distribution of the SC and IM clades does not appear to be explained by present day ocean currents, and their wide distributions may result from low habitat specificity as both are abundant on exposed to sheltered rocky shores. These clades, therefore, colonize a wide range of habitats, which act as stepping stones for larval dispersal across oceanographic systems. The TC clade appears to be specific to exposed rocky shores and its distribution may be limited by its low abundance. The endemism of the SI clade suggests that this clade cannot cross the distinct horizontal Hydrochemical Front around 10oS in the Indian Ocean.

S4-1.2 CHAN, K.Y.K.*; CLAY, T. W.; GRÜNBAUM, D. ; Univ. of Washington, Seattle; *kychan@uw.edu*

Physical constraints on larval swimming and their implications for dispersal

Most planktonic larvae of marine invertebrates are denser than sea water and rely on swimming to locate food, navigate advective currents and avoid predators. Hence, larval swimming plays an important role in larval survival and dispersal. Larval swimming is biomechanically constrained by the morphologies of larval bodies, which are often complex and highly variable between developmental stages, and is strongly modulated by larval responses to environmental conditions. We combined a theoretical hydrodynamic model and experimental video observations to assess the functional constraints imposed by swimming on larval morphologies using larval sand dollars (*Dendraster excentricus*) as a model system. Larval sand dollars propel themselves with ciliated projections called arms, adding pairs of arms as they develop. In the hydrodynamic model, observed morphologies of larval sand dollars fell within a narrow range of key morphological parameters that minimized downward transport in shear flows, outperforming hypothetical alternative morphologies. The model further suggested that ontogenetic changes in larval morphologies could lead to different vertical larval movements, potentially resulting in stage-dependent vertical distributions and lateral transport. This tight coupling between larval swimming and morphology suggests the hypothesis that stress-induced morphological perturbations could compromise larval swimming. To test this hypothesis, we exposed larval sand dollars to elevated pCO_2 level, which potentially reduces calcification and growth. Observed morphological changes included some predicted to enhance and some predicted to reduce swimming, suggesting compensation to preserve swimming performance. Consistent with the compensation hypothesis, observed swimming performance in still water was unchanged. These results support the importance of swimming as a driving factor in the evolution of larval morphology.

101.1 CHANG, J*; ROY, K; EASTMAN, JM; SMITH, SA; SANTINI, F; BAUM, JK; HASTINGS, PA; SIDLAUSKAS, BL; ALFARO, ME; Univ. of California, Los Angeles, Univ. of California, San Diego, Univ. of Idaho, Moscow, Brown Univ., Providence, RI, Oregon State University, Corvallis; *jchang641@ucla.edu*

Phylogenetic clustering of commercially exploited fish species

Currently, over three-quarters of the world's fish stocks are depleted, overexploited, or fully exploited. Typical marine fishing practices tend to target the largest species in the food web, which alters life history traits, such as age to maturity, and increases risk of extinction. Although the short-term evolutionary effects on exploited species are well-documented, exploitation pressures across the fish tree of life have not been systematically assessed. We collected exploitation data from Fishbase.org for 7,159 ray-finned fishes on a megaphylogeny of containing 7,958 species and use community phylogenetic measures to determine clustering patterns across the tree. Here we show that commercial fishing is overdispersed at both broad and shallow phylogenetic scales, indicating that exploitation targets lineages in a manner that maximizes the potential loss in biodiversity. As a second measure of the threat posed to clade biodiversity, we calculated rates of body size evolution across the megaphylogeny. We found that exploited lineages exhibit significantly faster rates of body size evolution, suggesting that the species that we tend to eat are also those whose evolutionary history is exceptionally unique. Together these results suggest that humans are preferentially eating away at the richest branches on the fish tree of life.

S1-2.3 CHAPMAN, J.W.; Rothamsted Research, UK; *jason.chapman@rothamsted.ac.uk*

Recent insights from entomological radar studies of high-altitude insect migration

Billions of insects migrate between winter and summer ranges to take advantage of seasonally available breeding resources. To cover the distances required (100s km), many insects rely on wind assistance, and routinely ascend 100s m above the ground to migrate in fast-moving airstreams. Given that wind speeds are typically three to five times faster that the insects' airspeeds, it was not clear what influence high-flying migrants could exert on their migration direction. To answer this question, I have studied the flight behavior and migration patterns of large nocturnal moths in Europe with specialized entomological radars. Radar observations demonstrated that an ability to select favorably-directed airstreams (i.e. northwards in spring and southwards in fall) was widespread among high-flying migrant Lepidoptera, and thus the migrants gained considerable wind assistance for their seasonal migrations. Furthermore, moths preferentially flew at the altitude of the fastest winds, and partially compensated for small degrees of lateral wind drift away from their seasonally-preferred migration directions. Trajectory simulations show that these flight behaviors result in a 50% increase in mean nightly migration distance compared to passively-transported particles (300 km versus 200 km) and a significant decrease in lateral drift. Comparison of moth migration parameters with those of nocturnal passerine migrants demonstrates that the moths' highly efficient strategies resulted in them achieving the same travel speeds and directions as birds capable of flying three times faster. The flight strategies employed by migrant moths explain how such small, short-lived and relatively slow-flying species are able to cover such great distances in seasonally-beneficial directions.

4.3 CHARBONNIER, J.F*; VONESH, J.R; Virginia Commonwealth University, Richmond; *charbonnierj@vcu.edu*

How froglets pay the price: carry-over effects on morphology and performance in response to pond drying

Animals with complex life cycles cope with environmental uncertainty by altering life history switchpoints through developmental plasticity. This plasticity may impact morphology, locomotor performance, and survival in later life stages. Hydroperiod is an important factor which may alter life history switchpoints in aquatic organisms. Many amphibians can plastically respond to changes in hydroperiod, but few studies have examined the post-metamorphic costs of this plasticity. To investigate the potential carry-over effects of plasticity to reduced hydroperiod, we studied the Tungara frog, *Physalaemus pustulosus* a tropical anuran which breeds in highly ephemeral habitats. We conducted a field study with three different water level treatments (Constant high volume, constant low volume, and decreasing water volume) in 60 L mesocosms and measured time and size to metamorphosis, tibiofibula length and jumping performance. We also conducted a complimentary laboratory study which similarly manipulated water levels, and also manipulated resource levels. In our field experiment, frogs from decreasing water volumes emerged earliest and had smaller body size. In our laboratory study, frogs from the low volume treatment emerged earliest and had smaller body size. In both studies, froglets from decreasing water treatments had shorter tibiofibulas relative to their size and reduced jumping performance. Our results demonstrate that animals which display plasticity in the timing of ontogenetic shifts may experience costs on their morphology and performance later in life. We interpret these results within the context of past studies which manipulate how hydroperiod may impact amphibian development.

87.2 CHEN, Z-F*; MATSUMURA, K; WANG, H; ARELLANO, S.M.; YAN, X; ALAM, I; ARCHER, J.A.C.; BAJIC, V.B.; QIAN, P-Y; The Hong Kong Univ. of Science and Technology (HKUST), HKUST, Woods Hole Oceanographic Institution, King Abdullah Uni. of Science and Technology (KAUST), KAUST; *chenzf@ust.hk*

Toward an understanding of the molecular mechanisms of barnacle larval settlement: a comparative transcriptomic approach

The barnacle, *Balanus amphitrite*, is a globally distributed biofouler and a model species in intertidal ecology and larval settlement studies. However, a lack of genomic information has hindered the comprehensive elucidation of the molecular mechanisms coordinating its larval settlement. We used 454 pyrosequencing-based transcriptomic profiling to identify key molecular changes during larval settlement. We collected 630,845 reads of which 215,308 were from the larval stages and 415,537 from the adults; 23,451 contigs were generated while 77,785 remained as singletons. We annotated 31,720 of the 92,322 predicted open reading frames, which matched hits in the NCBI NR database, and identified 7,954 putative genes that were differentially expressed between the larval and adult stages. Of these, several genes were further characterized with quantitative real-time PCR and *in situ* hybridization, revealing some key findings: 1) vitellogenin was uniquely expressed in late nauplius stage, suggesting it may be an energy source for the subsequent non-feeding cyprid stage; 2) the locations of mannose receptor-like genes suggested they may be involved in the sensory system of cyprids; 3) 20 kDa-cement protein homologues were expressed in the cyprid cement gland and probably function during attachment; and 4) receptor tyrosine kinases were expressed higher in cyprid stage and may be involved in signal perception. Overall, our results provide not only the basis of several new hypotheses about gene functions during larval settlement, but also the availability of the transcriptome dataset for *B. amphitrite* for further exploration of larval settlement and developmental pathways.

11.5 CHEN, T*; BOYCE, M; ORTIZ, C; Massachusetts Institute of Technology; *tingchen@mit.edu*
Microstructure and mechanics of the tiled and actuating exoskeleton of the helmet urchin, Podophora atrata
The helmet urchin, *Podophora atrata* possesses an unusual reduction in spines which forms a smooth tiling of mm-sized, flattened aboral plates, each articulating with the underlying test via a ball-and-socket joint. The microstructure is a porous network of single-crystal magnesium calcite with a few percent of intercalated organic. With high resolution X-ray microcomputed tomography, 3D microstructural characterization revealed a gradient in volume porosity from 10% at the joint to 50% at the outer surface. The galleried mesh (avg. pore size ~ 15 microns) was modeled using 3D elastic finite element analysis that consisted of a microstructurally-based volume element with periodic boundary conditions and a heat flow algorithm was used to model the anisotropic directionality of the unit element's local coordinates with respect to the global coordinates of the aboral plate. Loading configurations on the unit elements resulted in an orthotropic effective mechanical behavior with the stiffness in the plane transverse to the long axis of the microstructure (E1, E2) approximately half the stiffness in the axial direction (E3). E3 was found to decrease linearly from 0.87 of the solid elastic modulus (Es) to 0.34 of Es as the volume fraction decreases from 0.88 to 0.46. E1 and E2 also decrease linearly from 0.49 of Es to 0.18 of Es. Simulation of blunt indentation showed that the graded porosity of the microstructure exhibits a lower effective stiffness than the solid material but serves to increase the strains near the exterior surface of the aboral spine while reducing the strains near the joint. This open-pore structure and trabeculae alignment results in a directional strengthening due to inhomogeneous deformations in the porous structure and provides resistance against blunt impacts and containment of penetration into the surface of the plate.

23.5 CHICOLI, A*; LUN, Y; BUTAIL, S; COOMBS, S; PALEY, D; University of Maryland, College Park, Bowling Green State University, Ohio; *achicoli@umd.edu*
Making waves: Quantitative analysis of information transmission in schooling fish
Benefits of schooling behavior are often cast in terms of predator evasion. The collective response of fish to a predator is an extremely rapid, propagating wave of visual and hydro-acoustic information, also known as the 'Trafalgar effect'. The alignment and density of the school is likely to play a role in this information transmission, although little is known of what interactions among group members lead to predator detection and group cohesion. In this study, we test the hypothesis that school cohesiveness improves the signal-to-noise ratio for intraschool transmission of threat information. Experiments were performed on Giant Danio (*Devario aequipinnatus*) in a no flow condition and a flow condition, to simulate a more naturalistic environment. Using a high frame rate camera recording at 400 fps and a tracking system developed by our lab, we are able to extract the position, orientation and shape parameters of each fish in the school. Using this data, we quantify the benefits of cohesive schooling in the context of signal detection theory. The results of this study will help improve our understanding of collective behavior and the mechanisms of information transmission in fish schools.

88.1 CHILDRESS, M.J.*; HELDT, K.A.; MCCLELLAN, K.L.; Clemson University; *mchildr@clemson.edu*
Opposites attract: Lobsters prefer to share dens with opposite behavioral phenotypes
Caribbean spiny lobsters are known to be gregarious and are often found sharing dens with conspecifics. Previous work has found that gregarious lobsters may benefit from a reduction in predation though decreased time to find dens (guide effect), decreased risk of predation (dilution effect) or increased probability of survival once attacked (group defense). Despite these benefits of being gregarious, half of all juvenile lobsters in the Florida Bay nursery are found in dens by themselves. In this study, we compared the odor preferences and den choices of juvenile lobsters in relation to familiarity and dominance status. Wild-caught juvenile lobsters were housed with size-matched conspecifics and in aquaria with a single shelter. We recorded the number of aggressive acts and assigned dominant status to the individual with the highest average. Then both dominant and subordinate individuals were allowed to choose between the odors of familiar/unfamiliar and dominant/subordinate conspecifics in a Y-maze choice test. Both dominant and subordinate lobsters showed no general preference for odors of conspecifics, but significantly preferred odors of opposite social status. To test if this preference would influence den choice, ten pairs of familiar lobsters were released into a large mesocosm with ten identical artificial crevice shelters. The frequency of co-denning between opposite social status lobsters was higher than predicted by random chance. These results suggest that juvenile spiny lobsters are more attracted to conspecifics of opposite social status and are more likely to share shelters with these individuals. We hypothesize that such a choice reduces aggression between den-mates and thus reduces the costs associated with sharing crevice shelters.

22.6 CHIU, Chen*; SWARTZ, Sharon/M; BREUER, Kenneth/S; Brown University; *Chen_Chiu@Brown.edu*
The interactive flight of bats
Bats often encounter conspecifics and/or heterospecifics in nature. Some bat species also emerge from their roosts together in large groups at dusk. Previous studies in flying/swimming animals have demonstrated that animals can take the advantage of wakes created by other individuals to fly/swim at lower energy. Therefore, we hypothesize that flying bats could interact in a manner that is energetically or aerodynamically beneficial. We investigated detailed flight kinematics of two short-tailed fruit bats, *Carollia perspicillata*, in the wind tunnel. Preliminary data show that the trailing bat synchronized its wing beat pattern with the leading bat when flying close together. In addition, the wing beat pattern of the trailing bat shows a small time delay compared to the leading bat's wing beat pattern. This result suggests that the trailing bat tried to match its wing beat frequency with the leading bat. Future experiments will explore flight interactions in more detail, and extend analysis of multi-animal flight to additional species. More bat pairs will be tested in the wind tunnel under different speeds to study velocity dependence of wing beat synchronization behavior and variation among individuals. We will also probe the mechanistic basis of wing beat synchronization by analyzing differences in flight energetics between the bat that flies in the leading vs. trailing position and if the bat can take any aerodynamic advantage of group flight. In addition, we will compare two bat species, *C. perspicillata* and *Eptesicus fuscus*, characterized by different wing design and flight behavior, and look for patterns used by each species to adjust their flight behavior when flying with other bats of either the same or different species.

29.4 CHONG, T.*; NEWMARK, P.A.; Univ. of Illinois, Urbana-Champaign; *chong@illinois.edu*

Role for a DM domain gene in male-specific reproductive development in the simultaneous hermaphrodite Schmidtea mediterranea.

In simultaneous hermaphrodites, little is known about how sex-specific reproductive organs develop and whether male and female reproductive structures are co-dependent. The sexual strain of the freshwater planarian *Schmidtea mediterranea* is a good model in which to address this question: it is a cross-fertilizing, simultaneous hermaphrodite with male and female reproductive organs that develop post-embryonically. In this study, we examined a gene from the DM (*doublesex/male-abnormal-3*) domain gene family, *Smed-dm4*. DM domain genes are conserved transcription factors that regulate sexual differentiation across phyla. In situ hybridization to detect *dm4* transcript in sexual planarians revealed expression in a subset of cells in the male gonads, male accessory reproductive organs, and the brain. Knockdown of *dm4* results in disruption of the male components of the reproductive system, such as the sperm ducts, testes, and seminal vesicles. In these animals the testes, including the *nanos*-positive germline stem cells, are not detected. By contrast, the female reproductive organs appeared normal, as seen through the expression of nanos and other genes expressed in oocytes, oviducts, and glands around the copulatory apparatus. Our results suggest that *dm4* plays a role in male-specific sexual development in planarians. The presence of sex-specific pathways in planarians like *S. mediterranea* could allow the evolution of simultaneous hermaphrodites into distinct male or female sexes, as seen in more derived flatworm species like the parasitic schistosomes. The role of *dm4* in sexual development in lophotrochozoans provides additional evidence for the evolutionary conservation of sex determination mechanisms across metazoans.

24.1 CHOUDHURY, U.*; DUDEK, D.M.; Virginia Tech; *udit10@vt.edu*

Dynamic Mechanical Properties of Cockroach Resilin

Resilin is a cuticular protein found in a variety of insects. It can stretch up to 300% of its natural length without any creep or relaxation. Further, it operates across a wide frequency range from 5 Hz in locomotion to 13 kHz in sound production. Both the protein sequence and composition of natural resilin as well as the dynamic mechanical properties vary substantially across species. This suggests that mechanical properties may be evolutionarily tuned for specific functions within an insect. Here, samples of resilin obtained from the tibia-tarsal joint of the cockroach, *Periplaneta americana*, were tested using a custom built dynamic mechanical analyzer. The material properties in compression are obtained from the rubbery to glassy domain with time-temperature superposition (2oC to 50oC) and time-concentration superposition (0 % to 90% ethanol by volume in water). At low frequency the storage modulus was found to be 1.5 MPa increasing to about 5 MPa in the transition zone. The glass transition frequency at 22oC in complete hydration was found to be 250 kHz. The data shows that cockroach resilin is less resilient than dragonfly resilin at low frequencies, returning about 79% of the elastic strain energy at 25 Hz compared to 97% for dragonfly resilin. However, at the glass transition (250 kHz) the material returns about 47% of the elastic strain energy compared to 30% in dragonfly (2MHz). The resilin pad is a composite structure, acting as a compressive spring to passively extend the tibia-tarsal joint during cockroach locomotion. Its mechanical properties are more similar to the composite locust pre-alar arm than to the pure resilin dragonfly tendon, suggesting that macroscopic structural influences may be as important as molecular sequence differences in setting properties.

42.4 CHUNG, BP*; LINAN-VELEZ, G; CATTAERT, D; EDWARDS, DH; Georgia State University, University of Bordeaux 1; *bchung4@student.gsu.edu*

A hybrid neuromechanical system for studying reflex reversal in crayfish

Resistance reflexes help to stabilize posture against outside perturbation. During voluntary movement, however, these types of reflexes can lead to interference. In both vertebrates and some invertebrates, descending motor commands include excitation of inhibitory interneurons that prevent unwanted reafference through primary afferent depolarization (PAD). In crayfish, the coxo-basal chordotonal organ (CBCO) is a stretch receptor that spans the coxa-basipodite joint that enables the walking legs to move up and down. CBCO afferents mediate resistance reflexes to maintain leg position during standing, but during walking those resistance reflexes are reversed to produce assistance reflexes. To study how reflex reversal occurs in a closed-loop system, we record from CBCO afferents, central neurons (CNS), and depressor (Dep) and levator (Lev) motorneurons (MNs). The isolated nervous system is connected to a computational neuromechanical model of the crayfish thorax and leg forming a real-time, closed-loop hybrid system. Dep and Lev MN activity excite model Dep and Lev muscles that move the model leg. The leg movement stretches and releases the model CBCO. Changes in the model CBCO length are transduced into identical movements of the live CBCO which generates afferent responses that excite the CNS. We use this system to determine the dynamic changes in reflex loop gains as the system switches from resistance to assistance reflexes during the onset of locomotor central pattern generator (CPG) activity.

111.2 CLAGHORN, G.C.*; MEEK, T.H.; PEREA-RODRIGUEZ, J.P.; GARLAND JR, T.; University of California, Riverside; *gclag001@ucr.edu*

Neurobiological correlates of voluntary exercise: Effects of selective breeding and a high-fat diet

Patterns of brain activity during voluntary exercise differ between mice from lines that have been selectively bred for high voluntary wheel running (HR lines) and those from non-selected control (C) lines in regions associated with motivation, reward, learning, and energy balance (Rhodes et al. 2003, Behav. Neurosci. 117:1243-1256). In addition, a diet high in fat with added sucrose (Teklad Western Diet [WD]) was previously shown to stimulate wheel running in HR mice, with little or no effect on C mice (Meek et al., 2010, Int. J. Obesity 34:960-969). We hypothesize that basic neurobiological differences underlie the disparate response to WD between HR and C lines. More generally, highly palatable diets have been shown to change the reward response to unrelated stimuli, and the underlying physiology of these changes may shed light on addiction, compulsive overeating, attention deficit hyperactivity disorder or other human afflictions. Shortly following weaning at 21 days of age, HR and C mice were given ad lib access to either WD or standard chow and access to a wheel for ~6 weeks, at which point wheel running had reached an apparent plateau. Brains were harvested during peak wheel running, 2-3 hours after the onset of darkness. Patterns of brain activity will be examined in areas implicated in motivation, energy balance, and learning using cFos immunohistochemisty. Activity in regions of the dopaminergic signaling pathways will be examined with cFos and the colocalization of cFos and tyrosine hydroxylase. We hypothesize statistical interactions between line-type (HR vs. C), diet, and amount of wheel running prior to sampling. Supported by NSF Predoctoral Fellowship to GC and NSF grant IOS-1121273 to TG.

95.3 CLAIRARDIN, S. G.*; PAITZ, R. T.; BOWDEN, R. M.; Il. St. Univ.; *sgclair@ilstu.edu*

Endocrine disrupting compound metabolism and the effects of bisphenol-a during development in the red-eared slider turtle (Trachemys scripta)

Bisphenol-A (BPA), an endocrine disrupting compound (EDC), can have a wide range of effects including sex reversal, which are often linked to inappropriate estrogen signaling. However, the mechanisms of action for BPA have yet to be fully characterized. One pathway that may be altered is estradiol (E_2) metabolism, as BPA and E_2 are metabolized by the same conjugative enzymes. We have previously shown that BPA can inhibit metabolism of maternal E_2 during early development in *Trachemys scripta* eggs, which may lead to estrogenic effects. Interactions between timing of exposure and of E_2 metabolism could play a role in defining how EDCs impact development. The present study aimed to understand effects of dose and timing on the outcomes of BPA exposure and whether EDC metabolism may play a role. To test effects of dose and timing on sex, eggs were treated with 0, 3.5 or 35ppm BPA on day 0 (within 24 hrs of laying) or day 21 (beginning of sex-determining period). Eggs were incubated in a fluctuating temperature regime (28° +/- 4C) until hatch. Sex will be determined and ratios compared among groups. To test effects of dose on survival, eggs were treated on day 0 with one of 10 doses (ranging from 0-70ppm BPA), and eggs incubated at 27&degC until hatch to quantify hatching success; sex will be determined and compared among groups. To understand how BPA may elicit its effects, we asked how BPA is metabolized and moved around the egg after exposure. Eggs were exposed to ^{3}H-BPA on day 0 and sampled every 5 days throughout development to identify and quantify metabolites. Connections between EDC metabolism/movement and end-point effects will inform our understanding of overall toxicity, and will provide a mechanistic understanding to aid in interpretation and prediction of context-dependent effects.

83.1 CLARDY, Todd; Virginia Institute of Marine Science; *tclardy@vims.edu*

Using fractals to describe morphology and ontogeny of lateral line canals of Xiphister (Cottiformes: Stichaeidae), with comparisons to other stichaeids

Fishes of the family Stichaeidae, commonly known as pricklebacks, are a diverse group of about 37 genera and 76 species distributed in intertidal and continental slope waters of the North Pacific, Arctic and North Atlantic Oceans. A peculiar characteristic of some stichaeid genera is the presence of multiple, complexly branching trunk lateral line canals. This condition is rare among teleostean fishes and is found in members of only twelve other families. In this presentation, I describe the morphology of the trunk lateral line system of the two species of *Xiphister* using a fractal approach. Both species each have seven trunk lateral line canals, which are supported by dermal, ring-like ossifications. Lateral line systems in *Xiphister* were traced from cleared and stained specimens (32.4-170.1 mm SL) and their fractal dimensions were measured using the box/count method. This method calculates the complexity of a 2-dimensional object and yields values ranging from one (simple) to two (complex). At small sizes, trunk lateral lines in *Xiphister* are poorly developed resulting in low fractal dimensions (1.1-1.3). As *Xiphister* increase in size, branching of trunk lateral lines increases resulting in greater complexity and higher fractal dimensions (1.4-1.5). The implications of increasing fractal dimension of lateral line systems in *Xiphister* will be discussed, and comparisons to other fishes with multiple trunk lateral lines will be made.

1.1 CLARK, A/J*; SUMMERS, A/P; College of Charleston, Friday Harbor Laboratories, Univ. of Washington; *clarkaj@cofc.edu*

Ontogenetic scaling of the morphology and biomechanics of the feeding apparatus in the Pacific hagfish Eptatretus stoutii

The scaling patterns of feeding systems can indicate feeding habits and ontogenetic dietary changes. The form and function of the support skeleton, musculature and teeth were examined in an ontogenetic series of Pacific hagfish *Eptatretus stoutii* spanning about a six-fold range in total length. Tooth area, feeding apparatus length, basal plate size, theoretical dental plate retractile force, penetration force, and applied tooth stress were measured relative to body size. Morphological variables (e.g. tooth area and basal plate size) scaled with positive allometry and functional variables (e.g. retractile force and applied tooth stress) scaled isometrically with total length. These results suggest that juveniles do not undergo ontogenetic dietary changes and consume functionally equivalent prey to adults, though adults can grasp proportionally larger portions of food. Low tooth stress in juveniles and adults imposes mechanical constraints to puncturing and tearing, which are circumvented by a preference for softer prey tissue or the inclusion of knotting behaviors for reducing tougher prey.

33.1 CLEMENTE, CJ*; RICHARDS, CT; Harvard University; *clemente@rowland.harvard.edu*

Limitations to swimming speed in drag based aquatic systems

Within terrestrial systems, the fastest sprinters are neither the largest, nor the smallest, but are intermediately sized. The initial increase in speed is because stride length increases more rapidly than stride frequency decreases as animals get larger. Yet above a certain size, locomotory performance is constrained due to the effects of body weight causing mechanical stress on musculoskeletal designs. However, in aquatic systems, organisms can achieve neutral buoyancy and therefore the effects of mass related stress increases are likely to be smaller. This leads to the question, of what is limiting speed in drag based aquatic systems. How much do the force-length and force-velocity properties of the muscular skeletal system limit total performance? To answer these questions we measured swimming speed in the aquatic frog *Xenopus leavis* , for individuals ranging in body mass from 1g to 200g. We then created a mathematical rowing frog model, incorporating the force-length and force-velocity effects, along with the scaling exponents for morphological features, to assess if these variables can limit maximal swimming performance. Measurements for sprint speeds of *X. leavis* using high speed video (250 Hz) suggest that speed initially increases with body size from 0.84 $m.s^{-1}$ for 1g frogs (mean = 1.28g) up to 1.36 $m.s^{-1}$ for 20g frogs (mean = 20.12). However further increases in body size did not result in greater swimming speeds (i.e. 200g frogs swam at 1.35 $m.s^{-1}$). The virtual frog model, underestimated maximal sprint speed achievable (0.51 $m.s^{-1}$) but did predict an optimal body size with respect to swimming speed at 120g, after which maximum speed declined. Preliminary analysis of the model suggests that propulsive drag produced by the feet, and therefore musculoskeletal force-velocity effects may limit speed in drag based aquatic systems.

104.2 CLIFFORD, MR*; RIFFELL, JA; University of Washington; *cliffmar@uw.edu*
The role of pollinator olfactory processing in biasing floral scent evolution
Chemical communication is an important and ancient method of information transfer between angiosperms and the animals with which they interact. However, in stark contrast to the rich literature investigating the visual aspect of pollination syndromes evolved by flowering plants to attract certain animal pollinators, quite little is known about the possibility of corresponding olfactory signals. We investigated this possibility by asking (1) whether convergent evolution has shaped the floral scents of plants that attract the same pollinator classes to inhabit the same chemical space, and (2) what kind of neural response is stimulated in insect pollinators by the chemical components of typical bird-, bat-, bee-, fly-, and moth- attracting floral scents. We used dynamic sorption to capture headspace volatiles from a wide variety of flowering plants from the both field and the UW Botany Greenhouse, and ran these samples through a GCMS to identify and quantify proportions of individual chemical components in each floral scent. We then chose available flowers that typified the scent most attractive to certain pollinator classes and collected multiples of those species. We used multi-channel recording from the antennal lobe to assess the neural response of different insect pollinators to these typical floral scents. Understanding chemical communication between plants and their pollinators can help us understand the basic evolution of this widespread mutualism. It may also be critical to helping us develop crop plants that are attractive to alternative pollinators, helping to ensure food-security and mitigate economic damage as the future of commercial honeybee pollination remains uncertain.

89.1 CLOSE, M T*; CUNDALL, D L; Lehigh University; *mclose@lehigh.edu*
Extensible tissues and their contribution to macrostomy in snakes
Snakes swallow by passing whole prey between their mandibles. In three species of macrostomatan snakes we examined, the intermandibular soft tissues stretch five to eight times their resting distance during feeding and manual manipulations produced greater separation. Histological comparisons of unstretched and stretched lower jaws reveal some inextensible elements, including the mandibles, tongue, trachea, and epidermis. Lower jaw extensibility relies solely on the ability of the epithelia surrounding the region and the soft tissues around and between inextensible structures to stretch. The effects of stretch on epithelia primarily consist of unfolding of mucosa and interscale epidermis. The dermis matches scale patterns, its deepest elastic layer spanning the entire lower jaw, and its most superficial inelastic layers limited to scale regions. Elastin networks extend superficially into scales and major interscale folds, and remain anchored to these regions during extension. Nerves and vessels run longitudinally in loose connective tissue deep to the dermis. Muscles extending from the mandibles to the midline stretch, and appear to serve in producing the major folds of the rest condition, but their behavior and structure are complex and will be dealt with elsewhere. Our results suggest that collagen and keratin provide structural support and limit extension whereas elastin networks provide recovery and refolding following extension.

84.3 COHEN, J.H.; Univ. of Delaware; *jhcohen@udel.edu*
Visual ecology of bi-lobed eyes in an Antarctic euphausiid
Big-eye krill, *Thysanoessa macrura*, are common luminescent Antarctic euphausiids with a circumpolar distribution extending from coastal waters into the subantarctic. They are omnivores often occurring in dense aggregations in the upper 400 m, and are prey for fish, whales and seabirds. Each *T. macrura* compound eye consists of discrete dorsal and ventral lobes. Based on eye morphology, Land (2000) proposed that dorsal eye lobes of midwater animals detect dark objects silhouetted against a bright background of downwelling light, while ventral eye lobes detect bright luminescent flashes against a dark background. In the present study, extracellular electroretinogram recording was used to measure aspects of the visual physiology of dorsal and ventral eye lobes in *T. macrura* collected near Palmer Station on the West Antarctic Peninsula to test whether sensitivity and temporal resolution of each eye lobe support these different ecological roles. Distinct spectral sensitivity maxima were observed for dorsal and ventral eye lobes, 463 nm (dorsal lobe, n=3) and 492 nm (ventral lobe, n=7), which is consistent with the dorsal lobe as a silhouette detector and the ventral lobe as a luminescence detector. V-logI functions were obtained from dark-adapted dorsal and ventral eye lobes; resulting log *K* values suggest the dorsal silhouette detector is more sensitive to light than the ventral luminescence detector. Temporal resolution as measured by critical flicker fusion frequency for dark-adapted eyes at 0.7°C was similar for dorsal silhouette-detecting lobes (17 Hz) and ventral luminescence-detecting lobes (20 Hz). Collectively, spectral sensitivities most strongly support different ecological roles for dorsal and ventral eye lobes in *T. macrura*, which provides physiological evidence for Land’s hypothesis, but contrasts with another bi-lobed euphausiid.

13.6 COHEN, K.L.*; SEID, M.A.; WARKENTIN, K.M.; Boston Univ., Univ. of Scranton; *kcohen@bu.edu*
The mechanism of rapid, plastic hatching in red-eyed treefrogs
Although environmentally cued hatching is common and widespread in animals, including 12 families of amphibians, mechanistic studies treat hatching as a fixed developmental process. The treefrog *Agalychnis callidryas* can hatch in seconds up to 30% early in response to multiple risk cues, offering a robust model of plastic hatching. High-speed video of hatching shows a sequence of (1) mouth gaping and body tremulation, (2) presumably enzymatic vitelline membrane rupture, sometimes without physical contact, and (3) swimming movements by which embryos exit the egg. To assess the location and timing of hatching enzyme release and membrane rupture in relation to behavior, we cued embryos to hatch then turned some to a new position after tremulations began. Rupture was highly localized at the initial snout position. Turned embryos remained trapped in the collapsed membrane until they returned to the original rupture or tremulated again and made a second hole at a new snout location. In contrast to the gradual enzyme release and general membrane degradation described for other anurans, hatching in *A. callidryas* appears mediated by rapid, localized release of enzymes under behavioral control. We identified two candidate structures for a source of hatching enzymes. (1) Cells morphologically similar to described hatching glands are highly localized above the mouth, increase in prominence through the period of hatching competence, and disappear rapidly after hatching regardless of its timing. (2) The buccal roof of hatching-competent embryos stains positive with an antibody that marks hatching glands in *Xenopus laevis*. Elucidating the mechanism and control of the hatching process is necessary to understand the context and capacity for environmentally cued hatching.

32.5 COLLAR, David*; MEHTA, Rita; REVELL, Liam; ALFARO, Michael; WAINWRIGHT, Peter; Univ. California, Santa Cruz, Univ. Massachusetts, Boston, Univ. California, Los Angeles, Univ. California, Davis; *dcollar@ucsc.edu*

Does feeding mode constrain diversification of the skull in elopomorph fishes?

Behavioral innovations dramatically alter the way morphological traits interact with the environment and may cause shifts in the selective regime those traits experience. An intriguing model for examining the effects of behavioral innovation is the origin of biting as a mode of prey capture in anguilliform fishes (i.e., true eels). Whereas most teleost fishes expand the oral cavity to generate a suction-induced water flow that draws prey into the mouth, many anguilliform species apprehend prey by making contact with the oral jaws, a feeding mode that imposes very different functional demands on aquatic predators compared to suction feeding. In this study we assess whether biting behavior has led to a change in the pattern of diversification of three skull modules--the oral jaws, hyoid, and opercular series. We infer phylogenetic relationships among 60 elopomorph fishes (anguilliform eels plus the tarpons, bonefishes and ladyfishes), reconstruct the history of biting and suction feeding in this clade, and fit evolutionary models that allow rates and covariances of trait change to vary in suction feeding and biting lineages. Although feeding mode does not alter the rate of evolution of skull modules, biting is associated with substantially weaker correlations between evolutionary changes in the oral jaws and opercular series and between the hyoid and opercular series. We suggest that biters have experienced relaxation of the suction-imposed demand for highly coordinated movements between cranial modules, resulting in greater independence among cranial modules and ultimately evolution of a wider array of skull forms.

S3-1.2 COLLIN, R; Smithsonian Tropical Research Institute; *collinr@si.edu*

What Can "Intermediates" Tell Us About Evolutionary Transitions Between Modes of Invertebrate Development?

Mode of development in marine invertebrates has been largely viewed as a dichotomy between small eggs that develop into free-living planktotrophic larvae and large eggs that bypass the larval stage and develop directly into juveniles. Modes of development viewed as intermediate between these two extremes include facultative feeding larvae, non-feeding lecithotrophic larvae, and poecilogony where nutritional mode varies within a species. Available phylogenies, however, do not usually show these forms in positions intermediate between planktotrophs and direct developers, and recent optimality modeling efforts have also shown that "intermediate" nutritional modes may be more evolutionary stable than previously believed. Are these forms truly transitional or intermediate, in evolutionary terms? Do evolutionary transitions between modes of development necessarily involve these forms? Does the evolutionary potential of poecilogonous forms differ from that of other "intermediate" forms of development? And how could natural selection act on existing genetic variation to drive evolutionary changes between developmental forms? To get at these questions we need to move away from the legacy of the bimodal view of egg size and development modes and not fall into the trap of viewing all "intermediates" as equal.

2.2 COLLINS, CE*; ANDERSON, RA; MCBRAYER, LD; Georgia Southern University; *cc03836@georgiasouthern.edu*

Sprint Sensitivity to Substrate and Ecomorphological Correlates in Six Terrestrial Lizard Species

Sprint performance is important to terrestrial lizards for predator evasion, prey acquisition, and fitness. Because many terrestrial species encounter a variety of substrates during locomotion, relationships between morphology, performance, and habitat use are ripe for research. Results from previous studies suggest increased limb length and sprint speed is correlated with saxicoly. Results from studies on locomotion over compliant surfaces such as sand, however, are less clear despite psammophily likely imposing selective pressure. Sprint sensitivity, or the variation in sprint performance due to differences in habitat or substrate use, has been useful in studies of arboreal lizards. This study measured sprint sensitivity among six terrestrial lizard species that occupy rocky, sandy, and/or semi-arboreal habitats. We quantified maximum velocity as each lizard accelerated from a standstill and ran down a 5 meter runway constructed in the field. Each animal was run three times on each of three substrate types (Runway A – sand (<2mm); B – pebbles (4-10 mm); C – cobbles (>200mm). All runs were videotaped and reviewed to estimate maximal velocity over 5 meters. We infer from our results reduced sprint sensitivity saxicolous lizards. Higher overall velocity, yet greater sprint sensitivity, was observed in lizards that predominately use sand substrates. Here we use our results to discuss the evolutionary implications of differential substrate use in terrestrial lizards including morphology, locomotor capacity, and habitat selection.

98.4 COMBES, S.A.*; RUNDLE, D.E.; IWASAKI, J.M.; Harvard University; *scombes@oeb.harvard.edu*

Dragonfly versus fruit fly: Biomechanics, behavior and strategy during aerial predator-prey encounters

Despite extensive research on the ecology and population dynamics of predator-prey systems, our understanding of the physical interaction between animals and the factors that determine the outcome of an encounter remains limited. We performed over 3000 controlled predation trials to assess how the capture success of dragonflies (*Libellula cyanea*) hunting fruit flies (*Drosophila melanogaster*) is affected by environmental conditions and prey behavior. We also analyzed 50 high-speed videos of predation encounters to understand how the flight mechanics of both predator and prey affect the outcome. We find that the flight performance of fruit flies in our natural, outdoor enclosure differs significantly from previously published accounts of *Drosophila* flight capabilities in the laboratory. In addition, the pursuit strategy and capture success of dragonflies is highly dependent on prey behavior. Fruit flies perform a series of random turns (saccades) during normal cruising flight, but the speed and curvature of these turns varies between individuals. Rather than adopting the most direct route to interception, dragonflies approach their prey from below, optimizing their ability to visually track prey and minimizing the likelihood of being detected. Fruit flies that perform frequent, rapid saccades are more difficult for dragonflies to approach in this manner, and occasionally detect the approaching predator in time to initiate evasive maneuvers. Overall, dragonflies are more successful at capturing fruit flies that perform slow, moderate turns during cruising flight. These results highlight the difficulty of fully understanding complex flight behaviors such as predation and escape through experiments performed in artificial settings or by eliciting these behaviors with artificial stimuli.

116.2 CONDON, CH*; COOPER, BS; YEAMAN, S; ANGILLETTA, MJ; Arizona State University, Indiana University, Bloomington, University of British Columbia; *catriona.condon@asu.edu*

Evolution of thermal acclimation in constant and heterogeneous environments

Experimental studies of the evolution of thermal acclimation are dominated by tests for an adaptive benefit of acclimation under all conditions, an idea known as the beneficial acclimation hypothesis (BAH). Empirical support for the BAH is relatively weak, perhaps unsurprisingly, given the underlying assumption that acclimation is both cost-free and unperturbed by environmental heterogeneity. In this study, we compared the BAH to two alternative hypotheses that predict the evolution of acclimation capacity is affected by thermal heterogeneity among generations and non-adaptive processes such as gene flow among environments. We examined the evolution of developmental acclimation within twenty selection lines of Drosophila melanogaster evolving for over three years to constant and fluctuating thermal environments. Five replicated populations evolved in each of the four selection treatments: constant high (25 °C) and low (16 °C) environments, a treatment where temperature fluctuated between 16 and 25 °C among generations and a second fluctuating treatment where gene flow was maintained between populations exposed to 16 and 25 °C. We raised female D. melanogaster at 16 and 25 °C and measured a reaction norm for daily fecundity for 10 isofemale lines within each of the selection lines.

45.5 CONNOLLY, MH*; DUTKOSKY, RM; HEAH, TP; SAYLER, GS; HENRY , TB; University of Tennessee, Knoxville ; *mconnol3@utk.edu*

Vitellogenin gene expression is correlated with stage 2 oogenesis in zebrafish (Danio rerio)

Vitellogenin genes (e.g., *vtg-1*) code for egg yolk proteins that are highly induced by estrogen and estrogen mimics. While induction of *vtg-1* has been established as a biomarker of exposure to environmental estrogens in male fish, little is known about how its expression relates to the stages of oogenesis in females, especially among fish with asynchronous egg development. The objective of this study was to relate hepatic *vtg-1* expression to changes in oocyte and ovarian morphology in adult zebrafish (*Danio rerio*). Liver and gonad samples were collected from female fish 1-32 days post-spawning and analyzed using qRT-PCR and histological methods. Four stages of oocyte development were distinguished at all time points under investigation. Notably, the composition of these stages within the ovary indicates that zebrafish eggs develop in distinct batches, which may be reminiscent of seasonal spawning behavior observed among wild zebrafish. *Vtg-1* was positively correlated with the presence of stage two oocytes, suggesting that it is required during early vitellogenesis. In addition, the greatest upregulation of *vtg-1* occurred one hour post-spawning, indicating that the event of spawning itself may be important to the regulation of oocyte development in fish.

83.2 CONNORS, M.J.*; KALLAI, I.; GAZIT, D.; ORTIZ, C.; Massachusetts Institute of Technology, Hebrew University; *connors@mit.edu*

Three-dimensional structure of the shell plate assembly of the chiton Tonicella marmorea and its biomechanical consequences

Chitons are of great interest from a biomechanical perspective because instead of a single continuous shell, they possess an assembly of eight overlapping exoskeletal plates. These plates provide protection while still allowing for some degree of flexibility during locomotion over rough surfaces, as well as when rolling defensively into a sphere-like conformation if dislodged from a surface. In this study, X-ray micro-computed tomography was used to elucidate the detailed mechanism of conformational change from a passive (slightly curved, attached to surface) to a defensive (rolled, detached from surface) state of *Tonicella marmorea*. The passive and defensive conformations exhibited differences in longitudinal curvature index (0.43 vs. 0.70), average plate-to-plate overlap (~62% vs. ~48%), cross-sectional overlap heterogeneity (60-82.5% vs. 0-90%, fourth plate), and plate-to-plate separation distance (100% increase in normalized separation distance of plates 4 and 5). This work provides an understanding of how *T. marmorea* achieves the balance between mobility and protection. In the passive state, the morphometry of the individual shell plates and plate-to-plate interconnections results in an approximately continuous curvature and constant armor thickness (homogeneous protection); mobility is limited but armor coverage and protection is maximized. When the chiton is in the defensive state, the underlying soft tissues gain greater coverage and protection by the plates and the animal gains mobility through tidal flow, but regions of vulnerability are opened dorsally, due to the increase in plate-to-plate separation distance and decrease in plate-to-plate overlap.

30.2 CONTRERAS, H.L.*; DAVIDOWITZ, G.; University of Arizona; *hcontrer@email.arizona.edu*

The effect of nectar sugar concentration on the specific dynamic action of the hawkmoth Manduca sexta

Studies on birds have shown that the cost of processing a meal is higher when dilute nectars are ingested compared to when more concentrated nectars are consumed. Most of the metabolic costs in these studies are associated with the need to warm large volumes of liquid to body temperature. In this study we examined the metabolic cost of processing nectars of different sugar concentrations in nectar feeding ectotherms. Adult *Manduca sexta* hawkmoths naturally feed from flowers of *Datura wrightii* and *Agave palmeri* in the wild, although they have an innate preference for *D. wrightii*. Flowers from *D. wrightii* are known to produce a more concentrated nectar (22%) compared to *A. palmeri* (12%) and therefore, for a specific volume of nectar, provide a higher energy content than *A. palmeri*. However, the metabolic cost of processing nectar of different sugar concentrations in *M. sexta* is not known. While *M. sexta* don't need to warm their liquid meals, consuming dilute nectars may be more costly to them by imposing additional energy costs on maintaining proper water balance. We predict that *M. sexta* feed preferentially on concentrated nectar because the cost of processing a concentrated nectar is lower than the cost of processing a more dilute nectar. Therefore the benefits of feeding from a concentrated nectar, like that of *D. wrightii*, are two-fold: 1. Receive a higher energetic reward; 2. Spend less energy on osmoregulation.

78.8 COON, CAC*; MARTIN, LB; University of South Florida; *ccoon@mail.usf.edu*

Do changes in parasite prevalence facilitate range expansion of Kenyan house sparrows (Passer domesticus)?

The enemy release hypothesis (ERH) posits that invaders are less affected by parasites and predators in their new range, either due to life history characteristics of the enemy or by chance alone, thereby allowing invaders to reallocate resources to growth and reproduction and/or increase their competitive ability, facilitating successful establishment and spread. Traditionally, the ERH refers to the loss of parasite diversity, specifically parasite species richness. However, the ERH could potentially be expanded to include information about changes in parasite prevalence and abundance with specific predictions about the functional types of parasites (based on transmission, pace-of-life, etc.) with time since invasion. This information could greatly inform our understanding of the success of invasive species and allow us to model the colonization and spread of nonindigenous species based on their parasite fauna. We used house sparrows (*Passer domesticus*) in one of their latest independent invasions, in Kenya, to make and test our predictions regarding infection prevalence with time since invasion and loss and gain of parasites given the parasites' life history characteristics.

14.2 COOPER, Lisa Noelle*; JAST, John; BEHRINGER, Richard R.; CRETEKOS, Chris; RASWEILER, IV, John J.; SEARS, Karen E.; Univ. of Illinois, Univ. of Texas, Univ. of Idaho, SUNY Downstate Med. Ctr.; *l.noelle.cooper@gmail.com*

Cellular patterns and biomechanical consequences of bat wing development

Mammals evolved a stunning degree of phenotypic diversity in bone architecture in response to their occupation of extreme habitats. To achieve powered flight, bats altered the architecture of their long bones by reducing mineral concentrations and altering cross-sectional geometries. This study aimed to quantify differences in adult bone architecture of the short-tailed bat (*Carollia*) relative to terrestrial rodents (*Mus*, *Peromyscus*). By integrating microstructural analyses via nanoindentation tests with whole bone bending tests, as well as visualization of cross-sectional areas, this study offers a thorough documentation of architectural differences in limb bones of aerial and terrestrial mammals. Nanoindentation tests revealed that the metacarpals of bats are 40% as stiff and 36% as hard as that of *Mus*. Whole bone bending tests showed that the humerus of bats and mice are roughly equivalent in stiffness, however bat radii were more compliant. Micro-CT scans showed the humeral, femoral, and tibial cross-sectional geometries are equivalent in both groups; however, distal bones of the bat displayed 8-40% larger medullary cavities compared rodents. To determine how endochondral ossification differs between *Carollia* and *Mus* diaphyseal dimensions were measured. Results indicate that *Carollia* delays appositional ossification relative to *Mus*, but begins diaphyseal longitudinal growth earlier. At late fetal stages, *Carollia* rapidly elongates the diaphysis, a finding consistent with reports that most endochondral ossification occurs postnatally in bat forelimb bones. These findings further our understanding of the microstructural properties of chiropteran bone biology.

12.4 COOPER, B.S.*; HAMMAD, L.A.; FISHER, N.P.; KARTY, J.A.; MONTOOTH, K.L.; Indiana University, Bloomington; *brascoop@indiana.edu*

Selection favors increased cellular plasticity in a variable environment

Theory predicts that developmental plasticity, the capacity to change phenotypic trajectory during development, should evolve when the environment varies sufficiently among generations, owing to temporal (e.g., seasonal) variation or to migration among environments. We characterized the levels of cellular plasticity during development in populations of *Drosophila melanogaster* experimentally evolved for over three years in either constant or temporally variable thermal environments. We used two measures of the lipid composition of cell membranes as indices of physiological plasticity (a.k.a. acclimation): (1) change in the ratio of phosphatidylethanolamine (PE) to phosphatidylcholine (PC) and (2) change in lipid saturation (number of double bonds) in cool (16ºC) relative to warm (25ºC) developmental conditions. Flies evolved under variable environments had a greater capacity to acclimate the PE/PC ratio compared to flies evolved in constant environments, supporting the prediction that environments with high among-generation variance favor increased developmental plasticity. Our results are consistent with the selective advantage of a more environmentally sensitive allele which may have associated costs in constant environments.

48.6 CORDLE, M.E.*; MEADE, M.E.; NICHOLS, A.; Jacksonville State University; *mecordle@gmail.com*

Metabolic physiology of the stream minnow, Campostoma oligolepis, inhabiting a polluted stream.

Snow creek, Oxford, Alabama, was a victim of industrial heavy metal and PCB contamination in the 1970s. In those years, high concentrations of contaminants resulted in the death and/or migration of many aquatic organisms from the creek. Cleanup efforts began in the 1980s although mercury (Hg) and PCBs remain above EPA limits. A diversity of aquatic organisms currently inhabit the creek, although many sensitive species remain to be found. In this study we examined oxygen consumption rates in fishes inhabiting Snow creek and other unimpacted regional streams. Our goal was to determine if fishes inhabiting Snow creek had altered metabolic rates, as indicated by altered oxygen consumption rates. Fish examined from unimpacted streams included those inhabiting Shoal creek, a relatively pristine site in the Talladega National Forest, AL, and Mill creek, a relatively unimpacted site in Jacksonville, AL. Weight specific metabolic rates (MO_2;mgO_2/kg*hr ± S.D.)for fishes inhabiting Snow, Shoal, and Mill creeks, respectively, were 412.62±41.56, 298.67±57.57, and 312.24±36.38. Metabolic rates were therefore 25% higher in fishes inhabiting the contaminated site. Previous studies have demonstrated gill damage and osmoregulatory stress in fishes chronically exposed to Hg and PCBs. We hypothesize that osmoregulatory stress may be one factor contributing to the observed increased metabolism in fish from contaminated sites in this study.

62.1 CORNELIUS, JM*; HAHN, TP; CHAPPLE, TK; WILKELSKI, M; Max Planck Institute of Ornithology, University of California, Davis; *cornelius@ucdavis.edu*

Seasonal changes in energy expenditure, corticosterone and behavior in free-living red crossbills, Loxia curvirostra

Energy is the currency of life, where a surplus allows survival and reproduction and a long-standing debt leads to death; yet monitoring of energy expenditures in free-living animals has been relatively limited by available technology. Radio transmitters that have been specially modified to detect heart rate, however, allow for real-time estimation of energy expense in free-living, behaving animals. Red crossbills live at northern latitudes year-round and breed opportunistically throughout much of the year. They therefore offer a unique opportunity to examine the eco-physiology of different life cycle stages under drastically variable seasonal conditions. Here we present heart rate data, corticosterone levels and behavioral ecology of free-living, non-breeding red crossbills in the summer and winter, as well as molting red crossbills in the autumn. We discuss these variables in the context of red crossbills' unique opportunistic and nomadic annual schedules and the highly seasonal conditions of our field site in Grand Teton National Park.

8.4 COTRONE, M.C.*; EARLEY, R.L.; DRAUD, M.; University of Alabama, Tuscaloosa, Long Island University - C.W. Post, Brookville, NY; *mccotrone@crimson.ua.edu*

Contest behavior is mediated by resource payoff value in female convict cichlids (Amatitlania nigrofasciata).

Contest behavior has evolved in animals as a means of acquiring and retaining fitness-related resources. Historically, contest behavior has been studied primarily in males but, in some systems such as the convict cichlid (*Amatitlania nigrofasciata*), both males and females compete vigorously for limiting resources. It is therefore important to investigate the rules of engagement employed by females. The sequential assessment model (SAM) predicts that contestants gather information about their opponent's resource holding power (RHP) and use that information to decide whether to flee or persist in a contest. Male contests show evidence of SAM, but there is evidence that female contests are structured differently. This study examines the mechanics of female contests and the role of resource payoff value (RPV) in contests. We show that females do not strictly follow the rules of SAM, but do show signs of assessment when RPV is low. By changing the reproductive state (RS) of female convict cichlids, RPV can be increased or decreased. Consequently, contests between females with high RPV had higher rates of escalated behavior and were more likely to end in draws than low RPV contests. However, RPV asymmetries did not predict contest outcome in females. The results suggest that RPV plays an important role in the structure of female contests and may influence the strategy used by contestants.

6.10 COUGHLIN, D. J.*; MISTRY, H.; CAMPION, L. A.; CHOI, S.; Widener Univ.; *djcoughlin@widener.edu*

Contractile Properties and Myosin Expression in Swimming and Feeding Muscles of Centrarchid Fishes

In centrarchid fishes, such as bluegill and largemouth bass, the contractile properties of feeding and swimming muscles show different scaling patterns. While the maximum shortening velocity (V_{max}) and rate of relaxation from tetanus of swimming or myotomal muscle slows with growth, the feeding muscle show distinct scaling patterns. Epaxial muscle, which is used to elevate the head during feeding strikes, retains fast contractile properties across a range of fish sizes in both species. In bass, the sternohyoideous muscle, which depresses the floor of the mouth during feeding strikes, shows faster contractile properties with growth. The objective of this study was to determine the molecular basis of these different scaling patterns. We examined the expression of two muscle proteins, myosin heavy chain (MyHC) and parvalbumin (PV), that affect contractile properties. We hypothesized that the relative contribution of slow and fast MyHC isoforms will modulate V_{max} in these fishes, while the presence of PV in muscle will enhance rates of muscle relaxation. Myotomal muscle displays an increase in slow MyHC expression with growth, in agreement with its physiological properties. Feeding muscles such as epaxial and sternohyoideus show no change or a decrease in slow MyHC expression with growth, again as predicted from ontractile properties. PV expression in myotomal muscle decreases with growth in both species, as has been seen in other fishes. The feeding muscles again show no change or an increase in PV expression with growth, contributing to faster contractile properties in these fishes. Both MyHC and PV appear to play important roles in modulating muscle contractile properties of swimming and feeing muscles in centrarchid fishes.

90.3 COX, Robert M*; CALSBEEK, Ryan; University of Virginia, Dartmouth College; *rmc3u@virginia.edu*

Experimentally decoupling reproductive investment and energy storage to investigate the functional basis of life-history trade-offs

The trade-off between reproduction and survival is central to life-history theory, but we currently know little about the physiological mechanisms that link these two components of fitness. We have previously shown that the elimination of reproduction via surgical ovariectomy (OVX) dramatically increases the survival of brown anole lizards (*Anolis sagrei*) in the wild. This survival advantage persists even after the conclusion of the reproductive season and is accompanied by increases in growth, fat storage, hematocrit, and immune function. Collectively, these results suggest that reproduction leaves females energetically compromised and unable to fully support maintenance functions that could otherwise improve their survival. To test this hypothesis, we assigned females to three treatment groups: (1) bilateral OVX, (2) unilateral OVX, and (3) intact SHAM control. As predicted, unilateral OVX induced levels of reproductive output, growth, and fat storage that were statistically intermediate between SHAM and bilateral OVX. Survival followed a similar stepwise decrease from bilateral OVX (0.33) to unilateral OVX (0.31) and SHAM (0.26), but these differences were not significant. At the conclusion of the breeding season, we decoupled these reproductive manipulations from their effects on energy storage by dividing the survivors from each group into two further treatments: (1) surgical excision of abdominal fat bodies, or (2) sham surgery (fat bodies intact). Although this manipulation had a strong and persistent effect on energy stores, it did not influence survival in any of the three reproductive treatments. This suggests that the energetic savings of reduced reproductive investment is insufficient to fully explain the accompanying increase in survival in this species.

107.6 COX, Suzanne M*; MODARRES-SADEGHI, Yahya; PATEK, Sheila; University Of Massachussettes, Amherst; *suecoxdesigns@gmail.com*

physical model of the feeding strike of the mantis shrimp

The goal of this study is to combine physical and mathematical modeling in conjunction with measures of live animal performance to probe the mechanical design of the mantis shrimp's extremely fast feeding appendage while also measuring the fluid dynamic effects of these movements, particularly focusing on the production of cavitation bubbles. Our physical model is driven in similar environmental conditions to our laboratory aquaria and is powered by a latch-released spring that maintains the radial motion, scale, maximum velocity and acceleration that closely approximate a mantis shrimp's strike (*Gonodactylaceus smithii*"). We varied spring constant, force and delivery time while holding appendage dimensions constant as an aluminum cylinder that is similarly sized to the study animals. We developed and applied a mathematical model based on spring mechanics, beam theory and linkage mechanics and used it to hone the spring design and linkages of the physical model. Velocity and acceleration were calculated from high speed images (30,000 fps) of the model and live mantis shrimp as were cavitation presence, absence, and onset speed. Ten strikes from each of 5 animals were analyzed with an average velocity of 18 m/s and acceleration of $2x10^4$ m/s^2. The model produced velocities up to 29 m/s and accelerations to $3x10^4$ m/s^2. Our key findings were that G. smithii appendages cavitate on impact and rarely cavitate in forward motion. The model cavitates on impact, but it also cavitates in forward motion at speeds where none was seen in animals. This indicates that one or more of the model's simplifications are fluid dynamically relevant for cavitation onset and suggests exploration of the relevance of the of shape, material and surface properties of the appendage.

28.5 COX, Christian L.*; DAVIS RABOSKY, Alison R.; CHIPPINDALE, Paul T.; The University of Texas, Arlington, The University of California, Berkeley; *clcox@uta.edu*

The evolution of Mc1R in the snake genus Sonora

Color pattern polymorphism (CPP) presents an interesting puzzle in evolutionary biology. Because genetic drift will fix neutral alleles over time, the persistence of polymorphism must be explained by additional neutral (e.g., drift with gene flow) or selective (e.g., frequency dependent selection) processes. Understanding how this polymorphism is generated and maintained in natural populations is integral to understanding basic evolutionary processes such as aposematism, sexual selection, and speciation. An excellent system for studying CPP is the ground snake (*Sonora semiannulata*) which has four different dorsal color patterns that vary in frequency across their geographic range. A powerful method for understanding CPP is to examine genetic loci underlying color pattern for the signature of selection. One gene (*Mc1R*) has emerged as a particularly important single gene underlying the genetic architecture of color pattern (specifically melanin) in many vertebrates. We examined the *Mc1R* sequence across the geographic range of *S. semiannulata*, among all other species of *Sonora*, and two sister genera (*Chilomeniscus* and *Chionactis*) that are also polymorphic. We found that the entire Mc1R coding region is variable among *Chilomeniscus*, *Chionactis*, and *Sonora* (approximately 4% sequence divergence). Relative to an outgroup (*Thamnophis sirtalis*), there is a large (12 bp) indel common to all included taxa, with a separate 6bp indel present in only one Sonora species. Future association tests between amino acid substitutions and color pattern will test whether the considerable sequence variation in *Mc1R* within *Sonora* is important for CPP in these snakes. These results will help further understanding of how selective and neutral forces maintain polymorphism in natural populations.

105.1 CRAFT, Jonathan D*; DELORENZO, ME; SOTKA, EE; College of Charleston; *craftjd@gmail.com*

Cold-exposure compromises feeding resistance toward seaweed secondary metabolites in the sea urchin Arbacia punctulata.

Ambient temperature and plant secondary metabolites are common stressors for herbivores, but there are more examples of their independent, rather than combined, effects. We assessed whether evolutionary history, temperature, and seaweed secondary metabolites could explain feeding behaviors in subtropical (27°N) and temperate (41°N) lineages of the sea urchin *Arbacia punctulata*. We simultaneously acclimatized individuals of both lineages to three temperatures (15ºC, 22ºC and 27°C) and measured feeding in response to *Dictyota pulchella* metabolites. Temperate individuals ate lower proportions of *D. pulchella*-coated food than did subtropical individuals, and the proportion was consistently low across all temperatures. Subtropical individuals consumed less *D. pulchella*-coated foods when held at 15ºC relative to 22ºC or 27ºC. When isolated with either control or *D. pulchella*-coated foods, the consumption rates of temperate urchins were additively decreased by *D. pulchella* secondary metabolites and decreasing temperature. Whereas these factors caused a synergistic decrease in the feeding rate of the subtropical urchins. The feeding rates and preferences of subtropical individuals were reduced at 15ºC relative to warmer temperatures. Subtropical *A. punctulata* rarely experience temperatures below 19ºC, thus, this population may have been cold-stressed. Cold-stress was independently suggested by higher glutathione S-transferase levels in Subtropical urchins at 15°C than at 27°C. Thus, subtropical *A. punctulata* are more resistant to metabolites of the tropical *D. pulchella* than temperate individuals, and cold-stress can compromise this feeding resistance.

97.4 CRANDELL, KE*; TOBALSKE, BW; University of Montana, Missoula; *kristen.crandell@umontana.edu*

A Novel Unsteady Aerodynamic Mechanism in Avian Flight

The overarching significance of Reynolds number (Re), along with differences in body size, musculoskeletal morphologies, and wing kinematics, all lend support to the hypothesis that unsteady aerodynamics are only prevalent in insect flight. Consistent with this, it is generally assumed that quasi-steady aerodynamics are adequate for understanding flight in birds and bats. Unsteady mechanisms in insects, at Re<7,000, include leading edge vortices (LEV's), rotational circulation, wake recapture, and "clap and fling." Recently, LEV's and rotational circulation have been observed on hummingbirds and small bats, but these animals are at the same Re as large insects. We undertook this study to test for unsteady effects in larger birds. Here, we present results from particle image velocimetry (PIV) and kinematic analyses of diamond doves (*Geopelia cuneata*, n = 5) during take-off. The birds used an unsteady mechanism previously unrecognized in vertebrates: the clap and peel. We estimate net thrust production from the 'clap' phase, wing-wing contact, to be 8% of body weight. Circulation grows continuously as the wings come apart during the "peel" phase, kinematically distinct from a "fling." This initiates lift production earlier during wing translation and, thereby, directly overcomes the Wagner effect. This may contribute up to 24% body weight support during slow flight. This extends our understanding of the relevance of unsteady aerodynamics to vertebrate flight. NSF IOS-0923606 and IOS-0919799.

109.4 CRESPI, Erica J.*; FITES, J. Scott; ROLLINS-SMITH, Louise A.; Washington State University, Vanderbilt University Medical Center; *erica.crespi@wsu.edu*

Leptin enhances proliferation of amphibian lymphocytes

Leptin is a cytokine hormone that is best known for regulating food intake and energy expenditure, but recent studies in mammals have shown that it also affects immune responses in mammals. In amphibians, leptin has been shown to have similar effects on food intake, but relatively little is known about leptin's interactions with the immune system. We tested the hypothesis that leptin is a modulator of splenocyte activity in adult *Xenopus laevis*, as the spleen is the main site of lymphocyte production in amphibians and the leptin receptor is expressed in *X. laevis* whole-spleen extracts. First, we examined the effects of leptin on proliferation of adult *X. laevis* lymphocytes with or without additional mitogenic stimuli in ^{3}H-thymidine incorporation assays. As has previously been shown for mammalian species, leptin had a dose-dependent enhancement of lymphocyte proliferation driven by the T cell mitogens phytohemagglutinin (PHA) and phorbol myristate acetate (PMA), but unlike mammals, it caused a modest increase in proliferation when cells were treated with leptin alone. Leptin also enhanced T cell proliferation stimulated by allogeneic cells in a mixed lymphocyte response assay. In a separate experiment with *X. laevis* juveniles, leptin treatment increased the inflammatory response around the site of a saline injection, and leptin further enhanced inflammation after PHA injection. These data provide both in vitro and in vivo evidence that leptin is a pro-inflammatory cytokine that directly stimulates lymphocyte proliferation or survival in amphibians. These findings suggest that leptin's immunomodulatory function is evolutionarily conserved across vertebrates, and leptin may be a nutritional cue that enhances the function of the immune system and contributes to the well-being of amphibians.

6.6 CRESPO, J. G.*; VCIKERS, N. J.; GOLLER, F.; University of Utah, Salt Lake City, Utah; *jose.crespo@utah.edu*

Female pheromones modulate muscle activation patterns for pre-flight warm-up in male moths

In *Helicoverpa zea*, the pheromone-mediated upwind flight of males is elicited by a two-component pheromone blend. Efficient upwind locomotion may require that moths warm up their endothermic flight muscles by shivering before engaging in flight. Previously, we showed that male *H. zea* sensing the attractive pheromone blend warmed up at a faster rate than males that were not exposed to this stimulus. We now investigated how heating rate is modulated. Possible mechanisms for increasing heat production include recruitment of additional motor units, increasing the rate of muscle contraction and reducing the mechanical movement by more simultaneous contraction of the antagonistic flight muscles. To test which mechanisms are used, we compared electromyographic recordings of the main flight muscles (i.e. the wing depressors or dorsal longitudinal muscles and the wing elevators or dorsal ventral muscles) of males exposed to the attractive pheromone blend with those of males not exposed to the odor. In addition, we simultaneously recorded the thoracic temperature and wing movements of these moths. Results indicate that the main mechanism for increasing heat production is the recruitment of additional motor units in both antagonistic flight muscles. Interestingly, the activation rate of monitored motor units did not change substantially, perhaps indicating that activation rate is not modulated and may be adjusted to the muscle contraction rate that is possible at any given thoracic temperature. Thus, sensing the pheromone induces males to recruit more motor units for achieving a higher heating rate. Supported by NSF grant IOB-0416861 to NJV and NSF DDIG grant IOS-1110836 to JGC.

114.2 CRINO, O.L.*; KLAASSEN VAN OORSCHOT, B.; TOBALSKE, B.W.; BREUNER, C.W.; University of Montana; *ondicrino@gmail.com*

Developmental stress: morphological, physiological, and behavioral consequences in the zebra finch

Animals exposed to stress during development experience sustained morphological, physiological, and behavioral consequences. Among other effects, developmental stress sensitizes neural circuits that direct how an animal will respond to stressors as an adult. By increasing the sensitivity of animals to stressors, developmental stress can track through an animal's lifetime affecting it at multiple life-history stages. Although the effects of developmental stress are well studied, few experiments evaluate performance measures across multiple systems or multiple life-history stages. Using the zebra finch (*Taeniopygia guttata*) as a model system, we evaluated the effects of developmental stress using morphological, physiological, and behavioral metrics. We fed nestlings corticosterone (CORT; the dominant avian glucocorticoid) dissolved in peanut oil for 16 days during the nestling period (12- 28 days post-hatch). CORT treatment during development significantly reduced juvenile body size, but enhanced learning. We are currently examining how developmental stress affects flight performance, endogenous CORT secretion, and corticosteroid binding globulin capacity. Taken together, these data will provide an integrated examination of how developmental stress tracks across multiple life-history stages and provide insight into the fitness consequences of developmental stress. NSF IOS-0923606.

S6-1.4 CRISTOBAL, S; AMELINA, H; APRAIZ, I*; BAYAT, N; DANIELSSON, G; LinkÃ¶ping University, Sweden, Stockholm University, Sweden; *susana.cristobal@liu.se*

Environmental proteomics in pollution assessment

The environmental sciences are investing great effort into the study of and/or prediction of the effects from the anthropogenic impact on the environment and pollution assessment. On one hand, studies have often been performed on individual organisms, using high concentrations of toxicants and short-term lethal effects as endpoints. On the other hand, traditional attempts to predict effects on organisms and to assess the quality of specific ecosystems based on chemical analysis have proven inefficient. Difficulties arise not only from the wide variety of chemicals but also because the effects can be caused by additively or synergism. It has been difficult to distinguish pollution-related changes from "natural" variations using single biomarkers. Therefore, the analysis of an organism's proteome allows the detection of changes in the level of individual proteins in response to environmental stressors and could provide a more robust approach for environmental assessment and ecotoxicology. Proteins are key elements of the cellular machinery and changes in the environment will result in changes in the expression of proteins. Environmental proteomics can therefore provide a more robust approach for the assessment of (the cause and effects of) environmental stress. However, environmental proteomics is still in its infancy compared to the state of art reached for medical sciences. Quantitative proteomics could lead to the discovery of biomarkers of exposure and to provide new insights into the mechanisms of toxicity. Examples of protein expression profiles for marine pollution assessment or to detect effects of exposure to pollutants will be presented.

7.2 CROTHERS, L.R.*; GERING, E.J.; CUMMINGS, M.E.; University of Texas at Austin; *crothers@mail.utexas.edu*

Is brighter better? Aposematic signal variation predicts male-male interactions in a polymorphic poison dart frog

Many species use conspicuous "aposematic" signals to communicate unpalatability/unprofitability to potential predators. Although aposematic traits are generally considered to be classic examples of evolution by natural selection, they can also function in the context of sexual selection, and therefore comprise exceptional systems for understanding how conspicuous signals evolve under multifarious selection. We used males from a highly territorial poison frog species (*Dendrobates pumilio*) in a dichotomous choice behavioral test to conduct the first examination of how aposematic signal variation influences male–male interactions. Our results reveal two behavioral patterns: (1) male dorsal brightness influences the behaviors of male conspecifics such that males approach and call to brighter males more frequently and (2) a male's dorsal brightness predicts his own behavior such that bright males approach stimulus frogs faster, direct more calls to bright stimulus frogs, and exhibit lower advertising call pulse rates (a fitness-related trait). Our behavioral results thus suggest that there is a third component to the evolution of aposematic signals in this species—the response of males to signal variation—and reveal the potential for sexual selection by male–male competition to impact the trajectory of aposematic signal evolution.

64.4 CROWLEY, Louise M.; American Museum of Natural History, New York; *crowley@amnh.org*

Systematics and Phylogenetics of the Arks (Arcoida: Bivalvia): A combined analysis of morphology and molecular data.

The Arcoida is a large group of mostly marine bivalves, with a global distribution and includes arks, bittersweets and dog cockles. In this study, the phylogenetic relationship of the Arcoida is inferred from a systematic analysis based on both morphological and molecular data. This is the first analysis in which representatives of all seven nominal families are included. 141 morphological characters from the external shell and internal anatomy were coded for 131 taxa. The phylogenetic signal of both these character types was explored. Few non-homoplastic synapomorphies for the group were recovered; shell tubules are confirmed as the sole non-homoplastic synapomorphy for the order. Shell characters failed to recover the majority of the higher taxonomic ranks that they were initially used to describe. Little coherent signal was received from the analysis of anatomy alone. Four genes: 18S rRNA, 28S rRNA, H3 and COI were also investigated using direct optimization as implemented in POY (Varón et al., 2008). These data were analyzed individually as well as simultaneously with the morphological data. A Sensitivity Analysis (Wheeler, 1995) of the molecular data was also performed—this explores the effects of parameter costs (i.e. indels and transition/transversion ratios) on the phylogenetic results. The results of these phylogenetic analyses do not reflect the current classification of the group. In this study, the majority of the higher taxonomic groups of Newell (1969) were not recovered, including the two superfamilies Arcoidea and Limopsoidea, as well as five of the families; only the monophyly of the Glycymerididae and Noetiidae is supported. A major taxonomic review of the order is necessary. This analysis is the largest and most comprehensive phylogenetic analysis of the Arcoida to date.

S8-2.3 CRUICKSHANK, Tami; National Evolutionary Synthesis Center; *tami.cruickshank@gmail.com*

Evolutionary consequences of context-dependent maternal effects

Context-dependent maternal effects are common; environmental variation among dams may be reflected in distributions of offspring phenotypes. I examine the evolutionary genetic consequences of plasticity due to maternal effects, focusing on properties that are unique compared with within-generational plasticity. First, the evolution of adaptive maternal effects requires a correlation between maternal and offspring environment. When environmental conditions are highly correlated across generations, the contribution of adaptive maternal effects to offspring phenotype (and to the distribution of brood phenotypes) is facilitated. Secondly, maternal effects enable dams to alter the distribution of offspring phenotypes; this results in more structured populations and allows dams to maximize fitness by altering this distribution. I consider both the correlation between maternal and offspring environments and tensions between individual adaptation to changing environments within a generation and maternal manipulation of offspring phenotypes. Finally, these environmental maternal effects will be compared to the constitutive expression of genetic maternal effects, highlighting the substantial influence of both the genotype and the condition of dams (rearing environment, available resources) on brood phenotypes.

8.5 CUNNINGHAM, C.B.*; CHASE, K; RUFF, J.S.; EDMUNDS, T.N.; POTTS, W.K.; CARRIER, D.R.; University of Utah; *c.cunningham@utah.edu*

Heritability, Size, and Aggression Interact to Influence Social Dominance Ability in Male House Mice

The evolutionary importance of physical conflict to anatomical, behavioral, and life history traits has been recognized since Darwin. Despite the importance of competitive ability to the evolution of many animals, little is known about the traits that interact to determine it. Male house mice (*Mus musculus*) use agonistic physical competition to establish social dominance relationships. Importantly, this behavior almost completely determines the reproductive fitness of an individual male. In this study, we used recently, wild-derived male house mice to evaluate their ability to gain and hold a preferred territory over multiple days. We estimated the consequences of several factors predicted to influence dominance ability; heritability, size, and aggression. We found that social dominance ability exhibited high narrow-sense heritability, $h^2 \approx 0.62$. Body mass had a moderate positive influence on social dominance ability; however, small males were still able to succeed. Aggression measured as latency to attack and frequency of attacks during resident-intruder assays was not correlated with dominance ability. These results highlight the lack of understanding of this fundamental behavior and suggest a more complex foundation to dominance ability than is generally assumed to be true.

41.1 CURRIE, Suzanne*; FULLER, Adam; EARLEY, Ryan L; COOPER, Chris; REAGAN, Kelly; TAYLOR, D Scott; WRIGHT, Pat A; Mount Allison University, Sackville, NB, University of Alabama, Tuscaloosa, University of Guelph, Guelph, ON, Brevard County Environmentally Endangered Lands Program, Melbourne, FL; *scurrie@mta.ca*

Wild but not angry – mangrove rivulus Kryptolebias marmoratus captured from crab burrows in the field show little sign of aggression

The hermaphroditic mangrove rivulus *Kryptolebias marmoratus* reared in the lab in isolation have been used as a model species to understand combat behaviour and contest outcome in teleost fish. Anecdotal information in the literature suggests that *K. marmoratus* leave water (emerse) in response to aggressive social encounters. With this in mind, we tested the hypothesis that wild fish would form social hierarchies and "losers" would escape by emersing more often than "winners". Our results demonstrated that wild fish engaged in few aggressive encounters, whether in natural crab burrows or placed in dyads or triads in aquaria. This passive behaviour was not correlated with testosterone levels, as there were no significant differences between testes testosterone concentrations in wild fish in behavioural trials relative to lab-reared or wild control fish. Social interaction did not increase the number of emersion attempts. In fact, post-interaction emersion rates were ~60% lower relative to pre-interaction rates. In follow-up experiments on lab-reared fish we tested the hypothesis that social isolation under laboratory conditions alters behaviour. Group-reared fish habituated to an intruder stimulus, whereas fish reared in isolation remained aggressive. Taken together, these findings reveal that wild fish are not strongly aggressive which may relate, in part, to early social interactions with conspecifics in crab burrows.

69.3 CURTIS, N.E.*; FANG, X.; JIANG, X.; SCHWARTZ, J.A.; PIERCE, S.K.; Univ. of South Florida, Tampa, Beijing Genomics Institute-Shenzhen, China; *jschwart@usf.edu*

Algal, nuclear-encoded gene sequences are present in the transcriptome of the kleptoplastic sea slug, Elysia chlorotica- Further evidence for horizontal gene transfer

Digestive cells of the opisthobranch sea slug, *Elysia chlorotica*, sequester chloroplasts from the heterokont alga, *Vaucheria litorea*. The chloroplasts continue to photosynthesize for as long as 10 months in the absence of any additional algal food. Previously, 11 nuclear-encoded algal genes have been found using PCR in genomic DNA of adult slugs and veliger larvae; the latter do not contain symbiotic plastids. Here we report that a partial analysis of the *E. chlorotica* transcriptome (Illumina HiSeq 2000) has revealed 101 *V. litorea* chloroplast genome protein coding genes, and of greater importance, 111 transcripts matching 52 *V. litorea* nuclear-encoded genes. Many of these transcripts encode gene products used in photosynthesis and plastid maintenance. The rarity of these algal matching transcripts suggests that, unlike in the alga, the expression rate of the transferred genes in the slug is low. These results provide further evidence that many algal nuclear genes have been somehow transferred to the *E. chlorotica* genome. We are presently attempting to sequence the entire *E. chlorotica* genome to identify the full complement of genes necessary to maintain this long-lived endosymbiosis.
(Supported by BGI and an anonymous donor)

89.6 CURTIS, Abigail A.*; FARKE, Andrew A.; Univ. of California, Los Angeles, Raymond M. Alf Museum of Paleontology; *abigailacurtis@gmail.com*

Strut Your Stuff: Frontal Sinus Complexity in Bovidae and Carnivora

Paranasal sinuses, cavities found in the skulls of many mammal species, form when nasal epithelium pneumatizes surrounding bones. Of the paranasal sinuses, the frontal sinuses are the most variable, and were acquired and lost multiple times within Mammalia. Here we investigate frontal sinus complexity in bovids and carnivores, two clades that independently evolved frontal sinuses exhibiting great morphological disparity. The frontal sinuses range from puny to expansive, and from relatively simple, un-strutted sinuses, to highly complex sinuses with extensive struts. We addressedtwo questions in this study: 1) does sinus complexity increase with sinus size?; and 2) does the presence of supra-cranial structures affect sinus complexity? We sampled multiple individuals of 45 species of bovids and 24 species of carnivores and representing the morphological and taxonomic diversity within each clade. Sinus surface area and volume, proxies for sinus size and complexity, were reconstructed from CT (computed tomography) scans of each specimen. Sinus surface area and volume are strongly correlated and scale with positive allometry in both bovids and carnivores, suggesting that sinus complexity increases at a greater rate than sinus volume. Bovids have a higher scaling coefficient than carnivores, suggesting that supracranial structures may increase sinus complexity.

17.3 CUSHMAN, K.C.*; MERZ, R.A.; Swarthmore College; *cushman.kc@gmail.com*

Maximizing feeding in minimal flow: behavioral and morphological plasticity of Balanus glandula

Phenotypic plasticity is one mechanism by which intertidal organisms can thrive in a variety of local flow environments. The barnacle *Balanus glandula* exhibits plasticity in both its feeding behavior and the morphology of its feeding cirri. In general, barnacles feed actively at lower flow speeds, but transition to feeding passively at higher speeds, thus taking advantage of ambient currents instead of using metabolic energy to create flow. Additionally, individuals in habitually low flow environments have longer and thinner cirri than barnacles in high flow regimes. This allows high flow barnacles to feed in velocities that would deform slender low flow cirri. We hypothesized that long thin cirri are advantageous for feeding in slow velocities and that passive feeding can occur at lower speeds. We compared barnacles from two areas of Argyle Lagoon, WA- the tidal channel (flows ranging from 0-70 cm/s) and the adjacent bay (flows ranging from 0-6 cm/s). These areas share the same water supply, so both groups of barnacles experience the same temperature, food supply and larvae. In a flow tank, barnacles were placed in water velocities varying from 0-12 cm/s. Low flow barnacles employed passive feeding over about two-thirds of this range, with a decreasing ability to feed in high flows already apparent at the fastest speeds. In contrast, high flow barnacles fed passively over only the upper half of these velocities, with increasing passive feeding at higher speeds. If passive feeding requires less energy than active feeding, then barnacles benefit from the ability to feed passively in the flows they regularly encounter. Having long thin cirri reduces the total range of velocities at which a barnacle can feed, however this cirral form allows barnacles to feed using less energy in slower flows.

18.4 DALTON, E.*; SOCHA, J.J.; Virginia Tech; *elan@vt.edu*
The role of the abdominal pump in rhythmic tracheal compression in the ground beetle, Pterostichus tristis
Abdominal pumping is a widespread behavior in insects, with multiple physiological roles that include respiration and circulation. Although in some insects respiratory patterns have been correlated with abdominal movements, the specific mechanical effects of these movements on the animal's respiratory system are generally unknown. Conversely, some insects (such as beetles, ants, and crickets) create convection in the respiratory system by compressing the tracheal tubes, yet the underlying physiological mechanisms of tracheal collapse are also unknown. This study aimed to investigate the relationship between the abdominal pump and the compression of tracheal tubes in the carabid beetle, *Pterostichus tristus*. We evaluated the effects of the abdominal pump on CO_2 expiration using a high resolution flow-through respirometry system (10 Hz, 1 L/min flow rate) and monitoring the pumping activity of the abdomen by displacement of the dorsal cuticle (IR sensor). The analysis of the relationship between abdominal pumping and external respiratory patterns will provide insight into the functional role of the abdomen in regulating insect gas exchange. To fully test the role of the abdominal pump as a mechanism of internal tracheal compression, future experiments will use x-ray visualization to investigate the timing of tracheal collapse with abdominal movements.

S7-2.3 DANIEL, TL*; WILLIAMS, CD; Univ. Washington; *danielt@uw.edu*
Modeling many molecular motors mostly motivated by moth movement
All animal movement is mediated by the action of muscles comprised of millions of motor molecules suspended in an elastic network of filaments. Over the past decade, substantial modeling efforts, combined with experiments, have shown how single motor molecules collectively contribute to whole cell behavior: myofilament lattice spacing, motor molecule geometry, and molecular kinetics all conspire to determine the temporal dynamics of force generation. At the same time, there has also been considerable attention aimed at integrating cell- and tissue-level aspects of contraction (e.g. length-tension or force-velocity behaviors) to models of limb or whole animal movement. Connections between these two scales of analysis are rare. We have developed spatially explicit models of myosin force generation. These models seek to reveal how molecular scale processes determine tissue and appendage level performance. We use a combination of work loop studies and x-ray diffractometry of the flight muscles of *Manduca sexta* to test these models and explore the consequences of ultrastructure and molecular mechanics to muscle force generation.

115.1 DANIELSON-FRANCOIS, A.*; DROBOT, Y.; University of Michigan - Dearborn; *danfranc@umd.umich.edu*
Nuptial thief: male spiders steal food from mating partners
Adult male spiders do not build webs. Once males molt to maturity, they wander in search of females to mate. For orb-weaving spiders, not building a web means that no prey can be captured and hence males cannot feed themselves. In some sexually dimorphic orb-weaving species with extremely tiny males, such as *Nephila*, the males are kleptoparasitic and subsist on the leftover remains of prey not eaten by females. No spider species has been observed to have males that steal prey items caught by females. Here, we report for the first time that males of at least one orb-weaving species, *Tetragnatha elongata*, are able to feed as adults by actively stealing food from their female partners after mating. We collected adult *T. elongata* in southeastern Michigan and performed 165 staged matings in the laboratory. We found that male food-stealing behavior was significantly influenced by the relative body masses of males and females. When the difference in body mass was minimal, males were able to steal prey. This finding suggests that males may have a trade-off between acquiring food resources and achieving greater reproductive success with larger more fecund females.

72.5 DANTZER, B*; BOONSTRA, R; BOUTIN, S; HUMPHRIES, M.M.; PALME, R; MCADAM, A.G.; Michigan State University, University of Toronto at Scarborough, University of Alberta, McGill University, University of Veterinary Medicine, University of Guelph; *bendantzer@gmail.com*
Adaptive hormone-mediated maternal effects in red squirrels
Red squirrels (*Tamiasciurus hudsonicus*) in the Canadian Yukon live in a variable environment in which fluctuations in population density driven by pulses of their major food source generate density-dependent selection on offspring phenotype. Population density during pregnancy is positively associated with the strength of directional selection on offspring postnatal growth rates. We conducted a multiyear study (2007-2011) to test the hypothesis that the hormonal responses of breeding female squirrels to variation in population density are associated with adaptive modifications in offspring growth rates. We found that pregnant and lactating squirrels experiencing heightened population density had significantly higher fecal cortisol (FCM) and androgen (FAM) metabolite concentrations. Heightened FCM and FAM during pregnancy and lactation were associated with significantly higher offspring growth rates. When population density was experimentally elevated using long-term food supplementation or playbacks of territorial vocalizations, pregnant and/or lactating squirrels also had significantly higher FCM and FAM. Offspring growth rates were significantly higher on the high density food-supplementation study area compare to lower density control study areas. Similarly, females experiencing experimentally heightened perceived density (playbacks) produced offspring that grew significantly faster than those exposed to control playbacks but at a similar rate to those produced by females on the high density food-supplemented study areas. These data suggest that the endocrine responses of female red squirrels to variation in population density influences offspring postnatal growth rates in a direction that is adaptive.

80.2 DARLING, CL*; BURNETT, LE; BURNETT, KG; College of Charleston; *darlingcl@gmail.com*

Recovery from hypoxia and hypercapnic hypoxia: Impacts on the transcription of key antioxidant genes in the shrimp Litopenaeus vannamei.

The Pacific whiteleg shrimp, *Litopenaeus vannamei*, inhabits coastal estuarine waters which are prone to intermittent bouts of low oxygen (hypoxia) and high carbon dioxide (hypercapnia) followed by a return, or recovery, to fully air-saturated levels of oxygen and carbon dioxide (normoxia). Hypoxia (H) and hypercapnic hypoxia (HH) can cause oxidative stress which induces production of reactive oxygen species (ROS) that damage surrounding cells and tissues. In vertebrates, sudden rises in oxygen levels also increase ROS production. Cellular production of antioxidants, which convert ROS into non-toxic molecules, can prevent cell damage. Here we examine antioxidant production in the hepatopancreas of *L.vannamei* after recovery from H or HH. Prior studies revealed that transcription of antioxidants thioredoxin-2 (TRX-2) and glutathione-s-transferase (GST) was significantly upregulated (2.7; 2.9-fold, respectively) after 4 h exposure to H. Only GST was significantly upregulated (3.9-fold) after 4 h in HH; neither antioxidant was upregulated after 24 h in H or HH. In the current study we exposed shrimp to H or HH for 4 or 24 h. Shrimp subsequently recovered in normoxia for 1, 6, or 24 h. Transcriptional changes of TRX-2, GST, and other antioxidant-related genes are currently being quantified by qRT-PCR. Based on prior studies detailed above, we expect that transcription of antioxidant-related genes will further increase in response to increases in oxygen during recovery from 4 h H or HH, but that this increase will not occur during recovery from 24 h H or HH, leaving these animals susceptible to oxidative damage as tissue oxygenation returns to normal levels.

3.6 DARNELL, M.Z.*; FOWLER, K.; MUNGUIA, P.; University of Texas at Austin; *mzd@mail.utexas.edu*

Carapace coloration affects body temperature and limits activity in the fiddler crab Uca panacea

Ectotherms can regulate body temperature behaviorally or, in some cases, by changing coloration. Body coloration, however, is also used in communication and camouflage. Organisms using color change for thermoregulation, including fiddler crabs, typically become darker in response to low temperatures or lighter in response to high temperatures which increases the absorption or reflection, respectively, of solar radiation. Often these processes, thermoregulation and communication for example, may be in conflict; therefore the ability to change color becomes habitat- and context-dependent. In the intertidal, organisms such as fiddler crabs are exposed to a wide range of diel and seasonal temperatures. We investigated the effect of coloration on body temperature and activity in the fiddler crab *Uca panacea* using artificially-applied color. When exposed to a source of radiant heat in the laboratory or exposed to solar radiation, black-painted crabs became significantly warmer than white-painted crabs. Unpainted and clear-painted crabs reached intermediate temperatures. We then placed painted crabs in outdoor mesocosms and monitored activity levels. Activity was greatest in the morning and late evening. Crabs painted white were active more than crabs painted black or control crabs, especially in the unvegetated portion of the mesocosm. Activity during the daytime hours was limited by high temperatures, although this effect was ameliorated in light-colored crabs. These results indicate that carapace coloration and color change are important determinants of body temperature in fiddler crabs and can influence distribution in intertidal habitats. Coupled with previous results on color change and thermoregulation, these results support the hypothesis that carapace coloration plays a role in maintaining optimal body temperatures and may influence crab distribution and activity.

85.5 DAVIES, Sarah W.*; MEYER, Eli; MATZ, Mikhail; Univ. of Texas at Austin; *daviessw@gmail.com*

Lack of Caribbean coral recruitment: A mismatch between larvae and settlement cues?

Larval recruitment is critical for establishment and recovery of coral populations. Caribbean coral recruitment success has been low in recent years, especially in the northernmost reef in the Gulf of Mexico, the Flower Garden Banks (FGB). In contrast, recruitment success remains high among Pacific corals. We investigated whether these regional differences might be explained by the lack of appropriate Caribbean settlement cue, or by impaired cue perception by Caribbean coral larvae. We collected natural settlement cue (crustose coralline algae, CCA) from Caribbean (Florida, FGB, Bonaire) and Pacific (Great Barrier Reef (GBR), Pohnpei, Guam) locations, and tested these cues on four species of GBR corals (*Acropora millepora, A. tenuis, Favia lizardensis*, and *Ctenactis echinata*) and three FGB species (*Montastrea franksi, Diploria strigosa*, and *Stephanocoenia intersepta*). Larvae from both regions responded strongly to specific cues, suggesting that low Caribbean recruitment is not due to impaired cue perception. Caribbean CCA induced settlement in both Caribbean and Pacific species, indicating that appropriate cue is present on Caribbean reefs. Settlement cue rankings differed among species, suggesting species-specific preferences. Among Caribbean corals, we found that larvae responded more strongly to Caribbean CCA than Pacific, suggesting co-adaptation of corals and CCA. Through high-throughput 454 sequencing of small subunit (SSU) ribosomal amplicons, each CCA sample was characterized revealing high diversity among samples and a positive correlation between relative proportion of CCA sequences (of any species) and settlement response. Overall, our results indicate that lack of coral recruitment in the Caribbean does not result from absence of settlement cue or impaired responsiveness to that cue, and must therefore result from some other factor.

96.1 DAVIS, J.E.*; GUINAN, J.A.; Radford University; *jdavis319@radford.edu*

Parental behavior and corticosterone during the breeding season in eastern bluebirds (Sialia sialis)

Breeding animals face a trade-off between investment in self and investment in offspring; too much investment in self can reduce offspring survival and fitness, while too much investment in offspring can increase individual mortality or decrease long-term reproductive success. Reproductive and stress-related hormones play an important role as mediators of this balancing act. Previous studies have correlated reductions in reproductive and parental investment with increased stress and elevated plasma corticosterone. In addition, the physiological and behavioral responses of an individual both influence and are influenced by the physiology and behavior of close social interactants, such as mates and offspring. Here we present both behavioral and hormonal data gathered from adult and nestling eastern bluebirds in southwestern Virginia across three consecutive breeding seasons with high nest failure rates. Our data demonstrate a negative relationship between female plasma corticosterone and female parental behavior, as well as a positive connection between female corticosterone and parental investment by males. These findings suggest that males may attempt to compensate for decreased maternal investment related to increased maternal stress. In contrast, little relation was found between parental corticosterone and offspring corticosterone or health. However, our data do suggest a positive relationship between parental feeding rates and overall nestling corticosterone. This may indicate that parents attempt to behaviorally buffer against increased nestling stress.

13.1 DAVIS, Marcus C. ; Kennesaw State University;
mdavi144@kennesaw.edu

A comparative assessment of musculoskeletal development in basal actinopterygians

The pattern of musculoskeletal development has been extensively studied in tetrapods and in the derived actinopterygians (teleosts). What is lacking are adequate descriptions of muscle and skeletal growth in more basal osteichthyan taxa, such as the non-teleost actinopterygians. Here we assess the patterns of associated muscle and skeletal element formation during embryonic and larval development in the basal actinopterygians *Polyodon spathula*, *Lepisosteus osseus*, and *Amia calva* using immunostained whole-mount and sectioned material. When placed in the phylogenetic context of more derived taxa, these data provide insights into the conserved musculoskeletal developmental pattern considered primitive for Osteichthyes. As such, these results will also provide crucial tests of previous hypotheses of muscle homology and evolution in teleosts and tetrapods. A similar pattern of early recruitment of muscle groups necessary for ventilation, feeding, and vision is observed in all three taxa. This observation supports the notion that common environmental and physiological constraints also play a role in determining the order (and timing) of appearance of certain functional musculoskeletal systems. Despite such conservation and constraint, the distinct morphologies that characterize each taxon (i.e. musculoskeletal proportions and the specific connections between elements) emerge early in the developmental program.

6.1 DE BOEF MIARA, M.*; BIEWENER, A.A.; Concord Field Station, Harvard Univ., Cambridge, MA;
mdeboef@oeb.harvard.edu

Measuring muscle pennation in vivo using sonomicrometry and 3-D X-ray cinematography methods.

In vivo muscle performance is dependent on many anatomical and physiological factors including muscle fiber type, force-length properties and architectural organization. Many of these factors are fixed or change very slowly and thus *in situ* or post-mortem measures can be used for *in vivo* analyses. In contrast, a few factors may change so quickly that direct *in vivo* measures are desirable. In this study one such component of muscle architecture, pennation angle, was observed *in vivo* in the medial and lateral gastrocnemius of Helmeted Guineafowl (*Numida meleagris*). This was done in two ways. First, a triad of sonomicrometry crystals simultaneously measured muscle depth and muscle fascicle length. Assuming these measures formed two sides of a right triangle, trigonometry was used to calculate pennation angle. Later, these same crystals were observed using 3-D x-ray cinematography allowing for a direct measure of pennation. In both muscles a characteristic pattern of change in muscle pennation was observed during each stride with pennation angle decreasing during stance and increasing during swing. These patterns were exaggerated as locomotor speed and muscle force increased. A comparison of the two methods revealed that while 3-D cinematography is more accurate, with good crystal placement, sonomicrometry alone can give consistent results.

62.4 DE BRUIJN, R*; MERULLO, D; ROMERO, LM; Tufts University, Medford, MA; *robert.debruijn@tufts.edu*

Heart rate response of molting and non-molting European starlings to artificial rain and cooling

Free-ranging animals continuously need to adjust to changes in their environment. One of the most unpredictable environmental phenomena that an animal has to cope with is inclement weather, which may consist of changes in temperature and precipitation. Being able to appropriately respond to changes in weather is crucial as weather often reduces an animal's opportunity to forage and can be a serious threat to survival. We have previously shown that animals exposed to a rapid 30 min decrease in temperature show an acute stress response. This study investigated the heart rate response of European Starlings (*Sturnus vulgaris*) to a short, 30-minute, burst of artificial rain. The birds were exposed to three additional 30-minute trials: a 4 °C decrease in temperature; a combined exposure to rain and room temperature wind; and a combination of rain with a 4 °C decrease in temperature. Eighteen birds were used, eight of which were molting. Both molting and non-molting birds responded to all trials with an increase in heart rate and the heart rate responses of the animals were similar across trials. We conclude that both a minor change in temperature and exposure to rain elicit an acute stress response in these animals, but that combining such stressors does not elicit a stronger response. These results suggest that the response to acute stressors such as those used in this study may be an important mechanism by which animals cope with minor rapid environmental changes.

32.2 DEAN, Mason*; HUBER, Dan; GOO, Brian; DANOS, Nicole; SHIMADA, Kenshu; SUMMERS, Adam; MPI, UT, UCI, UCI, DePaul, FHL/UW; *mason.dean@mpikg.mpg.de*

On the jaws of lamniform sharks

The 15 species of lamniform sharks vary widely in feeding niche, including piscivores, megacarnivores and filter feeders. The functional morphology of their feeding apparatus is difficult to study in vivo due to their large size, rarity and/or pelagic habit. To determine whether, and how, skeletal structure and performance vary with ecology, we examined the cranial skeleton of all lamniforms and two non-lamniform species using computed tomography (CT). First, we quantified shape-based descriptors of jaw structure along jaw length, such as polar moment of area, slenderness ratio, mineralized cross-sectional area, and anatomical orientation of the cross-section's major axis. These data then allowed us to assess the contribution of shape to skeletal mechanics (e.g. resistance to bending, torsion, and buckling), to locate areas of reinforcement and define their magnitude, and to describe the probable primary orientation of loading. Our results suggest diet-specific structural organization in the jaws, but also broad consistencies across species. The mineralized tissue of the jaws is arranged to resist flexion ~5–20 times better than if it were a solid rod of circular cross-section, lower than maxima reported for durophagous species. Jaws are heavily mineralized (i.e. have comparatively small lumina) at their ends with tissue organized to resist torsion and flexion (i.e. exhibiting high polar moment, compressiform cross-section) in areas beneath teeth and/or at joints and muscle attachments. Highly eccentric upper jaw cross-sections tend to be mirrored in lower jaw shape. These data suggest that skeletal geometry in sharks may be organized in predictable ways, as in bone, to resist dominant loading regimes. We discuss results in the contexts of shark phylogeny and the potential mechanical demands of predation.

94.1 DEARY, Alison/L*; HILTON, Eric/J; College of William and Mary, Virginia Institute of Marine Science, Gloucester Point, VA; *aldeary@vims.edu*
Comparison of lower jaw levers in the oral jaws of early life history stage drums (Family Sciaenidae) of the Chesapeake Bay
In fishes, a correlation exists between the morphology of the feeding apparatus and the foraging ecology. Although numerous biomechanical models of the fish jaws and skulls have been tested, relatively few actinopterygian fishes have been examined to understand the morphological diversity and ontogenetic changes of lever mechanics. The goal of this study is to examine the lever mechanics of the lower jaw in the family Sciaenidae during ontogeny to determine if and when changes are observed and how they relate to foraging ecology. Sciaenids along the East Coast of the United States are able to partition their niches through variation in the oral jaw structure as adults. However, very little is known about the link between morphology and foraging ecology outside of the adults, especially in sciaenids. Jaw elements were measured using a Zeiss SteREO DiscoveryV20 microscope after specimens were cleared and stained and stomachs were removed. The stomach contents were analyzed using a compound light microscope and contents were classified into broad taxonomic groupings by the prey's primary habitat (i.e. benthic crustacean, pelagic crustacean, etc.). Sciaenids have significantly different premaxilla, lower jaw, and ascending process lengths by 20.0 mm standard length (SL), suggesting that early life history stage sciaenids do exhibit differences in the oral jaws that reflect the foraging ecology of the adults. I hypothesize lever mechanics will also exhibit significant differences by 20.0 mm SL, further suggesting that sciaenids may be able to partition their niches before reaching the late juvenile stage.

75.5 DEBAN, Stephen*; ANDERSON, Christopher; LARGHI, Nicholas; SANDUSKY, Paula; Univ. South Florida, Tampa; *sdeban@usf.edu*
Evolution of elastic mechanisms in salamander tongues
Plethodontid salamanders are characterized by specialized tongue projection, with ballistic projection evolving three times independently. All ballistic taxa project their tongues with high muscle-mass specific power output (i.e., peak instantaneous mechanical power >1000 W/kg muscle mass) via an elastic-recoil mechanism that amplifies muscle power and confers relative thermal insensitivity to tongue projection. Using high-speed imaging and temperature manipulations, we probed the mechanism of tongue projection in several taxa with and without ballistic projection. We found that taxa with high power output (>1000 W/kg muscle mass) also posses low thermal sensitivity and vice versa, but that not all taxa with these features project their tongues ballistically. High power output and low thermal sensitivity may have evolved concomitantly twice in the Plethodontidae, in *Hydromantes* and in the clade containing *Pseudotriton*, *Eurycea* and *Batrachoseps*. Thermal sensitivity and low power output (<100 W/kg) were found in non-ballistic *Plethodon* and *Desmognathus* and are presumably ancestral for the family. These results suggest that both thermal insensitivity and high power output in excess of peak muscle power favor the evolution of elastic-recoil mechanisms, and may be a precursor to ballistic movement.

15.9 DEFUR, Peter L; Virginia Commonwealth University; *pldefur@vcu.edu*
Physiological responses of blue crabs, Callinectes sapidus, swimming upriver into freshwater.
More than 30 years ago, David Towle began a life-long series of investigations into how the crab gill functions, notably in freshwater, based on blue crabs swimming up the James River in late summer. Dr. Towle was following up on work begun by other investigators and his research led the way for numerous other investigators who pursued similar lines of research. Physiological responses of blue crabs swimming up river into fresh water include much more than ion regulation. Blue crabs also modulate the composition of the respiratory pigment and up-regulate ion transport functions. In freshwater, blue crab also encounter hypoxia and continue molting processes. Blue crabs encountering hypoxia in freshwater are able to maintain blood pH and ion transport function, stabilize oxygen uptake via a more efficient oxygen transport properties of hemocyanin.

72.1 DELIA, J. R. J.*; WARKENTIN, K. M.; Boston University, Boston; *jdelia@bu.edu*
Hatching plasticity and the function of parental care in two glassfrogs (Anura: Centrolenidae)
The history and diversity of parental care among frogs has provided key insights into the adaptive evolution of life histories. Although there are examples of more complex parental care strategies, in many species care appears to primarily protect eggs from predators and dehydration. In glassfrogs, parents hydrate and guard arboreal eggs, but the quality of care varies. *Hyalinobatrachium fleischmanni* embryos respond to dehydration risk caused by poor paternal care by accelerating their timing of hatching. We conducted male-removal experiments with this species at different embryonic stages and monitored egg fates to assess the function of care, how environmental conditions affect the adaptive value of care, and embryo responses to risk in two sites (Mexico and Panama). We conducted parallel experiments with a more intensely guarding congener, *H. colymbiphyllum*, that co-occurs at our site in Panama. In *H. fleischmanni*, weather conditions affected the initial period of care required to avoid lethal egg dehydration, and care intensity varied concurrently. Predation, mainly by spiders that build webs over clutches, was much higher in Panama, and hatching timing was earlier than in Mexico. Dehydration and predation were the primary sources of mortality in unattended clutches, and both triggered early hatching. The period of obligate care required for egg hydration was shorter in *H. colymbiphyllum*, and their intense guarding reduced predation by spiders compared to *H. fleischmanni*. These results reveal variation in the relative advantages of different parental care strategies among closely related, ecologically similar species, and how the nature and quality of parental care can affect adaptive embryo behaviors.

S6-2.3 DENSLOW, ND*; MARTYNIUK, C; ALVAREZ, S; VILLENEUVE, DL; ANKLEY, GT; University of Florida, University of New Bruswick, Donald Danforth Plant Science Center, U.S. EPA, ORD, NHEERL, MED, Duluth; *ndenslow@ufl.edu*

Proteomic expression patterns in fathead minnows exposed to trenbolone and flutamide

Insights into androgen signaling in the liver of fathead minnow (Pimephales promelas) was obtained using non-gel based proteomics analysis. We exposed female fathead minnows for 48 hr through the water to a prototypical androgen (17beta-trenbolone, 5 µg/L), a prototypical anti-androgen, flutamide (500 ug/L) and a mixture of the two at these concentrations. The concentrations chosen had been previously shown to reduce plasma hormones and ovulation in females therefore affecting reproductive physiology. Proteomics was performed by LC MS/MS on an Applied Biosystems QSTAR instrument using iTRAQ isobaric tags to quantify changes in protein expression. Over three hundred proteins were identified in the fathead minnow liver encompassing a wide variety of molecular functions from transcription regulation to catalytic activity and up to structural cellular function. While flutamide appeared to influence the changes more dramatically than trenbolone, there were several proteins that were altered reciprocally by trenbolone and flutamide suggesting that they may be good candidates for protein biomarkers that are regulated directly through the androgen receptor. Among the proteins directly regulated were phosphoglycerate mutase 1(PGAM1), ferritin heavy chain (FTH1), leucine amino peptidase (LAP3), betaine homocystein S-methyl transferase (BHMT), ubiquitin C (UBC), SMT3 suppressor of mif two (SMT3H1), SET nuclear oncogene (SET) and glutathione S-transferase theta 1 (GSTT1). These and others had roles in growth, cell differentiation, catabolism and secretion of proteins. Information garnered through proteomics was complementary to experiments performed previously using microarray analysis in the same tissues.

81.6 DEVRIES, M. S.*; CHRISTY, J. H.; Univ. of California, Berkeley, Smithsonian Tropical Research Institute; *msdevries@berkeley.edu*

Why stomatopods are striking

Some species of stomatopod crustaceans produce extremely fast and powerful strikes with highly specialized appendages. These strikes are thought to be used both for crushing hard-shelled prey and for fighting with other stomatopods. Yet, we know little about the relative use of the striking behavior for predation and aggression. To begin to untangle how strikes are used, we first examined strikes in the context of feeing. Using stable isotopes and behavioral experimentation, we determined the diet of the stomatopod, *Neogonodactylus bredini*, a common predator on Caribbean coral reefs. Although we had expected individuals to consume hard-shelled prey items exclusively, we found that 17% of the diet consisted of soft-bodied prey. Observations of feeding events on live prey showed that *N. bredini* used multiple strikes to break apart hard prey but often only one or a few strikes to stun or kill soft-bodied prey. Powerful strikes may be favored if food items are rarely found and stomatopods must be prepared to break hard prey when they are encountered. We observed stomatopods in the field and measured prey abundance. Although, prey items (crabs, hermit crabs, snails, worms) were abundant where stomatopods were active, in 100 hours of observations no direct prey capture events were documented. However, we observed 20 aggressive interactions in which the stomatopods actively struck at each other, suggesting that during their daily activities, strikes are important for dealing with intraspecific aggressive interactions. Overall, the dual-functionality of the stomatopod strike appears to widen diet breadth while also allowing stomatopods to be aggressive towards competitors in a diverse coral reef environment.

44.5 DIAL, TR*; HEERS, AM; TOBALSKE, BW; Brown Univ, Univ of Montana; *terry_dial@brown.edu*

Ontogeny of aerodynamics in Mallard ducks: comparative performance and developmental implications

Wing morphology correlates with flight performance and ecology among adult birds, yet the impact of wing development on aerodynamic capacity is not well understood. To gain insight into the effects of life-history strategy and ontogeny on wing function, we used a propeller and force-plate model to study aerodynamic force production across a developmental series of the precocial-flying chukar partridge (*Alectoris chukar*) and altricial-flying mallard duck (*Anas platyrhynchos*). In both species, coefficients of lift (C_L) and drag (C_D) increase throughout ontogeny. The chukar generated aerodynamic forces early (<8 days), yet improved gradually throughout a 100-day ontogenetic period. The mallard delayed aerodynamic force production until just prior to fledging (day 60), yet showed dramatic improvement within a condensed two-week period. In the adult stage, mallard wings exhibit higher lift-to-drag ratios (C_L:C_D= 5), at lower angles of attack (α=11˚) compared to chukar wings (C_L:C_D= 4;α = 15). Chukar generate less lift per unit drag but produce large resultant aerodynamic forces (vector sum of lift and drag) and rely on these at an early age to rapidly accelerate and escape predation. Mallards, in contrast, generate more lift per unit drag but produce smaller resultant aerodynamic forces – optimizing economy over maximal force production, delaying wing function and seeking refuge in aquatic habitats. Throughout development, feather microstructure (feather unfurling, asymmetry and barbicel overlap) more so than gross wing morphology (aspect ratio, moment of area or camber) correlated to lift generation (C_L and C_L:C_D). The early onset of restricted ontogenetic change in chukar wing morphology and performance compared with the delayed, but radical, change in the mallard wing, implicate life-history strategy as a possible mechanism influencing locomotor diversity in the avian clade.

34.5 DIAMOND, SE*; SORGER, DM; HULCR, J; PELINI, SL; SANDERS, NJ; ELLISON, AM; GOTELLI, NJ; DUNN, RR; North Carolina State Univ., Harvard Forest, Univ. of Tennessee, Univ. of Vermont; *sarah_diamond@ncsu.edu*

Predicting regional and global responses of ants to climate change

Global climate change has already altered the conditions nearly every terrestrial organism on Earth faces. A key question becomes how the responses of organisms to such change are likely to vary across taxa and regions. We first develop models for physiological thermal tolerances in ants based on current and projected future climates. We found that tropical ants have lower warming tolerances, a metric of susceptibility to climate warming, than temperate ants despite greater increases in temperature at higher latitudes. Using climatic, ecological and phylogenetic data, we refine our predictions of which ants (across all regions) were most susceptible to climate warming. We found that ants living in the canopies of hot, tropical forest are the most at risk, globally, from climate warming. Unfortunately this is where many, perhaps most, ant and other species on Earth live. Secondly, we examine the potential for physiological thermal tolerances to predict the responses of many species of ants to experimental climatic warming in two large-scale experimental arrays, positioned at the northern and southern boundaries of temperate hardwood forests in eastern North America. We found that ants with higher thermal tolerances had greater maximal accumulation temperatures (temperature treatment weighted by ant density in the treatment) and thermal accumulation slopes (slope of the linear relationship between ant density and temperature treatment). This pattern held for the southern array, but not the northern array, supporting the findings of the global analysis showing ants inhabiting lower latitude environments to be more at risk from climate warming.

80.3 DIAZ, S.*; THALER, C. D.; SHIRKEY, N. J.; BROWN, T.; CARDULLO, R. A.; HAMMOND, K. A.; University of California, Riverside; *soniadiaz01@gmail.com*

Changes in Pulmonary Surfactant in Deer Mice (Peromyscus maniculatus) at High Altitude

A complex mixture of proteins and lipids, known as the pulmonary surfactant system, reduces the surface tension at the air-liquid interface within the lung. While the lipids are primarily responsible for lowering surface tension, surfactant proteins (SP-B & SP-C) are critical in the adsorption and spreading of lipids at the air-liquid interface and modify the properties of the surface film. Previous studies in our lab have demonstrated differential increases in the surfactant lipids that increase membrane fluidity in deer mice living at high altitude in cold conditions. As a result we predicted that mice acclimated to high altitude will also up-regulate the amounts of surfactant proteins present in their lung in an effort to offset the destruction of the lipids and aid in the recycling of lipids to and from the air-liquid interface. The total surfactant protein content of the lung surfactants is 43% higher in animals acclimated to high altitude than it is in animals acclimated to low altitude and we are currently using Western blotting to determine if this change reflects changes in SP-B, SP-C, or both. These results provide insight into how changes in the composition of the surfactant facilitate the overall plasticity of the surfactant system and aid in the maintenance of higher metabolic rates of deer mice at high altitude.

53.4 DICKENS, M. J.*; CORNIL, C.A.; BALTHAZART, J.; University of Liege; *molly.dickens@ulg.ac.be*

Female perception of male mate as a stressor may depend on sexual experience

In Japanese quail (*Coturnix japonica*), male copulatory behavior includes actions that are potentially injurious to the female. Females may thus perceive a male mate as a stressor and mount a stress response, increasing HPA axis activity and plasma corticosterone (CORT) concentrations. In two separate experiments, we measured CORT in females immediately following 5 min of pairing with a mate. In experiment 1, sexually experienced females were either acutely stressed (ST) or non-stressed (ns) prior to mating and then mated with a male that was either ST or ns. Females (both ST and ns) paired with ns males had significantly higher CORT than their ST/ns counterparts paired with ST males. The number of neck grabs, a male behavior that can be classified as "potentially injurious" to the female, positively correlated with female CORT suggesting that females may perceive such behaviors as stressful. In experiment 2, sexually naive, ns females were paired with males that were non-stressed, stressed or severely stressed (exposed to additional handling). In these females, CORT was significantly higher only when the females were paired with severely stressed males. No relationship was observed here between CORT and neck grabs but CORT was significantly higher, on average, when the mate achieved a full copulatory sequence. In both experiments, female CORT was thus affected by the male stress status but in opposite directions. Comparison of the two data sets suggests that sexual experience may affect which male behaviors are perceived as stressful. While more controlled studies directly comparing and quantifying sexual experience will need to be conducted, these data highlight the complexity of the perception of male behaviors by females and a potential effect of previous experience.

119.1 DICKERSON, A. K.*; SHANKLES, P; MADHAVAN, N; HU, D.L.; Georgia Institute of Technolofy, Georgia Institute of Technology; *adickerson3@gatech.edu*

Insects flying in the rain

Mosquitoes thrive during rainfall and high humidity. If raindrops are 50 times heavier than mosquitoes, how do mosquitoes fly in the rain? In this combined experimental and theoretical study, we measure the impact force between a falling drop and a free-flying mosquito. High-speed videography of mosquitoes and custom-built mimics reveals a mosquito's low inertia renders it impervious to falling drops. Drops do not splash on mosquitoes, but simply push past them after impulsively acceleration the insect 30-300 gravities. Despite this large acceleration, mosquitoes are able to continue on their flight only briefly deterred. We rationalize the force imparted using scaling relations based on the time of rebound between a falling drop and a free body of significantly less mass.

52.1 DICKERSON, BH*; DANIEL, TL; RIFFELL, JA; University of Washington; *bdicker@uw.edu*

Shaken, not static: multimodal processing in the antenna of the hawkmoth Manduca sexta.

Insect antennae are integral to navigation through complex environments, serving a host of sensory modalities including chemical, mechanical, auditory, and thermal stimuli. Indeed, no other single sensory structure is involved in as many modalities as the antenna. In particular, the antennae of the hawkmoth *Mandua sexta* can detect different olfactory cues and their passive oscillation during flight enables the antennae to act as inertial sensors. The oscillations of the antennae, which are responsible for mechanosensory input, are determined by the antennae's flexural stiffness and mass distribution. Antennal oscillations may also modulate the boundary layer dynamics, affecting chemical flux and, in turn, chemosensory input. There exists, therefore, a potential interaction between mechanosensory and chemosensory input for a single sensory structure mediated by biomechanical processes. This interaction may also be mediated by dual input from primary afferents to local interneurons in the brain during sensory processing. Using multichannel electrophysiological measurements, we explored this interaction to test whether oscillation of the antennae affects neural representation of odor in the antennal lobe of *Mandua sexta*. Results show that the combination of antennal oscillation and odor presentation increases peak firing rates during the stimulus cycle by 28.0 ±17.4% in three of seven cells, while the remaining four cells show a decrease of 47.5 ±18.8% in response. Together, these data point to two potential mechanisms for sensory synergies: one mediated by biomechanical processes; the other by neural processing.

S1-1.7 DICKINSON, M.*; ZABALA, F.; POLIDORA, P.; ROBIE, A.; BRANSON, K.; PERONA, P.; Univ. of Washingon, IORodeo, Janelia Farm, HHMI, Caltech; *flyman@uw.edu*

Detecting motion while moving: a simple visual reflex revealed by animal-robot interactions

Ever since the Cambrian, there has been selective pressure on visual systems to develop mechanisms for detecting predators, prey and potential mates. Here, we used a tiny robot to show that walking fruit flies exploit an elegantly simple visual mechanism for detecting the presence of nearby moving objects. When an animal is at rest, an object moving in any direction may be easily detected by motion-sensitive visual circuits. During locomotion, however, this strategy is compromised by the spatially complex optic flow fields on the retina created by an animal's own motion through the environment. In particular, because stationary visual features in the environment move front-to-back (progressively) on the retina as an animal translates forward, moving objects that also create front-to-back optic flow are difficult to distinguish from the background. However, objects that move so as to create back-to-front (regressive) optic flow, may be unambiguously distinguished from the static background. Thus, animals ought to exhibit enhanced sensitivity to such patterns, a hypothesis we term 'regressive motion salience'. We explicitly tested this hypothesis by constructing a fly-sized robot that was programmed to interact with a real fly within a large behavioral arena. Our measurements indicate that whereas walking flies freeze in response to a regressively moving fly-sized object, they ignore a progressively moving one. Because the assumptions underlying the regressive motion salience hypothesis are general, we suspect this mechanism to be quite widespread among eyed, motile organisms. Our experiments provide further evidence for the utility of behavioral robotics as a method for analyzing the sensory basis of social interactions.

13.4 DICKSON, JM*; UDVADIA, AJ; JANSSEN, J; University of Rhode Island, Univsersity of Wisconsin, Milwaukee, University of Wisconsin, Milwaukee; *jdickson6@gmail.com*

Reduced lateral line canal development in the round goby, Neogobius melanostomus

Fish can detect water movement through mechanosensory organs of the lateral line system known as neuromasts. There are four major canal morphologies that can be found on the head of teleosts; narrow, reduced, widened, and branched. Round gobies, *Neogobius melanostomus*, have the reduced canal morphology where canal segments containing neuromasts are replaced by lines of superficial (SF) neuromasts below the eye. The reduced canal morphology is thought to be derived from the narrow canal morphology that results from changes in the onset or rate of development (i.e. neuromasts are present but canal development would be halted before the canal develops). We hypothesize that the initial development of the round goby should be similar to that described for narrow canal species. The initial development was documented using samples prepared for scanning electron microscopy and then confirmed in live fish by labeling neuromasts with the vital fluorescent stain DASPEI. Shortly after hatching the larger presumptive canal neuromasts or paedomorphic homologues are present. By 7 mm SL there are horizontal lines of SF present under the eye. At 9 mm SL the supraorbital canal above the eye has enclosed. Orthogonal lines of SF neuromasts have begun to form by 14 mm SL and by 30 mm SL the pattern of SF neuromasts reflects the adult pattern. In the mandibular region there is no enclosed canal, but there are two lines of SF neuromasts. One of those lines is in a groove, which is the first sign of canal development described in other fishes. More SF neuromasts may be advantageous because they are more sensitive to changes in velocity and they can detect lower frequencies.

S9-1.2 DIGGLE, PK; University of Colorado/Harvard University; *diggle@fas.harvard.edu*

Phenotypic plasticity and the evolutionary diversification of plant sexual systems.

Andromonoecy, a sexual system in which individuals bear both hermaphroditic (bisexual) and male flowers, has evolved independently in numerous plant lineages, yet the advantages of this system remain poorly understood. I will report on a comparative ontogenetic study of multiple andromonoecious species within the genus *Solanum*. Experimental analyses of several species suggest that male flower production varies with resource availability, that is, male flower production is phenotypically plastic. Production of male flowers, however, is a fixed feature of the phenotype in a small number of species within each of two clades. Comparison of ontogenies within a phylogenetic framework suggests that plasticity is plesiomorphic, and that the environmentally induced production of male flowers has become fixed during the evolution of the non-plastic species.

35.5 DILLON, M.E.*; FRAZIER, M.R.; University of Wyoming, Laramie, U.S. EPA, Western Ecology Division, Newport, OR; *Michael.Dillon@uwyo.edu*

Development time, seasonality, and body size clines in insects: a general explanation?

Body size clines and their underlying mechanisms have long fascinated ecologists. Bergmann originally documented consistent increases in body size with latitude among endotherm species. But his rule has since been extended to non-endotherms and both inter- and intraspecific patterns. Insects seem to be equally likely to show either increasing or decreasing size across altitude and latitude, a pattern that contradicts the general one and begs explanation. The body size cline an insect species expresses along latitudinal and altitudinal gradients has been hypothesized to depend on the species' development time relative to the growing season. Species with relatively long generation times and relatively short growing seasons run the greatest risk of running out of time or resources prior to completing development. To avoid this, populations living in colder environments may reduce development times by maturing at smaller body sizes. Based on this hypothesis, we predicted that: 1) insect species with longer development times are more likely to be smaller at high altitudes (i.e., negative body size cline); and 2) insects living in regions with short growing seasons are more likely to be smaller at high altitudes. We compiled studies measuring intraspecific changes in body size along altitudinal gradients and used both conventional and phylogenetically corrected analyses to test these predictions. Overall, preliminary analyses support the hypothesis, suggesting a general explanation for body size clines in insects.

S6-1.7 DILLY, GF*; YOUNG, CR; LANE, WS; PANGALINAN, J; GIRGUIS, PR; Harvard University, Mass. Inst. Tech., DOE Joint Genome Inst.; *geoff.dilly@gmail.com*

Exploring the limit of metazoan thermal tolerance via comparative proteomics: Thermally induced expression shifts in hydrothermal vent polychaetes P. sulfincola and P. palmiformis

Eukaryotic thermotolerance is challenged at deep-sea vents, where temperatures can surpass 300 °C. *Paralvinella sulfincola*, an extremely thermotolerant vent polychaete, and *Paralvinella palmiformis*, a congener with a more modest thermal tolerance, both flourish at vents along the Juan de Fuca Ridge, Washington, USA. We conducted a series of in vivo shipboard, high-pressure experiments on both species to examine physiological adaptations that confer pronounced thermotolerance in *P. sulfincola*. Quantitative µLC/MS/MS proteomics on 1296 referenced proteins informed by a deeply sequenced EST library, as well as glutathione (GSH - an antioxidant) assays revealed several trends. *P. sulfincola* exhibited an upregulation in the synthesis and recycling of GSH with increasing temperature, downregulated NADH and succinate dehydrogenases (key enzymes in oxidative phosphorylation) with increasing temperature, but maintained elevated levels of heat shock proteins (HSPs) across treatments. In contrast, *P. palmiformis* exhibited more classical responses to increasing temperatures, e.g. increasing HSPs. These data, among the first to quantify global protein and antioxidant responses to temperature in an extremely thermotolerant eukaryote, suggest that *P. sulfincola's* pronounced thermal tolerance is largely due to its capacity to mitigate oxidative stress via increased synthesis of antioxidants and decreased flux through the mitochondrial electron transport chain. This work informs our knowledge of hydrothermal vent ecology, and more broadly, that oxidative stress may ultimately be the key factor in limiting all metazoan thermotolerance.

107.4 DING, Y*; SHARPE, S.S.; MALADEN, R.D; GOLDMAN, D.I.; Georgia Institute of Technology; *dingyang@gatech.edu*

Using a sandfish simulation to compare undulatory swimming in sand and in fluids

The sandfish lizard (*Scincus scincus*) swims within granular media (sand) using axial body undulations to propel itself without the use of limbs. We have developed a numerical sandfish simulation that swims within an experimentally validated discrete element model of the granular medium. The numerical sandfish is composed of 60 motor-driven segments whose angular position is controlled to reproduce a traveling wave which resembles the body kinematics of the animal. Here we use the numerical model to study the detailed mechanics of undulatory swimming in a granular medium, including the kinematics, reaction forces from the medium, power, and internal torques. The simulation reveals that in sand-swimming, the oscillation patterns of the forward velocity, lateral velocity, and yaw motion, as well as the magnitude of motor torque and motor power as a function of body position are similar to those in undulatory swimming in water. However, because in granular media forces are independent of speed in the biologically relevant range (1-4 Hz), the required mechanical power is proportional to the frequency; in fluids power increases superlinearly. Unlike in fluids where streamlining can reduce drag by an order of magnitude, streamlining the sandfish head reduces head drag by only ~30% compared to a flat head. Head drag consumes ~30% of the total mechanical energy generated by the motors. Finally, unlike undulatory motion in water, the magnitude of the force on each segment depends on the displacement after the lateral motion of the segment reverses. This effect reduces thrust forces from the steady state estimates used in a previously developed resistive force theory of sand-swimming, and explains the overestimation of the swimming speed in that theory.

63.4 DLUGOSZ, E.M.*; HARRIS, B.N.; SALTZMAN, W.; CHAPPELL, M.A.; University of California, Riverside; *edlug001@ucr.edu*

Aerobic Physiology, Locomotor Behavior, and Glucocorticoids in California Mice

California mice (*Peromyscus californicus*) have high and variable baseline circulating corticosterone (CORT) levels, which may be important in glucose regulation, energy balance and the stress response. We hypothesized that individual variation in baseline CORT profiles would be correlated with individual differences in energy expenditure (both routine and maximal), aerobic physiology, and activity levels. To investigate this possibility, we tested 54 adult, colony-bred mice for baseline CORT levels (measured near both the circadian peak and the trough), voluntary activity (exercise in running wheels) and its energy costs, maximal oxygen consumption (VO_2max), and basal metabolic rate. Given the large number of organismal processes that may be regulated in part by CORT, we found suprisingly few significant relationships between CORT and performance, physiology or morphology, and these differed between the sexes. CORT levels were negatively correlated with both VO_2max in females and voluntary distance run in males. Our results, while not striking, suggest that individual CORT profiles may increase our understanding of how the endocrine system integrates and regulates processes at a whole-organism level.

43.9 DORGAN, K.M.*; ROUSE, G.; Scripps Institution of Oceanography; *kdorgan@ucsd.edu*

Peristaltic burrowing in beach sands by the polychaete Thoracophelia mucronata

Recent work has shown that a range of polychaete annelids extend burrows through muddy sediments by fracture. Beach sands, however, are non-cohesive granular materials with different mechanics than elastic muds. The opheliid, *Thoracophelia mucronata*, burrows by peristalsis in well-sorted beach sands, and differs anatomically from other opheliids that use lateral sinusoidal movements. Kinematic analysis of *T. mucronata* burrowing in cryolite, a clear mineral with similar refractive index to seawater, shows direct peristaltic waves ending with forward progression of the head and expansion of the anterior. Using chaetae stained with a fluorescent chitin dye as a body markers, we show that the body expands radially against the sand, and forward movement occurs in narrow, undilated segments. Both in cryolite and in spherical glass beads, movement of grains more than a few grain diameters from the worm was not observed during peristalsis, although worms occasionally dilate the entire anterior of the body and displace grains radially. No regions of fluidization were observed. This indicates that the worm is using normal rather than shear forces to locally rearrange grains, and that friction is minimal. Analysis of burrowing behavior helps explain the functions of several morphological characteristics - the anterior septa allows the worm to apply higher forces near the front where most of the grain repacking occurs, and a glandular ridge extending from the tenth segment is similar in size to the sand grains and likely anchors the worm in place during peristalsis. Burrowing behavior is kinematically similar to peristaltic burrowing in muds in that anterior expansions apply forces perpendicular to the direction of locomotion, but the mechanical response of the sand is very different.

S6-1.1 DOWD, W.W.; Loyola Marymount University; *wdowd@lmu.edu*

Experimental contexts and statistical choices: Challenges for interpreting the proteomics of environmental stress

Environmental physiology, toxicology, and ecology and evolution stand to benefit substantially from the relatively recent surge of 'omics' technologies into these fields. These approaches, and proteomics in particular, promise to elucidate novel and integrative functional responses of organisms to diverse environmental challenges, over a variety of time scales and at different levels of organization. However, application of proteomics to environmental questions suffers from several factors – some unique to omics technologies and some relevant to many related fields – that complicate interpretation of the data. I will explore two important contingencies in proteomics and how they challenge the interpretation of data regarding organisms' responses to environmental stress: 1. Dependence of biological conclusions drawn from environmental stress proteomics studies on the choice of experimental conditions; and 2. Dependence of biological inferences from a single multivariate proteomics dataset on the choice of statistical methods. I draw upon both a review of the literature and data generated from my previous and ongoing proteomics studies of coastal marine animals: responses to episodes of hypoxia or anoxia in the rectal gland of the epaulette shark (*Hemiscyllium ocellatum*), and comparative proteomics of differential thermal tolerance in the gills of intertidal *Mytilus* mussel congeners. Although some of these experimental design and statistical issues await further critical assessment and debate, I conclude by offering some suggestions for meeting these challenges.

89.2 DUBANSKY, Brooke H.*; HOMBERGER, Dominique G.; Louisiana State Univ., Baton Rouge; *bhopki1@tigers.lsu.edu*

Biomechanical properties of the intermandibulo-cervical integument of alligators: Implications for a more accurate understanding of the alligator feeding mechanism

Alligators do not use their tongues to transport food from their oral cavity into their pharynx and have, therefore, been thought to swallow prey items whole or in large pieces by using a cranio-inertial feeding mechanism, which would require the intermandibulo-cervical integument to be expandable circumferentially to let large prey items pass through the throat. The alligator integument comprises rigid, non-imbricating and hard-cornified scales that are separated by flexible and often expandable interscale skin. The interscale skin between rows of scales is folded in the resting position; it unfolds and expands upon being stretched and is returned to its folded resting position by the resilience of elastic fibers. The intermandibular integument is expandable in all directions (except where it forms a firm plate of tightly arranged scales underlying the hyoid), which allows the manipulation of large food items in the oral cavity. The cervical integument expands only along the longitudinal axis of the neck through the unfolding of the interscale skin between circumferential rows of scales, whose caudal edges slightly overlap the cranial edges of the following scale row in the resting position. Hence, the cervical integument cannot expand circumferentially. Therefore, while alligators use a cranio-inertial feeding mechanism that is generally correlated with swallowing large prey items, our functional-anatomical data reveal that the cervical integument of alligators actually limits the size of food items that can pass through the throat and, thereby, prevents swallowing food items that are too large to pass through the narrow thoracic inlet.

118.5 DUBANSKY, Benjamin*; BODINIER, Charlotte; RICE, Charles D.; WHITEHEAD, Andrew; GALVEZ, Fernando; Louisiana State University, Louisiana State Uinversity, Clemson University; *bduban1@lsu.edu*

Effects of exposure to crude oil from the Deepwater Horizon Oil Spill on populations of gulf killifish (Fundulus grandis) in Barataria Bay, Louisiana.

The Gulf killifish (*Fundulus grandis*) makes up a large percentage of the biomass of the coastal marshland affected by the Deepwater Horizon Oil Spill. We have conducted extensive sampling of killifish populations collected *in situ* before landfall of oil, and at different times over the last year post oiling. CYP1A protein, which is a key biomarker of exposure to hydrocarbons, is highly upregulated in expression in the gills, intestines, and kidney of fish sampled *in situ* from oiled sites. Additionally, epithelial damage and hyperplasia were found in the gills and intestines of oiled fish. We have also exposed gulf killifish embryos from an unoiled reference population to sediments collected at oiled and unoiled sites in Barataria Bay, Louisiana. Embyros exposed to oiled sediments showed developmental abnormalities characteristic of exposure to crude oil, and decreased hatching success and delayed development. Presently, experiments are underway to understand the extent of effects on larval killifish hatched in oiled sediment.

S7-1.6 DUDEK, Dan; Virginia Tech; *dmdudek@vt.edu*

Simple models for terrestrial locomotion and the materials that power it

It has long been known that a wide array of morphologically diverse terrestrial runners produce center of mass dynamics that are well modelled by a spring-loaded inverted pendulum (SLIP). This simple, general model has proven useful in generating and testing hypotheses regarding the passive dynamic stability, control, and energetics of running on the level. Similarly, despite differences in attachment mechanism, foot morphology, and leg number, geckos and cockroaches produce a common dynamic pattern while rapidly climbing. In the frontal plane, the center of mass (COM) cyclically accelerates up the wall in synchrony with cyclical side-to-side motion that results from alternating net lateral pulling forces. Modeling these dynamics requires only a rigid body and a linearly actuated spring. As with the SLIP model, using these dynamics as a target for biologically inspired legged robots has proven successful. Broad generalities can also be found in the materials and structures used by these diverse animals during running. For example, despite being composed of different materials with varying morphologies, many structures loaded during locomotion demonstrate frequency independent material properties. Combining simple frequency independent models of the materials with the models for the dynamics of the COM may lead to an integrative understanding of terrestrial locomotion from the molecular to the organismal level.

22.11 DUMONT, E.R.*; DAVALOS, L.M.; GOLDBERG, A.; SANTANA, S.E.; REX, K.; VOIGT, C.C.; Univ. of Massachusetts, Amherst, Stony Brook University, Univ. of California, Los Angeles, Leibniz Institute for Zoo and Wildlife Research ; *bdumont@bio.umass.edu*

Cranial Morphology, Feeding Performance and Diversification in New World Leaf-Nosed Bats

Ecological opportunity coupled with innovation in morphology is thought to open doors to new adaptive zones and promote species diversification, although in practice it has proven difficult to demonstrate this sequence. Among mammals, New World leaf-nosed bats (Phyllostomidae) are a good system in which to investigate this process because of their tremendous diversity in cranial morphology and diet. There are phyllostomid species that feed on insects, small vertebrates, nectar, blood and fruit. Moreover, several studies have suggested that the transition to frugivory provided an ecological opportunity that promoted diversification. Here we link the evolution of cranial morphology, biting performance, diet and species diversification rates in phyllostomid bats. We found that that our measure of cranial morphology is a good predictor of biting performance, and that diet and cranial morphology evolved together. We found a significant shift in speciation rate at the base of the most frugivous clade (Stenodermatinae). Following this increase in speciation rate, the rate of morphological evolution slowed while the rate of evolution in diet increased. This pattern suggests that cranial morphology stabilized once it resulted in a certain level of biting performance, and then niches within the new adaptive zone of frugivory were filled rapidly. The tree-wide speciation rate increased linearly with a increased frugivory, and was highest at both morphological extremes. These results suggest a central role for a novel stenodermatine skull phenotype and performance in the evolution of frugivory and increase in speciation within phyllostomids.

21.5 DUNKIN, R.C.*; TINKER, M.T.; WILLIAMS, T.M.; Univ. of California Santa Cruz, USGS-Western Ecological Research Center; *dunkin@biology.ucsc.edu*

From Tissues to Landscapes: Using Physiology to Answer Landscape Level Questions in Large Mammals

Elephants, the largest land mammal, are highly dependent on surface water for efficient heat dissipation. As a result, they must shuttle between two critical resources, water holes to satisfy thermoregulatory demands and quality foraging areas to meet nutritional needs. This lifestyle has physiological consequences for the elephant and substantial landscape-level impacts associated with elephant grazing. Here we examine how climate interacts with relative food abundance, thermal physiology and water use patterns of elephants. Relationships between ambient temperature (T_a), water flux, and heat transfer of adult elephants (n=13, mean body mass=3801kg) were empirically measured and used to construct a physiology–climate based stochastic dynamic state variable model (SDSV). Using this model, four food quantity-climate scenarios were used to explore how limitations in surface water, ambient temperature, and food abundance/quality together influence spatial-use patterns and habitat impacts by elephants. Elephants relied on evaporative cooling to dissipate more than 100% of resting heat production at $T_a \geq 28^oC$. This temperature-water relationship resulted in predicted mean ranging distances from water that were more than 4 fold greater in habitats with mild climate ($T_{amax}=21.2^oC$) relative to warmer climates ($T_{amax}=32.9^oC$). Reduction of elephant abundance in overcrowded reserves using surface water management has gained recent interest, yet determination of whether a population is water limited has proven difficult. These data demonstrate that physiology based approaches to landscape level patterns can provide powerful process driven tools for evaluating habitat needs and impacts of large mammals. Supported by WWQ and SICB.

109.2 DURANT, S.E.*; HAWLEY, D.M.; ADELMAN, J.S.; WILSON, A.F; HOPKINS, W.A.; Virginia Tech, Princeton Univ; *sarah.durant@tufts.edu*

Infection and cold stress result in additive energetic costs and altered host immunity in a naturally occurring host-pathogen system.

The role of abiotic factors such as temperature in mediating host susceptibility to pathogens is of growing interest in disease ecology. For endotherms, thermoregulation and resistance to pathogens are two energetically demanding processes that can co-occur during seasonal pathogen epidemics. In house finches (*Carpodacus mexicanus*) outbreaks of *Mycoplasma gallisepticum* occur in months when ambient temperatures are often below thermoneutral (TN). Here we examined whether ambient temperature mediates host susceptibility to *M. gallisepticum* by experimentally infecting wild-caught house finches at either TN or sub-thermoneutral (STN) ambient temperatures. We simultaneously quantified the resting metabolic costs of infection, measures of body condition, disease expression, immune responses, and pathogen loads at both ambient temperatures. The simultaneous, additive demands of thermoregulating and combating infection resulted in an average 42.2% increase in resting metabolic rate resulting in an additional nightime energy requirement of 4.68kJ per day compared to uninfected birds at TN, a value higher than the daily energetic cost of feather molt in passerines. Energetic costs of infection were equivalent at both ambient temperatures. House finches at STN temperatures had significantly lower disease expression and higher circulating levels of the cytokine interleukin-6 in response to experimental infection with M. gallisepticum than finches at TN, yet pathogen loads did not differ between the two ambient temperature treatments. To our knowledge, this is among the first studies to estimate the energetic cost of an acute infection with a naturally occurring, infectious wildlife pathogen in an ecologically relevant host.

37.1 DURYEA, MC*; KERN, AD; COX, RM; CALSBEEK, RG; Dartmouth College, Rutgers University, University of Virginia; *duryea@dartmouth.edu*

Approximate Bayesian analysis of sire precedence reveals first-male advantage in the brown anole lizard (Anolis sagrei)

Studies of the effects of mating order, classically analyzed as the proportional paternity of the second male (P2), have given us important insights on the relative effects of postcopulatory male-male competition and female choice on sexual selection. However, these patterns are often difficult to analyze because both distributions of offspring number and proportional paternities are not normally distributed. Here, we overcome these difficulties by developing an approximate Bayesian model to analyze the effects of male mate order in the brown anole lizard, Anolis sagrei. The model is robust to relatively small samples sizes and is useful for studying mate order effects in a variety of systems. We applied the model to paternity results from a laboratory mating experiment in which we allowed female anoles to mate sequentially with two males. We find a marked first male advantage, with first males siring 75% of the offspring on average. We also show that second males are more likely to sire offspring when significantly larger than the first male. We discuss our results in terms of the implications both for postcopulatory sexual selection in this species, and for future analyses of paternity order in general.

85.4 DUSTAN, P.*; DOHERTY, O.; PARDEDE, S. T.; VANCE, J.; COWAN, N. J.; College of Charleston, Charleston SC, Biosphere Foundation, Big Pine CA, WIldlife Conservation Society, Bogor Indonesia, Johns Hopkins University, Baltimore MD; *dustanp@cofc.edu*

Digital Reef Rugosity

Habitats with greater structural complexity contain more species due to increased niche diversity. This is especially apparent on coral reefs where individual coral colonies aggregate to give a reef its morphology, species zonation, and three dimensionality. Reef rugosity classically describes this complexity as the ratio of a straight line transect to the distance a flexible chain of equal length travels when draped along the reef. Variants of this technique including visual categories, small scale measurements, acoustic backscatter, raster satellite imagery and aerial-based lidar have characterized reef rugosity at scales ranging from microhabitats to kilometers. In most cases a positive relationship exists between fish community distribution and estimates of rugosity.

In this communication we describe a new simple digital technique to estimate reef rugosity. Digital Reef Rugosity (DRR) enables a diver to quickly, easily, and accurately measure reef topographical complexity at the centimeter scale along meter scale transects. Our data demonstrate a positive relationship between DRR and fish diversity across a number of different habitats on shallow water Balinese coral reefs and reinforce the concept that habitat complexity is a fundamental property of reef communities.

The power of DRR lies in its precision and ability to easily record digital data applicable to analysis and modeling. Since changes in the physical structure are reflections of population dynamics, DRR may become a useful quantitative community-level descriptor to explore the formation of ecological tipping points as coral reefs degrade into carbonate rubble and cease to support their fish populations.

S8-2.1 DWORKIN, Ian; Michigan State University; *idworkin@msu.edu*

Genetic Contingency: Intergrating genetic background and environment into the study of mutational effects.

In genetic analysis, it is well known that the observed phenotype is not only a function of a given mutation, but also the influences of the genetic background in which it occurs, and the environment in which the organism is reared. Yet, in most genetic analyses such influences are often removed from consideration (via studying in a single environment in an isogenic background), or worse, ignored. When such influences are explicitly considered, and allowed to vary experimentally, only the phenotypic consequences of the focal mutation are generally considered. However, to date it has been rare to consider other important aspects of the mutations, such as the ordering of allelic effects (allelic series), complementation among alleles, pleiotropy and epistasis. In this talk I will discuss recent work in our lab examining the context dependent nature of genetic effects, and discuss it within the context of considering the expressivity of mutations as quantitative traits, themselves amenable to genetic analysis.

119.5 DYHR, JP*; COWAN, NJ; HINTERWIRTH, AJ; MORGANSEN, KA; DANIEL, TL; Univ. Washington, Johns Hopkins Univ.; *jdyhr@uw.edu*

Flexible frames for flight

Moving animals modulate myriad muscles in response to multimodal sensory inputs. Coordinating movement during flight is challenged by an animal's inherent instability, additional degrees of freedom, and the need to produce constant lift forces. This difficulty is compounded by different levels of precision, delays and frequency responses of incoming sensory signals. Prior studies have focused on wings as the primary flight control structures, for which changes in angle of attack or shape are used to modulate lift and drag forces. Other actuators are reflexively activated during flight which do not directly modulate the wings but may nevertheless impact flight performance. We investigated the visual-abdominal reflex displayed by the hawkmoth *Manduca sexta* to determine the role of the abdomen in flight control. Moths were presented with vertically moving gratings during tethered flight to measure the open-loop transfer function between the visual stimulus and abdominal response. That transfer function reveals a delay of approximately 50 ms and a high pass filter behavior with a 3 dB cut off at approximately 0.5 Hz. We also developed a physical model of hovering flight wherein articulation of the thoracic-abdominal joint is used to redirect a constant lift force provided by the wings. We show that control of the joint, subject to a high-pass filter, is sufficient to maintain stable hovering at time scales on the order of 5 ms. Our results agree with the behaviorally measured visual-abdominal transfer function of the moth, indicating that they may use a similar control strategy. Taken together, our experiments and models suggest a novel mechanism by which articulation of the body or "airframe" of an animal can be used to redirect lift forces for effective flight control.

S2-2.3 EARLEY, Ryan L.*; HANNINEN, Amanda F; FULLER, Adam; GARCIA, Mark J; STANLEY, Shane; LEE, Elizabeth A; TAYLOR, D. Scott; University of Alabama, Brevard County Environmentally Endangered Lands Program; *rlearley@bama.ua.edu*

Plasticity, integration, and selection: prospects for exploring the evolution of complex phenotypes in a powerful fish model

Identifying where individuals 'precipitate out' in phenotypic space requires knowledge of how selection, constraint, and plasticity interact to shape behavioral, morphological, and life history traits. In any organism, this is a Herculean effort but sometimes we stumble upon species with novel characteristics uniquely suited to fill empirical niches within the biological sciences. The mangrove rivulus (*Kryptolebias marmoratus*) is the only known self-fertilizing, hermaphroditic vertebrate. Its unique style of sexual reproduction results in extensive inbreeding, and the natural generation of isogenic lineages whereby a homozygous parent produces offspring genetically identical to itself and all sibs. Males exist at low frequencies in a population, providing opportunities for outcrossing and the maintenance of high genetic diversity within and among populations. This species thus provides unprecedented opportunities to generate reaction norms for an arsenal of phenotypic traits *with replication* at the genotypic level; explore local adaptation and the genotypic/genomic basis for phenotypic diversity; and identify patterns of trait covariance driven by pleiotropic effects of genes or hormones that might constrain or liberate phenotypic evolution. We have collected over 200 genetically distinct lineages from 30 populations throughout the mangrove rivulus' range, extending from Central America to the Caribbean and coastal regions of central Florida. We reveal significant behavioral, morphological, and life history diversity among genotypes; a high degree of plasticity in response to the social and physical environments both during ontogeny and adulthood; and a potentially potent role for steroid hormones as integrators of suites of phenotypic traits.

108.1 EASY, Russell*; ADAMO, Shelley; Dalhousie University; *reasy@dal.ca*

Pitting the stress response against the immune response: changes in gene expression in the Texas Field Cricket (Gryllus texensis)

The immune response can damage as well as protect. Hsp90 is one of the most abundant proteins in animal cells and is involved in protein folding and cell signaling and is usually upregulated in response to stress. Nitric oxide (NO) is a signaling and effector molecule involved in the insect response to pathogen challenge. Glutathione-S-transferase (GST) is part of a class of enzymes involved in detoxification of oxidative stress products. The ability to survive an immune challenge may be directly dependant on changes in the relative amount of these proteins. Using real-time PCR we have shown upregulation of Hsp90 following heat stress however we also note a consistent downregulation of Hsp90 following acute and flying stress with a concomitant increase in GST and NO. This suggests a trade-off in gene activation in response to physiological stress. Future work will explore the phenotypic responses of these changes in gene regulation.

AMS.1 ECKELBARGER, Kevin J; University of Maine; *kevine@maine.edu*

A Tribute to Dr. Mary E. Rice: From Neanderthals to Naples - A Brief History of Marine Biology from Antiquity to 1900

Marine biology was born in the Mediterranean where Neanderthals exploited marine invertebrates, pinnipeds, cetaceans, and fish on the eastern shores of Gibraltar ~30,000 years ago and Aristotle studied marine organisms in the Aegean Sea in the 4th century B.C. The Age of Discovery spawned a revolution in anatomical and taxonomic studies throughout the Renaissance and the Enlightenment and marine biology benefited from technological advances of the Industrial Revolution and a Second Age of Discovery in the 18th and 19th centuries. Improvements in vessel technology and advances in microscopes, tissue microtomes, and histological techniques all helped advance the field. The collection of shallow water marine organisms in small boats gave way to deep-water dredging using larger vessels and trained crews. Short-term studies of marine organisms during brief visits to the seashore led to long-term studies conducted at permanent, coastal marine stations that proliferated during the last quarter of the century. Studies on the ecology, anatomy, physiology, embryology, and life histories of marine organisms generated progress in our basic understanding of cells, fertilization biology, development, and evolution. Numerous ocean expeditions both before and after the legendary British Challenger led to a better appreciation of the complexity of marine ecosystems and the role of plankton while dispelling the notion of an “azoic zone“, “living fossils”, and the pantheistic concept that abiogenic processes fueled the evolution of metazoans from inorganic matter. This presentation will highlight some of the contributions of both the celebrated and lesser-known pioneers who helped establish the modern field of marine biology.

8.3 EDWARDS, JE*; LAILVAUX, SP; University of New Orleans, Louisiana; *edjessicaedwards@gmail.com*

Staged Dominance Interactions Between Anolis carolinensis and Anolis sagrei Lizards.

The introduced lizard *Anolis sagrei* is known to commonly replace *Anolis carolinensis* as the most abundant anole of urban areas and other open environments. To assess whether dominance behavior might play a key role in this change, we caught *A. carolinensis* and *A. sagrei* males of various sizes and randomly matched them in staged interactions in lab. Preliminary analyses suggest that the predictors of interspecific fight outcomes between *A. carolinensis* and *A. sagrei* are not straightforward, and appear to be different for each species.

71.4 EERNISSE, D.J.*; KVIST, S.; BARRIO, A.; SIDDALL, M.E.; California State Univ. Fullerton, American Museum of Natural History, New York; *deernisse@fullerton.edu*

Cryptic species diversity in the marine pulmonate limpet subgenus Siphonaria (Heterosiphonaria) in the vicinity of the Gulf of California

Marine pulmonate “false” or “siphon” limpets (*Siphonaria* spp.) are among the most common and ecologically important tropical eastern Pacific rocky shore gastropods, yet they have been little studied and identification to species is challenging. We were able to study siphon limpets collected during a 2004 Sea of Cortez expedition as supplemented by some additional samples from between Baja California Sur and Manzanillo, Mexico. The subgenus *Heterosiphonaria* Hubendick 1945 has been used for all Panamic species, and is considered restricted to between Baja California Sur and Peru in the tropical Eastern Pacific. Given confusing morphological variation, we undertook a DNA sequencing approach, employing combined analysis of mitochondrial 16S and COI gene regions. This revealed at least five discrete groupings, each with strong bootstrap support. In contrast, only three species are currently recognized from this region, not including the more southern and morphologically distinctive “giant siphon limpet,” *S. gigas*. Some of our discrete clades appear to be Gulf of California endemics that do not correspond to any the about 11 total nominal species, including junior synonyms, proposed to date. Our results either imply unrecognized species diversity or strong phylogeographic structure. Inclusion of available GenBank Siphonariidae 16S/COI sequences supported the robust monophyly of tropical Eastern Pacific species, exclusive of other worldwide Siphonariidae. This partly corroborates the *Heterosiphonaria* grouping, which was proposed from genitalia affinities, but sequences for the *Heterosiphonaria* type species, *S. gigas*, are still lacking.

42.8 EICHINGER, J. M.*; SATTERLIE, R.A.; University of North Carolina Wilmington; *jme1463@uncw.edu*

Turning Mechanisms in Cubomedusae

Box Jellyfish (Class: Cubozoa) are strong, active swimmers capable of evading hazardous obstacles and orienting to photic stimuli. Directional swimming is accompanied by asymmetric deformations of the velarium, a striated muscle sheet encircling the bell opening. Radial, buttress-like muscles, termed frenula, are presently thought to serve only a stabilizing structural role during swimming. We hypothesize the frenula serve a greater function in turning behavior than previously thought. During a turning event, frenular contractions in the radial axis result in shortening of the bell height as the velarium is pulled upward towards the bell apex. Asymmetrical contractions would produce directional fluid ejection from the bell opening, which would propel the medusa into a turn. To investigate this behavior confocal-light microscopy, electron microscopy, videography and electrophysiological techniques were employed. Our results demonstrate that the frenulum is the most densely-innervated swim muscle in representative medusae of two cubozoan families (Carybdeidae; Tripedaliidae). The frenular nerve net also has a distinct radial orientation in parallel with muscle cell orientation, whereas subumbrellar and velarial neurons are distributed more randomly in non-directional networks independent of muscle cell orientation. Frequency dependent neuromuscular facilitation occurs in all three muscle sheets, but our results suggest the frenulum is a functionally unique muscle sheet. Contraction patterns and spontaneous, powerful contractions at high swimming frequencies suggest that the frenula may be important components in generating asymmetric velarial contractions to produce turning in cubomedusae.

84.5 EITING, T*; SMITH, T; FORGER, N; DUMONT, E; UMass Amherst, Slippery Rock Univ; *tpeiting@bio.umass.edu*

Comparing Sensory Abilities: Olfactory Bulb Size and Olfactory Sensitivity in Phyllostomid Bats

When comparing olfactory abilities across species, the relative size of the olfactory bulb (OB) is often used to represent olfactory sensitivity (ability to detect low concentrations of odors). Species with larger OBs for their brain (or body) size are thought to have greater sensitivity to odors. If this assumption is true, the size of the olfactory bulb can provide valuable insights into relative sensory abilities across species. However, using the relative size of the OB as a proxy for functional ability has potential pitfalls. OB size could be related to features that do not reflect olfactory sensitivity, such as the size of the neuronal cell bodies or the proportion of non-neuronal cells in the OB. In this study we examine whether OB size is a significant predictor of more direct measures of olfactory sensitivity. One such measure is the "convergence ratio," which is the ratio of the number of olfactory sensory neurons to the number of mitral cells with which they synapse. Higher convergence yields a greater chance of transmitting an action potential. Using 14 species of phyllostomid bats that represent a wide range of trophic adaptations, we test the hypothesis that relative size of the OB is a fair proxy for olfactory sensitivity. We predict a significant, positive relationship between relative OB size and the ratio of olfactory sensory neurons to mitral cells. Initial results based on cell counts derived from histological preparations support our hypothesis: relative OB volume is positively related to the olfactory convergence ratio. This finding supports the use of relative OB volume as a proxy for olfactory sensitivity in comparative studies.

77.4 ELAHI, R.*; SEBENS, K.P.; Friday Harbor Labs, University of Washington; *elahi@uw.edu*

A consumer one-two punch: facilitation and functional diversity prevent reversals in community state

Declines in global biodiversity have prompted ecologists to question the relative importance of diversity and identity in the context of species loss. We tested the effects of consumer functional diversity and identity on subtidal rock wall epifauna using two field experiments in the San Juan Islands, WA. In the first, we added urchins to walls every two weeks for three months and demonstrated that urchins control the structure of this community by grazing on sessile taxa, exposing algal crusts and bare rock (together considered 'space'), and facilitating chitons and other consumers. In the context of diet analyses, we conclude that urchins create space by consuming macroalgae and invertebrate colonies, while chitons maintain available space by grazing primarily on microalgae and diatoms. In the second experiment, we conducted a factorial removal of urchins and chitons from walls every two weeks for the duration of a year. The removal of each functional group in isolation had no effect on the epifaunal community, but the removal of both consumers caused a decrease in space and an increase in clonal ascidians. Together, these experiments suggest that urchins and chitons can be considered functionally redundant in the maintenance of space, but not the creation of space. Facilitation and redundancy among consumers may contribute to the resiliency of urchin-mediated 'barrens', even if urchins do not persist.

62.5 ELDERBROCK, E.K.*; SMALL, T.W.; SCHOECH, S.J.; University of Memphis; *kldrbrck@memphis.edu*

Plasma corticosterone and feather quality in the threatened Florida Scrub-Jay

Possessing feathers of high quality is important for survival and breeding success. However, because feather growth is energetically expensive, quality may vary with an individual's condition. Most birds undergo a period of molt during which energy expenditure is directed primarily to feather growth. Concurrently, the stress response is suppressed resulting in lower levels of corticosterone (CORT), a hormone known to negatively affect feather quality. Thus, we expected that during the breeding season with energetic expenditures directed toward reproduction, feathers grown would be of lesser quality. Our study species, the Florida Scrub-Jay (*Aphelocoma coerulescens*) is a cooperative breeder in which offspring remain in their home territory from 1-3 years. Because non-breeder helpers are reproductively inactive, we anticipated that they would have more energy to allocate to feather growth and would, thereby, regrow feathers of higher quality than breeding birds. To investigate this we captured jays in the pre-breeding season (Feb-March), followed a standard capture and restraint protocol for a stress series to measure CORT, and removed two tail feathers. At the end of May, following fledging of young, we re-captured all birds and collected the two re-grown feathers. We assessed feather quality by measuring growth and fault bars, total length, and brightness based on spectrometric reflectance. Contrary to the above prediction, feathers of non-breeders had significantly more fault bars than those of breeders. Further, there was an overall trend of baseline CORT being positively correlated with the number of fault bars. These data suggest that endogenous CORT levels may impact feather quality but it remains unclear to what extent competing energetic demands influence feather growth in this species.

84.6 ELZINGA, M.J.*; DICKSON, W.B.; DICKINSON, M.H.; Caltech, IO Rodeo, Univ. of Washington; *elzingam@caltech.edu*

The influence of sensory feedback delays on the yaw dynamics of insect flight

In closed loop systems, even modest sensor feedback delays may have potentially disastrous implications for performance and stability. Flies have evolved multiple specializations to reduce this latency in their sensory systems, yet even the mechanosensing haltere–which provides the fastest feedback during flight–involves a delay that is significant on the timescale of body dynamics. We explored the effect of sensor delay on flight stability and performance for flapping flight in the context of yaw turns through the use of a dynamically scaled robotic model of the fruit fly, *Drosophila melanogaster*. To perform this analysis we implemented a real-time feedback system that performed active turns in response to measured torque about the functional yaw axis. Active control over yaw torque was enabled through the modulation of a parameter governing the bilateral asymmetry in the angle of attack. With the robot under proportional control, we performed step and impulse response experiments in yaw velocity for a range of virtual feedback delays, similar in dimensionless timescale to those experienced by a fly. The results show a fundamental tradeoff between sensor delay and permissible feedback gain, and demonstrate a gain threshold, below which the system is stable regardless of delay. Proportional feedback control provides a method of active damping that is relevant even for delayed feedback on suitable timescales. Presented in the context of these findings, a control architecture whereby a haltere-mediated inner loop proportional controller provides damping for a visually mediated low-pass filter is consistent with tethered flight measurements, free flight observations, and engineering design principles.

6.3 ENG, CM*; LIEBERMAN, DE; BIEWENER , AA; Harvard University, Cambridge, MA; *cmeng@fas.harvard.edu*

In vivo strain patterns indicate different functions in the proximal and distal fascia lata of the goat

We examined strain patterns in the fascia lata (FL), a large sheet of fascia overlying the lateral thigh of goats (*Capra hircus*), to assess its role in mediating elastic energy savings for limb swing in relation to its role in stance. At the beginning of swing, the limb is retracted and decelerated and then reaccelerated to swing the limb forward. The energy in the decelerating limb could therefore be stored elastically and recovered to reaccelerate the limb. Although stance phase elastic energy storage has been well studied, the role of energy storage during swing has received less attention. Sonomicrometry crystals were implanted in the proximal and distal FL to obtain biaxial strains (longitudinal and transverse). Using sonomicrometry and EMG, we also examined how the tensor fascia lata muscle (TFL) contracts to transmit force via the proximal border of the FL and how the gluteobiceps (GB) contracts to transmit force via the distal, posterior border of the FL. These muscles are both knee extensors but TFL flexes the hip while GB extends the hip. During trotting and galloping, the distal FL stretches biaxially through the stance-swing transition and then shortens after initial swing consistent with its role in elastic energy recovery for limb swing. While the distal FL stretches GB actively shortens, indicating that the distal FL is stretched by active GB contraction. Conversely, maximal stretch in the proximal FL occurs during stance prior to swing. Activity and strain patterns in TFL are not as well matched with proximal FL compared to GB and distal FL. These results indicate that: 1) the proximal and distal FL may serve different functions during locomotion and 2) the distal FL has the potential to store and recover elastic energy during swing phase.

61.5 EME, J*; TATE, KB; KOHL, ZF; SLAY, CE; HICKS, JW; CROSSLEY II, DA; U N Texas, U Cal Irvine; *johneme34@gmail.com*

Cardiovascular plasticity during hypoxic development in reptile embryos

The cardiovascular (CV) system is the first operational organ system, but little is known about variation in CV regulatory maturation across the vertebrate evolutionary tree. In particular, reptiles are an understudied group that represents evolutionary intermediates between water-breathing vertebrates and endothermic, air-breathing tetrapods (birds and mammals). Reptile eggs, and presumably the ancestors of birds and mammals, incubate without maternal care and are subject to environmental stressors during development. One stressor is reduced micro-environmental oxygen content, and we have shown that this stress impacts reptilian CV function and maturation. Using two reptiles, Snapping turtles and American alligators, we investigated *in ovo* species differences in maturation and function of the CV system following chronic incubation in hypoxia (10% O_2). Hypoxia alters the tonic regulation of baseline CV variables, and results in relative cardiac enlargement. Assessment of CV reflexes induced via acute hypoxia or pharmacological stimuli indicate reflexes can be plastic and blunted by chronic hypoxic incubation. However, turtle and alligator embryos exhibit different patterns of CV maturation during development. Alligator embryos possess an adrenergic tone originating from circulating catecholamines only, and cholinergic tone is not present until just prior to hatchling. Turtle embryos display cholinergic tone at 70% of development, and rely on autonomic tone to control heart rate over the last 30% of incubation. Our data indicate that maturation of CV function exhibits phenotypic plasticity in response to hypoxic incubation in both species, and that turtle embryos display a more 'advanced' developmental program than alligator embryos. NSF CAREER IBN IOS-0845741 to DAC

75.1 ERICKSON, GM*; HAMILTON, M; BOURNE, GR; NORELL, MA; SAWYER, WG; Florida State Univ, Tallahassee, Univ. of Florida, Gainesville, Colorado School of Mines, Golden, American Museum of Natural History, New York; *gerickson@bio.fsu.edu*

Histology and wear biomechanics of hadrosaurid dinosaur teeth—reptiles that exceeded mammals in dental complexity

The grinding teeth of mammals (e.g. horses), are biomechanical marvels. Their complex four-tissue composition strategically wears, creating course surfaces to comminute tough and abrasive plants (e.g. grasses), liberating nutrients inaccessible to other herbivores. Grinding dentitions evolved repeatedly and exclusively in mammals with one notable exception: the duck-billed hadrosaurid dinosaurs. This innovation fueled their 35-million-year reign over Laurasian herbivorous niches. How this was achieved is a mystery. Reptile teeth consist of just two dental tissues and presumably lack biomechanical attributes for grinding. Here we show hadrosaurids broke from the reptilian template by evolving six-tissue composition. Three-dimensional wear modeling revealed how the intricate architecture morphed for grinding and dietary change. Hadrosaurids possessed the most histologically complex dentition— one that rivaled, if not exceeded, mammals in biomechanical sophistication.

63.2 ERNST, D.F.K.*; BENTLEY, G.E. ; UC Berkeley;
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Social Isolation, Reproductive Physiology and Behavior in Male Zebra Finches
Zebra finches are not highly photoperiodic and instead respond to environmental cues such as rainfall, food availability, and social cues to time reproduction. Unlike many photoperiodic species, zebra finches do not exhibit marked changes in hypothalamic GnRH-I content in different reproductive conditions. Instead, it is thought that regulation of the hypothalamo-pituitary-gonadal (HPG) axis occurs via regulation of GnRH-I release at the level of the median eminence. Type II iodothyronine deiodinase (DIO2) has been implicated in the rapid release of GnRH-I from the hypothalamus in photoperiodic species in response to a stimulatory cue. Thus, we hypothesized a role for DIO2 in zebra finch HPG activation in response to stimulatory social cues. We predicted that social isolation would cause downregulation of the HPG axis, and that subsequent presentation of a novel female would rescue this effect. Following two days of social isolation males were presented with a novel female, a novel male, or no stimulus. Males presented with a female exhibited increased activity, courtship and mating behavior compared with males in the other two groups. One hour following the behavioral assay, RNA was extracted from the brains for qPCR, and sections of the brain were retained for ICC. There were no differences in expression of genes for DIO2, DIO3, GnRH, GnIH, or CFOS in the hypothalamus, while the group of males presented with a female had significantly greater EGR-1 expression than the isolated group ($p<.03$). Males given a male conspecific had an intermediate amount of EGR-1 expression. ICC results show that EGR-1 was not co-localized with GnRH-I neurons. These data indicate a social effect on behavior and EGR-1 expression in the hypothalamus of males, but this effect does not appear to influence components of the HPG axis directly.

97.5 EVANGELISTA, D.*; CARDONA, G.; RAY, N.; TSE, K.; WONG, D.; Univ. of California, Berkeley;
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Measurement of the aerodynamic stability and control effectiveness of human skydivers during free fall and directed aerial descent
We examined the aerodynamic stability and control effectiveness of human skydivers during free fall using models in a wind tunnel, full-scale tests in an indoor skydiving vertical wind tunnel, and data collection during actual skydives. Maneuvers during flight at high angles of attack are important to understand and are relevant to the evolution of aerial behaviors in many taxa. Human free fall is an understudied and important point of comparison: humans use both inertial and aerodynamic mechanisms to accomplish maneuvers and direct their descent, they are the largest vertebrate known to perform aerial behaviors, they can be asked to perform specific test maneuvers, and they are large enough to carry a complete set of instrumentation. We find that maneuvers at skydiving speeds are dominated by aerodynamic torques (vice inertial, as in human gymnasts tumbling at low speed). Human use of limbs as aerodynamic surfaces is consistent with those of smaller animal skydivers. Stability varies depending on axis of motion and glide angle and stability shapes which behaviors are effective in accomplishing maneuvers. The wide suite of behaviors available to a large mammal with no obvious aerial adaptations, presented with an extreme aerodynamic challenge, reinforces the importance of a maneuvering perspective in comparative studies of flight biology.

16.9 FALK, Bryan*; PERKINS, Susan; American Museum of Natural History; *bfalk@amnh.org*
Comparative phylogeography of parasites in Anolis lizards on the Puerto Rican Bank
It is estimated that 30-50% of all living species are parasitic, but the factors that might have contributed to all this diversity remain poorly known. How important is the host in determining parasite diversification? How important are parasite traits such as mode of transmission? In order to answer these questions, we examine how host and parasite traits influence the patterns of diversification in parasites infecting *Anolis* lizards on Puerto Rico and the surrounding islands.

17.6 FARINA, Stacy C; Cornell University; *scf59@cornell.edu*
Cryptic and Rapid Gill Ventilation Behaviors of the Goosefish, Lophius americanus
The goosefish, *Lophius americanus*, is a benthic sit-and-wait predator that relies on a dorso-ventrally flattened head and a slow gill ventilation rate to remain hidden from prey. The opercular chamber is characterized by long, thin branchiostegal rays and a small opening posterior to the pectoral girdle. When unperturbed, *L. americanus* ventilates its gills once every 60-90 seconds, in a pattern termed cryptic ventilation. After feeding or a disturbance, the ventilation rate increases to 8-45 seconds (rapid ventilation). Both behaviors are marked by a large asymmetry between the inspiration and expiration phases, although the asymmetry is much more pronounced during cryptic ventilation. The relationship between the length of inspiration and expiration phases was also explored. Previously, authors have suggested that movements of the suspensorium and opercular series play little to no role in ventilation in *Lophius*. High-resolution video recordings, however, confirm that such skeletal movements are actively involved in the movement of water at the beginning of the suction phase and throughout most of the pressure phase. During rapid ventilation, movements of the suspensorium and opercular series make up a large portion of the ventilation cycle. When the jaws, opercular series, and suspensorium are not driving the movement of water during the inspiration phase, the hyoid slowly depresses and the branchiostegal rays slowly expand to increase the size of the buccal and opercular chambers. This slow expansion of the chambers frequently exceeds 60 seconds during cryptic ventilation in a pattern that maintains water flow across the gills.

S2-1.6 FARMER, J.L.; ORLANDO, E.F.*; University of Maryland, College Park; *eorlando@umd.edu*

Effects of Developmental Exposure to Ethinyl-Estradiol on Gene Expression and Fitness of the Adult Rivulus, Kryptolebias marmoratus

Concern over endocrine disrupting chemicals found in the aquatic environment and evidence of altered development and reproduction of fishes has suggested a need for further research into the potential effects of these pollutants. Exposure to even low concentrations of some estrogenic compounds, like ethinyl-estradiol (EE2), is known to affect development and reproduction in several fishes. Our study was conducted to determine the effects of EE2 exposure on the reproductive system of rivulus (*Kryptolebias marmoratus*), a self-fertilizing, simultaneous hermaphrodite. We hypothesized that exposure to EE2 during gonadal differentiation would direct hermaphroditic gonadal development towards a female phenotype in the adult. Expression of seven genes, with known relevance to gonadal development and function (*cyp19a1b*, *cyp19a1a*, *dmrt1*, *figα*, *erα*, *erβ*, and *vtg*), was measured using real-time quantitative PCR, and the reproductive fitness of fish was evaluated. Gonadal gene expression for *cyp19a1a*, *erα*, and *dmrt1* decreased in response to EE2 exposure. *Vtg* expression in the liver was unaffected; however, there was a significant decrease in *cyp19a1a* gene expression in the brain corresponding to increased EE2 exposure. While the EE2 treated fish showed reduced fertility and gonadal function, each treatment group contained fish that were still capable of internal fertilization; albeit with severely reduced efficiency. It is unclear if 0.1 ppm EE2 significantly affects fitness; however, 0.5 and 1.0 ppm EE2 result in a gonad with reduced testicular function and overall reduced fitness. Additionally, this study provides insight into the endocrine mechanisms regulating development and function of ovarian and testicular tissue in the same gonad.

51.2 FARRAR, N*; LUDEMAN, D; LEYS, S; University of Alberta, UAlberta; *nfarrar@ualberta.ca*

Evidence for a Functional Sensory System in Sponges

Sponges (Porifera) lack a nervous system, yet both larval and adult sponges are able to respond to external stimuli: glass sponges (hexactinellids) arrest the feeding current to prevent uptake of sediment and demosponges contract their canals in a rhythmical way to expel unwanted waste. One stereotypical behavior is an Inflation/Contraction (I/C), or 'sneeze'-like action that occurs in response to mechanical stimuli, and can be triggered by 75uM L-glutamate. As sponges were the first multicellular animals to evolve they are ideal organisms for exploring the physiology of the earliest sensory systems. Sponges have flagella on choanocytes, but the presence of cilia in canals is less well known. Here we show cilia line the epithelia of oscula in all 5 demosponges we have studied. The distribution and orientation of the cilia in the freshwater sponge Ephydatia muelleri suggests they function as flow sensors in the canal system. Their presence at the excurrent vent of the aquiferous system implies they may be involved in controlling or triggering the I/C response that demosponges use to expel wastes. To test this we used the aminoglycosidase antibiotic Neomycin sulfate and the steryl dye FM1-43, which disrupt signaling by primary cilia in other metazoans, and found both drugs depressed the I/C response relative to controls. Signaling through primary cilia in other organisms is known to involve $Ca2+$ influx. Cilia were longer in treated sponges than in controls, providing evidence that the drugs block calcium channels in the cilia and interfere with intraflagellar transport as in other animals. Using $Ca2+$ imaging we found that in E. muelleri the I/C response is accompanied by a rise in $Ca2+$ which travels as a wave along the epithelium of the canal system corresponding to waves of contraction. We hypothesize that signaling through primary cilia in the osculum controls contraction of the canals by generating a $Ca2+$ wave.

108.6 FASSBINDER-ORTH, C*; BARAK, V; BROWN, C; Creighton University, University of Tulsa; *carolfassbinder-orth@creighton.edu*

Avian Immune Responses to Alphavirus Infections

Immunocompetence is energetically and nutritionally costly, and animals with different life history strategies may exhibit differential investment in parts of their immune systems in response to immune challenges. The house sparrow (*Passer domesticus*) is a highly successful non-native species in North America that is more susceptible than the native cliff swallow (*Petrochelidon pyrrhonota*), to Buggy Creek virus (BCRV), an alphavirus vectored by an ectoparasitic swallow bug. Although previous work on alphavirus infections in mammals has suggested that a hyperactive innate immune response (especially prevalent in neonates) leads to a more severe alphavirus infection, details of the avian immune response to alphaviruses has not yet been reported. Additionally, BCRV exists as two distinct lineages (A and B) that differ by about 6% at the nucleotide level. Ecological differences between the two lineages, including preferential infection of vertebrate hosts by lineage A, suggest that these lineages have diverged in their transmission strategies. We experimentally infected adult house sparrows with BCRV lineage A and B and examined the differences in disease severity between the two lineages. Additionally, we sequenced 500 bp regions of 17 different house sparrow genes known to be involved in immune function and examined their relative gene expression levels after BCRV infection using a liquid-phase bead-based, multiplex array. The results obtained from studying this host-pathogen-vector system have the potential to expand our understanding of avian immune responses to arboviruses and also the relationship between avian life history strategies and immune function.

42.2 FECHKO, AS*; HINTERWIRTH, AJ; DANIEL, TL; University of Washington; *ambersf@uw.edu*

Gaining insight: visual feedback control in the hawkmoth Manduca sexta.

Animals acquire and process sensory information to control motion in complex environments. In the hawkmoth *Manduca sexta* both visual and mechanosensory information are critical components of the flight control circuit. Visual feedback control, in particular, depends on a host of optical characteristics and upon the gain between the torque generated by a flying insect and the resulting movement of the insect's visual field. To explore this relationship we built two coupled devices: (1) an optically based transducer that records torque produced by yaw motions in tethered insects and (2) a high spatial and temporal resolution (800 DPI, ~1kHz refresh rate) image feedback control system with a MEMS data projector. Using a custom C/OpenGL software platform, we control the relationship between the output of the torque sensor and the visual world presented to insects tethered in a flight arena. We specifically examined two questions: (1) to what extent does the feedback gain between torque and image motion determine an animal's ability to track a visual stimulus and (2) to what extent can an animal adapt to different gains applied to the feedback loop? For 4 moths controlling their visual world with at least 4 different feedback gains in a minimum of 50 trials per moth we found that (1) individual moths have an optimal gain at which they best track image motion, and (2) the ability to track a visual stimulus improves after repeated exposure to the same gain and visual image slip. Interestingly, all moths tested were able to track image motion when the gain was reversed, suggesting significant plasticity in the visual flight control circuit.

53.6 FEDORKA, Ken*; RADHAKRISHNAN, Preethi; University of Central Florida; *fedorka@ucf.edu*

Immune activation influences sperm viability and female sperm storage in Drosophila melanogaster

Recent work in vertebrates indicates that sperm viability may be indirectly influenced through male pathogen load. Unfortunately, little data exists regarding the influence of infection on sperm viability in male insects (which represent the majority of animals). Moreover, we know nothing about how infection influences viability within females, which is crucial considering the prevalence of female sperm storage across most animal taxa. To obtain a robust understanding of the role of infection on viability, we addressed the following questions in the fruit fly *Drosophila melanogaster*. First, does indirect systemic infection influence sperm viability in both male and female reproductive tracts. Second, if an infection effect is found, is it due to the migration of pathogen exotoxins into the reproductive tract, (2) a resource trade-off between immune and reproductive systems or (3) collateral damage caused by immune effectors. Third, does a localized reproductive tract infection via the sexual transmission of a pathogen also influence viability. We found that systemic infection with *pseudomonas aeruginosa* reduced sperm viability 24 hours after mating. Moreover, we found that immune activation with peptidoglycan alone (sin pathogen) also decreased viability and that this effect was most likely due to collateral damage and not a resource trade-off. Last, we found females mated to males passing a sexually transmitted pathogen exhibited empty sperm stores 48 hours after mating, suggesting that females can detect contaminated ejaculates and purge stored sperm. These data suggest that immune effectors directly deceases viability in both sexes when the immune system is activated. Furthermore, they suggest that STDs may play a key role in shaping female remating rates, thereby shaping the evolution of insect mating systems.

16.8 FEIS, ME*; THIELTGES, DW; OLSEN, JL; DE MONTAUDOUIN, X; JENSEN, KT; BAZAÏRI, H; CULLOTY, SC; LUTTIKHUIZEN, PC; University of Groningen, the Netherlands, and Royal Netherlands Institute for Sea Research NIOZ, Den Burg, the Netherlands, Royal Netherlands Institute for Sea Research NIOZ, Den Burg, the Netherlands, University of Groningen, the Netherlands, University Bordeaux 1, France, University of Aarhus, Denmark, University Mohammed V Agdal, Rabat Agdal, Morocco, University College Cork, Ireland; *pieternella.luttikhuizen@nioz.nl*

Parasite population genetic structure in relation to definitive host type

Population structure and dynamics are contentious issues in macroparasites because of their complex life cycle involving several host taxa during subsequent parasite life stages. The hosts often vary widely in dispersal potential with at present largely unknown effects on parasite population structure. Here, we take a comparative approach and study mitochondrial DNA variation in two macroparasite species that have the same first intermediate host species but have different definitive host types. We examined part of the cytochrome-*c*-oxidase gene for two digenean trematode parasites, *Labratrema minimus* and *Gymnophallus choledochus*, that have fish and birds as definitive hosts, respectively. Both infect the cockle *Cerastoderma edule* as first intermediate host. Samples of both parasites were obtained from cockle populations along the east Atlantic coast from Denmark to Morocco. The hypothesis was tested that birds as definitive hosts constitute larger connectivity and, hence, lower population genetic structure, than having fish as definitive hosts.

69.2 FERNANDES, D. A. O.*; PODOLOSKY, R. D.; College of Charleston; *daoriaf@hotmail.com*

Developmental consequences of association with a photosynthetic substrate for encapsulated embryos of an intertidal gastropod

Aggregation of embryos in clutches that lack internal circulation can increase the risk of hypoxia by limiting gas exchange. As a result, limits on oxygen solubility and diffusion in water can constrain the size and embryo concentration of aquatic egg clutches. Hypoxia in egg masses can slow embryo development, increase mortality, and reduce size at hatching. The risk of hypoxia for embryos, however, can be reduced by association with photosynthetic organisms. We examined whether embryo development in egg ribbons of the cephalaspidean mollusk *Haminoea vesicula* is significantly influenced by oviposition on eelgrass (*Zostera marina*). Association with a photosynthetic substrate had marked effects on development relative to association with non-photosynthetic substrates, and the direction of these effects was mediated by light conditions. Under intermediate and high light levels, association with eelgrass accelerated embryo development, while under dim light, the presence of the macrophyte increased development rate and reduced hatchling shell size. Benefits of association with eelgrass at higher light levels likely result from oxygen production by eelgrass photosynthesis, while we attribute costs under low light to oxygen depletion by eelgrass respiration. Association with *Z. marina* also limited microphyte growth in egg ribbons of *H. vesicula*. In the field, measurements of light attenuation within an eelgrass bed showed that conditions under which benefits accrue to embryos are ecologically relevant and correspond to spatial patterns of oviposition on eelgrass in the field. The choice of a photosynthetic oviposition substrate under appropriate light conditions can improve embryo fitness by accelerating embryo development without compromising hatchling size and by reducing the potential for excessive and harmful fouling by microphytes.

52.5 FERNANDEZ, M.J.*; GUO, M.; HEDRICK, T.L.; University of North Carolina at Chapel Hill; *mjfernan@email.unc.edu*

Load lifting with asymmetric wings in the hawkmoth (Manduca sexta)

In nature, wing damage is common in insects, resulting in wing asymmetries. Recently, we found that despite damaged wings, hawkmoths are able to maintain flight stability during hovering through neural modulation of muscle activity. Moths have to constantly steer to counteract the torque produced by the wing asymmetry. Therefore, we expect to see a cost to this constant steering on other aspects of flight performance such as maximum lift production. In this study we determined these costs by measuring (1) maximum load lifting capability and (2) oxygen consumption and carbon dioxide production during hovering flight in hawkmoths (*Manduca sexta*). We tested three cases: (a) symmetric undamaged wings, (b) asymmetric with one wing clipped, and (c) symmetric with both wings clipped. We found kinematic differences between the asymmetric wings including increased wingbeat frequency with wing area reduction and increased stroke amplitude on the clipped wing compared to the unclipped wing. Although force production is proportional to second moment of wing area, we expected to find a larger decrease in the maximum vertical force exerted by the moths in case (b) than would be predicted by the reduction in area alone. Indeed, we found a greater reduction in vertical force than expected from the change in wing area alone. Furthermore, when wing area is further reduced by clipping both wings symmetrically, vertical force production does not decrease below the levels measured for asymmetric clipping. We suggest that there is a significant cost in control in addition to the cost of the total reduced wing area seen in our asymmetric and symmetric wing clipping treatments.

22.10 FERRY, LA*; GIBB, AC; Arizona State Univ, Northern Arizona Univ; *lara.ferry@asu.edu*
Jaw Elongation and Piscivory in Fishes
Piscivory is a niche utilized by fishes due presumably to its obviously high energetic reward. However, eating other fish as food typically requires overcoming what has been termed 'gape-limitation'. Because fish tend to be among the largest prey organisms eaten by other fish, a large gape, as well as mechanisms for manipulating the large prey for transport are required. Many piscivorous lineages simply must grow into the piscivorous niche, waiting to attain a certain body size so that a minimum mouth size can also be achieved. Alternatively, several lineages independently have evolved jaw elongation associated with piscivory. Jaw elongation allows for a larger opening between the upper and lower jaw tips without concomitant changes to gape angle. Thus, the piscivorous niche is available to these species at a much smaller body size. Although the loss of features such as a lip ligament connecting the upper and lower jaws can assist with this, changes to the anatomy do not seem strictly necessary as the jaw opening mechanism (except for tip elongation) in largely conserved in several long-jawed species when comparing them with closely related short-jawed relatives from the same lineages. We illustrate this with kinematic data from prey-capture events from several independent lineages including the Esocidae, Cypriniformes, and Cyprinodontiformes.

3.2 FIELDS, L.G.*; DEVRIES, A.L.; University of Illinois at Urbana-Champaign; *lgfield2@illinois.edu*
Ecological physiology of the Antarctic Trematomus fishes: effect of temperature and ice on freeze avoidance
The frigid waters of the Southern Ocean encompass a range of habitats. The high latitudes can experience year-round ice cover whereas the lower latitudes have only seasonal ice cover in many places and more drastic seasonal temperature changes. Fishes of the genus *Trematomus* that colonized the Southern Ocean occupy niches ranging from bottom dwelling and ice-avoiding, to the sub-ice platelet layer. Although regarded primarily as a high latitude group because of their abundance, *Trematomus* species are also found in the lower latitudes of the Antarctic Peninsula and South Shetland Islands but in smaller numbers. Freeze avoidance in the Antarctic notothenioids is linked to the presence of antifreeze glycoproteins (AFGPs) and antifreeze potentiating protein (AFPP), both of which adsorb to endogenous ice crystals, inhibiting their growth. Both high and low latitude Trematomids possess AFGP and AFPP, but the relative concentration and contributions to the hysteresis freezing points differ depending upon a number of environmental factors. High latitude specimens of *T. bernacchii*, inhabiting the anchor/ice platelet layer, have the lowest freezing points (-2.14°C) and highest levels of AFGP and AFPP (53.56mg/mL) while *T. loennbergii*, a benthic species inhabiting the ice-free deep water, has the highest freezing points (-1.46°C) and lowest levels (39.89mg/mL). The same species inhabiting the low latitude waters have moderately reduced hysteresis freezing points (-1.64°C, -1.02°C) and reduced antifreeze protein levels (40.88mg/mL, 30.02mg/mL) for *T. bernacchii* and *T. loennbergii* respectively. How the geographic range and environmental factors associated with range such as seasonal temperature fluctuations and presence of ice has influenced their freeze avoidances is discussed.

S6-1.5 FIELDS, Peter A.*; COX, Kelly; KARCH, Kelly R.; Franklin & Marshall College; *peter.fields@fandm.edu*
Latitudinal variation in protein expression in the salt marsh mussel Geukensia demissa
Individuals of a broadly distributed species often experience significantly different environmental conditions depending on location. For example, *Geukensia demissa*, the ribbed salt marsh mussel, occurs intertidally from the Gulf of St. Lawrence to the Yucatan Peninsula; within this range, northern populations are exposed to temperatures cold enough to freeze tissue, while southern populations can experience temperatures approaching the species' upper lethal limit. We are interested in determining whether the species comprises a panmictic population demonstrating extreme eurythermality, or whether populations at different locations possess unique adaptations to cope with local conditions. We have collected *G. demissa* at nine locations from Maine to Mississippi and are using a proteomic approach to describe how protein expression varies across this species' latitudinal range. We acclimated individuals of each group to common conditions (18°C, constant immersion) for four weeks, and exposed a subset of these to acute heat stress (40°C for 1 h, followed by 24 h recovery at 18°C). Gill proteins were separated using 2-D gel electrophoresis, and image analysis software was used to detect proteins that vary in abundance with latitude, acute heat stress, or both. The proteins varying most significantly are being identified via mass spectrometry in order to detect differences in the mechanisms by which mussels from different locations protect themselves from heat damage. To put our proteomic work into context, we also are creating an ITS-based molecular phylogeny of these groups. By combining phylogenetic information and proteomic data on responses to acute heat stress, we expect to better describe how species adapt to environmental conditions across broad latitudinal ranges.

67.4 FIGUEROA, Alex*; LAILVAUX, Simon; University of New Orleans; *afigueroa21@gmail.com*
Ecomorphology and Convergence in Arboreal Snakes
Snakes are characterized by a constrained and specialized body plan, capable of slight modifications and adaptations relative to other vertebrates because they lack external appendages. Nonetheless, morphological differences have evolved among snakes of dissimilar habits. If morphological constraints restrict species to a limited set of adaptations, then selection may lead to species and communities comprising distantly related lineages similar in ecomorphology. Arboreality in snakes is represented by a suite of ecomorphological and physiological adaptations shaped by selection to overcome the environmental and ecological challenges presented by the arboreal lifestyle. Although convergence is likely to be prominent in arboreal snakes, it has seldom been quantified and specific ecomorphs have not been identified. Morphology most often reflects phylogeny, yet morphological divergence may also occur in response to ecological factors such as habitat use and diet. Therefore, a phylogenetic approach is essential for distinguishing between conserved morphologies due to common ancestry and morphological shifts associated with an ecological origin. Patterns of habitat use remain similarly unknown for arboreal snakes, but it is likely that snakes using trees partition the available habitat into structural niches due to the diversity and structural complexity of vegetation and microclimates setup by the trees vertical gradients. If so, these differences may be reflected in snake morphology, as species should be adapted for a particular structural niche, thereby limiting competition with sympatric species. Identifying the patterns of morphological adaptations and/or constraints considered indicative of arboreality will undoubtedly lead to a better understanding of the evolution and distribution of arboreal snakes.

113.5 FISH, Frank E*; GABLER, Molly K; BENESKI, John T; MULVANY, Samantha; MOORED, Keith W; West Chester Univ., Pennsylvania, Univ. of South Florida, Tampa , Princeton Univ. New Jersey; *ffish@wcupa.edu*

Hydrodynamic function of the cephalic lobes of the cownose ray for bottom swimming stabilization

The cownose ray (*Rhinoptera bonasus*) is an epipelagic swimmer that forages on the ocean bottom. To sense food under the bottom substrate, the ray deploys two depressible cephalic lobes, which are anterior modifications of the pectoral fins. The geometry and orientation of the cephalic lobes, when in contact with the bottom, indicate a potential passive hydrodynamic function. CT scans of cownose rays were used to define the external geometry of the animal with and without deployment of the cephalic lobes. Scale models of the rays without pectoral fins were produced with a 3D printer (ZPrinter 450) from reconstructed CT images. Models were tested in a flow tank at flow speeds in accordance with the typical swimming speeds of foraging rays. The models were connected to a force transducer to measure lift as the angle of attack was varied from -40º to 40º. A model head with the cephalic lobes deployed was constructed with dye injection ports for flow visualization. Models without cephalic lobes deployed generated a positive lift that increased curvilinearly with water speed. A negative lift was observed from models with the cephalic lobes extended. Flow visualization indicated that cephalic lobes directed the water flow downward in accordance with production of negative lift. Downward deflection of flow was due to a Venturi effect from the pressure difference between fluids located externally and internally of the lobes. The negative lift would aid in stabilizing the head to keep the sensory surface of the cephalic lobes in contact with the substrate and counter any pitching motions induced by oscillations of the pectoral fins.

10.1 FITES, J. Scott; RAMSEY, Jeremy P.; ROLLINS-SMITH, Louise A.*; Vanderbilt University, Nashville TN, James Madison University, Harrisonburg VA, Vanderbilt University Med. Center, Nashville TN; *louise.rollins-smith@vanderbilt.edu*

Paralysis of amphibian lymphocyte functions by products of the chytrid fungus, Batrachocytrium dendrobatidis

Batrachochytrium dendrobatidis (Bd) is a pathogenic chytrid fungus that infects the keratinized epithelium of amphibian skin. Severe infections cause lethal chytridiomycosis in many amphibian species, contributing to the decline of amphibian populations globally. Although amphibians have several types of immune defenses against *Bd*, the role of adaptive immunity in resistance to chytridiomycosis is unclear. Our previous studies of the effects of X-irradiation in *Xenopus laevis* suggested that adaptive immunity is an important component of resistance to *Bd* infection in this species. However, lack of extensive lymphocyte infiltration in diseased skin suggests an impaired immune response. We show here that mature *Bd* sporangia, but not zoospores, have the capacity to inhibit the proliferation of mitogen-stimulated B and T lymphocytes from *X. laevis* and *Rana pipiens*. This inhibition occurs even when the cells are separated from the lymphocytes by a cell-impermeable membrane in a transwell assay. One mechanism of inhibition is by induction of lymphocyte apoptosis. Supernatant factors shed by the fungus also inhibit lymphocyte proliferation and induce apoptosis. The active factors are heat-resistant, acid-resistant, and protease-resistant suggesting that the inhibitory factors are not proteins. Because the factors are released by mature sporangia containing cell walls and not by zoospores that lack a cell wall, we hypothesize that the inhibitory factors are cell wall components. Support: NSF 0843207.

103.3 FLAMMANG, B.E.*; LAUDER, G.V.; Harvard University; *bflammang@post.harvard.edu*

Navigation through obstacles by bluegill sunfish under different sensory conditions

Numerous studies have shown that the pectoral fins of bluegill sunfish act in a propulsive role, especially during swimming at slow speeds. In order to assess if sunfish are also capable of using their pectoral fins for tactile sensory input and to navigate through obstacles, we created two obstacle courses through which they swam under different water speed and sensory input conditions. The first obstacle course was a maze of alternating 2 cm diameter posts, 4 cm apart on center, through which the fish swam through at flow speeds of 0.0, 0.5 and 1.0 Ls^{-1}. Four fish each swam through the first obstacle under four treatment conditions: 1) with no modifications, 2) in complete darkness (filmed in infra-red) with lateral line intact, 3) lights on and lateral line knocked out with cobalt chloride, and 4) in complete darkness with the lateral line knocked out. A second set of experiments using an obstacle course with a narrowing angled entrance and long corridor was used to test the limit to the narrowness of a passageway through which a fish would swim forward and backward. Under normal conditions (in the light with lateral line intact), fish tapped obstacle posts as they passed them, reaching out with their fins to make contact with the obstacles. With reduced visual and lateral line input, fish tapped posts more frequently, for shorter periods of time, and swam through the obstacle at slower speeds. The limit to the narrowness of a passage through which a fish would swim was the width of its body. Flexibility of pectoral fins was important to permit fish to hover in confined spaces. These data provide behavioral evidence that fish actively use input from pectoral fin bending to assist in navigating through complex cluttered environments.

9.4 FLIES, Andrew S*; MANSFIELD, Linda S; TSAO, Jean I; HOLEKAMP, Kay E; Michigan State University; *fliesand@msu.edu*

Rank-related variation in immune function in a gregarious carnivore

Immune defenses are energetically costly in many ways, including nutritional demands of producing new immune defense cells and molecules, and collateral damage to unintended targets of immune defenses. A growing body of evidence supports the hypothesis that resource quality can affect immune function by reducing trade-offs among competing physiological functions. Here we tested the hypothesis that differential access to food resources would affect immune function among spotted hyenas (Crocuta crocuta). Spotted hyenas live in social groups containing up to 90 individuals; priority of access to food by individual group members is determined by their positions in a strict linear dominance hierarchy. Males disperse from their natal territories but females are philopatric and their offspring assume ranks immediately below them in the group's hierarchy; immigrant males are subordinate to all females. High-ranking hyenas are able to monopolize carcasses of prey animals, and feed until they are satiated, whereas subordinate group members generally obtain lesser quality and quantity of food. The top priority of access to resources enjoyed by high-ranking hyenas results in fitness benefits mediated by faster growth, earlier onset of breeding, and shorter inter-litter intervals. We predicted that superior food access would enhance immune defenses among high-ranking female spotted hyenas. We used serum from wild hyenas in bacterial killing assays to assess one aspect of immune function. Initial analyses showed that sera from high-ranking females had greater bacterial killing ability than sera from low-ranking females. We also inquired whether total immunoglobulins and white blood cells similarly vary with social rank.

3.1 FLY, E.K.*; HILBISH, T.J.; University of South Carolina; *efly@biol.sc.edu*
Comparative physiological energetics of the blue mussel species in response to increased temperatures
The three species of the blue mussel complex are distributed worldwide, but differ biogeographically with respect to temperature. *Mytilus galloprovincialis* is sub-tropical, while *M. edulis* and *M. trossulus* are cold-temperate and boreal, respectively. We examined whether these sister-species show physiological differences with respect to temperature, as is suggested by their global distributions. We hypothesized that the warmer-water species, *M. galloprovincialis*, has an advantage at higher temperatures than *M. edulis* and *M. trossulus*, in terms of maintaining a positive energy budget. We measured respiration rates, absorption efficiencies, and clearance rates of all three species at a range of temperatures (5, 10, 15, 20, 25, and 30°C) in both summer and fall. *Mytilus galloprovincialis* has a greater physiological advantage at high temperatures than the other two species. Of the three physiological variables measured, clearance rate is the driving force in determining each species' energy budget, and *M. galloprovincialis* maintains higher clearance rates at warmer temperatures than the other species. Thus, *M. galloprovincialis* maintains a positive scope for growth through 25°C, while *M. edulis* shows negative scope for growth at 25°C, and *M. trossulus* shows negative scope for growth values at 15°C and higher. The physiological advantage seen in *M. galloprovincialis* is expected to be a factor in the advance of this species into the colder-water species' habitat with warming water temperatures.

118.4 FLYNN, R.W.*; KUHNE, W.W.; SCOTT, D.E.; ERICKSON, M.R.; MILLS, G.L.; TUBERVILLE, T.D.; LANCE, S.L.; Univ. of Georgia, Savannah River Ecology Laboratory, Savannah River National Laboratory, UGA-SREL, UGA-SREL; *wflynn@srel.edu*
The Lethal and Sublethal Consequences of Copper Exposure For Lithobates sphenocephalus and Gastrophryne carolinensis
Exposure to environmental contaminants is one of the many documented causes of global amphibian population declines. Contamination of aquatic habitats with heavy metals is an increasingly common and pernicious problem for amphibians. Copper (Cu) is an essential trace element that is ubiquitous in nature and toxic to organisms at levels only slightly more than those needed for normal physiological function. We conducted a series of laboratory trials to investigate the effects of Cu exposure on *Lithobates sphenocephalus* and *Gastrophryne carolinensis* at environmentally relevant concentrations. We found significantly different susceptibilities to Cu at the individual, population, and species levels. For *L. sphenocephalus*, survivorship from the egg stage to metamorphosis is significantly reduced by exposure to >50 ppb Cu. In addition, egg/larval success differed among clutches, and both source of clutch and Cu treatment directly affected larval period. *G. carolinensis* embryos are substantially more sensitive to Cu than *L. sphenocephalus*, with levels as low as 15 ppb significantly reducing egg survival. To further examine impacts on *G. carolinensis* we assessed the effects of Cu level on embryonic developmental rate from fertilization to free swimming. We demonstrate that Cu exposure significantly delays development. Under natural conditions delayed development can be an important sublethal effect that increases larval susceptibility to predation, decreases competitive ability, and reduces the likelihood of reaching metamorphosis during short hydroperiod years. Overall, copper significantly affects amphibian larvae and chronic exposure may alter important population processes.

105.4 FORDYCE, J.A.*; NICE, C.C.; DIMARCO, R.D.; University of Tennessee, Texas State University; *jfordyce@utk.edu*
Ontogenetic and sex specific variation in chemical sequestration by a toxic herbivore
Many insect herbivores sequester plant secondary compounds that in turn provide them with defense against natural enemies. The pipevine swallowtail, *Battus philenor* L., sequesters aristolochic acids as larvae from their *Aristolochia* host plants, providing larvae and adults with defenses effective against a broad range of natural enemies. We examined ontogenetic variation in sequestered aristolochic acid content across eggs, six larval instars, pupae, and adults. We find evidence of selective sequestration of non-polar forms of aristolochic acid, and the possible interconversion of aristolochic acids by *B. philenor* larvae. Further, we find evidence of local adaptation to host plant chemotype and sex specific trade-offs associated with sequestration. We discuss the ecological and evolutionary consequences of this variation.

2.4 FOSTER, K.L.*; HIGHAM, T.E.; Univ. of California, Riverside; *kfost001@ucr.edu*
How fore- and hindlimb function changes with incline and perch diameter in Anolis carolinensis
Arboreal lizards often traverse a wide range of inclines and surface diameters in their habitats. To execute these complex locomotor behaviors, both the fore- and hindlimbs are likely important. However, few studies have examined the role of the forelimbs in lizard locomotion. To assess whether the fore- and hindlimbs of lizards respond similarly to changes in incline and perch diameter, we obtained three dimensional high speed video of 4 adult male green anoles (*Anolis carolinensis*) running on flat (9cm wide) and small, round (1.3cm diameter) perches inclined at 0º, 45º, and 90º. Overall, the forelimb extended and retracted faster through stance than the hindlimb, while initial flexion at footfall was faster in the hindlimb. Proximal joint angles of both limbs were more affected by perch diameter changes than distal joints, although the humerus and femur exhibited opposite trends. In contrast, the distal joints were more affected by incline than perch diameter. A greater number of variables were significantly affected by surface diameter than by incline and for the majority of those that showed trends with incline, the 45º treatment on the small perch was significantly different from the level and vertical. At all inclines, the manus were placed on the dorsal surface of small perches with the pes placed dorso-laterally, suggesting differences in the propulsive mechanisms and contributions between the forelimb and hindlimb. We not only show a differential response to habitat challenges between fore- and hindlimbs, but we suggest that the forelimb plays an important role in propelling arboreal anoles under certain circumstances. The next step is to investigate the physiological mechanisms underlying these functional differences between limbs in relation to habitat structure.

88.3 FOX, RA*; WILLIAMS, RN; Transylvania University;
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Badges of personality? Neophobia, corticosterone, and bib size in house sparrows Passer domesticus

In nonhuman animals, “personality” refers to individual variation in behavior that is consistent across time and/or context. Neophobia (i.e., reactivity to novel objects in a familiar environment) is a commonly-used index of personality in nonhuman animals, and has been linked to individual variation in basal levels of corticosterone (CORT) and/or CORT responsiveness to acute stress, as well as to ecologically-relevant outcomes such as the acquisition of dominance status in social groups. In the current study, we explore the relationship among neophobia, basal and stress-induced CORT levels, and bib size in house sparrows (*Passer domesticus*). The chest bib of the male house sparrow is a melanin-based signal that is thought to be related to social status and fighting ability. Because melanocyte stimulating hormone (MSH) and adrenocorticotropic hormone (ACTH, which controls CORT production by the adrenal glands) are both derived from the same precursor molecule, we predict that there may be a correlation between levels of circulating CORT and bib size in house sparrows, and that neophobia should be a predictor of these two variables.

16.4 FOX, Alicia M*; SCHREY , Aaron W; MCCOY, Earl D; MUSHINSKY, Henry R; University of South Florida;
amfox@mail.usf.edu

Comparison of Genetic Structure of the Florida Sand Skink, Plestiodon reynoldsi, in Homogeneous and Heterogeneous Habitat on Lake Wales Ridge in Central Florida

The Florida Sand Skink, *Plestiodon reynoldsi*, is a threatened fossorial lizard that occurs in the scrub found throughout the central ridges in Florida. Florida scrub is a highly heterogeneous habitat, including areas of continuous scrub and areas with a mosaic of scrub and wetlands. Genetic differentiation is known to exist among distinct geographic samples across its distribution; however, fine-scale analyses of genetic structure are needed to describe spatial genetic differentiation in this species. The goal of this study was to compare genetic structure of Florida Sand Skink populations in continuous and heterogeneous scrub. Multiple microsatellite loci were screened in individuals sampled from two sites: 1) a large homogeneous scrub location near Davenport, Florida, and 2) a large heterogeneous scrub at the Archbold Biological Station near Lake Placid, Florida, which has habitat heterogeneity and numerous small wetlands throughout the scrub. Samples at Davenport were collected from four sites (less than 2 km apart), each with multiple transects of pitfall arrays, while samples at Archbold were obtained from pitfall traps in 30 enclosures located in scrub patches. We determined the number of genetic clusters that occurred at each location in a similar geographic area. STRUCTURE revealed only one cluster at Davenport, while multiple levels of clustering were present at Archbold. Our study reveals that Florida Sand Skinks exhibit more genetic differentiation in a heterogeneous scrub than in a homogeneous scrub. These differences in genetic structure may have implications for the conservation and management plan for this threatened species.

27.2 FREDERICH, M.*; TOOMBS, C.; PENNOYER, K.; Univ. of New England, Biddeford; *mfrederich@une.edu*

Color-polymorphism in the Green Crab, Carcinus maenas: Are green morphs really more stress tolerant than red morphs?

Despite the name green crab, this species shows carapace coloration from bright green to dark red. Crabs are green after molting, delayed molting leads to darker red shades. Earlier work investigating organismic parameters suggests that the color-polymorphism is mirrored by physiological polymorphism, with green morphs more anoxia, hypoxia, and salinity tolerant. We tested the hypothesis that differential organismic stress tolerance is reflected in cellular stress parameters and ion transporters. Red and greens were exposed to 2h anoxia, 24h hypoxia or 72h low salinity (10ppt) stress. We analyzed at the organismic level treadmill running endurance, O_2 consumption, and heart rate, on the cellular level lactate accumulation, AMPK and HSP70 activity and mRNA expression in heart tissue, as well as ion transporters (mRNA and protein levels) in gills. At the organismic level under normoxic conditions no differences were found between red and greens. During anoxia red and greens did not differ in their organismic response, but greens showed elevated lactate, AMPK activity and HSP70 protein. During hypoxia, reds had reduced running endurance and increased HSP70 protein, but greens had higher lactate and AMPK activity. No differences were found in AMPK or HSP70 mRNA expression. During low salinity stress mRNA levels of NaK-ATPase, NaK2Cl-cotransporter, NaH-exchanger, carbonic anhydrase, AMPK and HSP70 showed differential expression, matching organismic parameters, and indicating that greens are more salinity tolerant. The data show color morph-specific stress tolerance, but greens are not generally more stress tolerant than red morphs. Funded by NSF-IOB0640478 and an APS summer research award.

70.1 FREEMAN, Christopher/J*; THACKER, Robert/W; BAKER, David/M; FOGEL , Marilyn; Univ. of Alabama, Birmingham, Carnegie Institution of Washington, Carnegie Institution of Washington; *cjfre@uab.edu*

Determining the benefits of symbiosis: tracing the products of symbiont nitrogen and carbon metabolism to host sponges using incubations with enriched stable isotopes

While some marine sponges host microbial communities that might confer supplemental nutrition crucial to host survival,our understanding of how these interactions benefit the host is still limited. To assess the transfer of symbiont nitrogen and carbon across the species *Aplysina cauliformis*, *Aplysina fulva*, *Chondrilla nucula*, *Neopetrosia subtriangularis*, and *Xestospongia bocatorensis*, which host abundant microbial populations, and *Niphates erecta*, which lacks symbionts, we conducted light-dark bottle incubations using seawater laced with inorganic compounds enriched in ^{15}N and ^{13}C followed by the isolation of sponge and microbial cell fractions from bulk sponge tissue prior to isotope analysis. Since these compounds can only be taken up by microbial symbionts, ^{15}N and ^{13}C enrichment of the sponge fraction is due to the transfer of enriched biomolecules produced by the symbiont. Enrichment of ^{15}N and ^{13}C was highest in sponges hosting dense communities of microbial symbionts and was directly related to the photosynthesis / respiration ratio of each species, suggesting that nutrient uptake and transfer is dependent on the productivity of the symbiosis. In a second experiment, we incubated *Aplysina cauliformis* in 4 treatments (full light, low shade, high shade, and dark) with enriched ^{13}C tracer. While the ^{13}C enrichment of microbial and sponge cell fractions was highest in the full light treatment, the nutritional interaction between symbiont and host remained stable across all treatments. Together these studies provide compelling evidence supporting the contention that hosting dense communities of microbial symbionts provides the host with access to products of novel microbial metabolic pathways.

37.3 FRIESEN, Chris/R*; ESTES, Suzanne; MASON, Robert/T; Oregon State Univ., Portland State Univ.; *friesenc@science.oregonstate.edu*
Snake Sex in the City or the Country? Different mating aggregation densities generate asymmetry in postcopulatory sexual selection in two populations of red-sided garter snakes
Models show that reproductive traits may quickly diverge via a coevolutionary arms race due to sexual conflict and sperm competition. The density of mating aggregations of garter snakes at spring emergence varies among populations which may lead to divergence because of sexual conflict and sexual selection within different social contexts. We found evidence of asymmetrical behavioral and postcopulatory prezygotic sexual isolation between two populations of Red-sided Garter Snakes (*Thamnophis sirtalis parietalis*). Asymmetry in reproductive isolation has been modeled as the transitory effect of rapid divergence of sexually selected traits facilitated by drift along the stable line of equilibria. Our study populations differ in several respects the most salient of which is low versus high density mating aggregations. The population with high density aggregations, and probably with the highest level of sexual conflict over mating, was also the population that exhibited homotypic mate preference and sperm precedence.

83.4 FRISCIA, A.R.*; SCHLINGER, B.A.; Univ. of California, Los Angeles; *tonyf@ucla.edu*
Unique Wing Morphology in Wingsnapping Manacus Manakins
Manakins (*Manacus* spp.) have complex courtship displays with loud, whip-crack-like, wingsnaps and rollsnaps. During wingsnaps, the wings are forcefully lifted over the head to strike at the wrists creating a loud snapping sound. Previous work has confirmed that the sound of the snap comes from percussion of the wings against one another. Investigation of the osteology of the wing discovered a unique morphology of the radius that may facilitate this sound generation mechanism. The radii of *Manacus* are considerably flattened cranio-caudally and broad dorso-ventrally. Interestingly, this morphology is shown in both males and females, even though the latter do not normally wing-snap. Other piprids (*Xenopipo*, *Corapipo*, *Chiroxiphia*, and *Pipra*) have complex courtship displays, and some do show a similar flattened morphology, especially when compared to other Tyrannides (*Cotinga*, *Sayornis*), but not to the extent seen in *Manacus*. This may indicate that the morphology is autapomorphous for Pipridae, and hints at a possible functional mechanism. The broadened radius may allow for larger muscle attachments and longer lever arms to facilitate the complex motions associated with the courtship displays in this family, and may have been further modified for sound production in *Manacus*. Supported by NSF IBN 0213194.

41.9 FULLER, Adam B.*; HANNINEN, Amanda F.; ROBINSON, Stephanie; LENOX, Annie; EARLEY, Ryan L.; Univ. of Alabama, Tuscaloosa; *atom.fullerene@gmail.com*
Social context and behavioral plasticity in the mangrove rivulus (Kryptolebias marmoratus)
A fundamental question in the biological sciences is how genes and environment interact to govern phenotype. Mangrove rivulus, *Kryptolebias marmoratus*, naturally produce genetically identical offspring through self fertilization, and therefore provide a powerful model in which to explore questions about behavioral and morphological plasticity in response to social context experienced during development. We used two isogenic strains of this species to examine how social environment and genetic background interact to dictate adult behavioral and morphological phenotype. In two separate experiments we raised fish from hatching to the onset of adulthood (10 weeks) either in isolation or in groups of two or four conspecifics. Growth rates, feeding rates, and within-group interactions were monitored throughout, and animals were subjected to standardized tests for aggression and boldness at 10 weeks. Fish raised with conspecifics grew more rapidly than isolates, but with greater variation between individuals. Within-group aggression contributed to the formation of dominance hierarchies in group-housed animals, and likely explains growth rate variance in that treatment. We also show that social context affects the adult behavioral phenotype. We discuss our results in the context of consistent behavioral and morphological differences that emerge as a consequence of differences in social environment experienced during early development.

1.2 FULLER, P. O.*; TAKADA, T.; OUFIERO, C. E.; WAINWRIGHT, P. C.; Univ. of California, Davis; *pfuller@ucdavis.edu*
The kinematic basis for the evolution of zooplankton feeding in haemulid fishes
Zooplankton prey are small, difficult to detect, and often evasive; therefore, reef fishes relying on midwater zooplankton for food require specific adaptations to overcome the difficulty of catching enough zooplankton to survive. Three closely related Caribbean reef fishes in the genus *Haemulon* were filmed in the lab to identify how feeding mechanics differ for fish specializing on zooplankton. These taxa represent an evolutionary transition to diurnal zooplankton feeding: *Haemulon vittatum* feeds on midwater zooplankton during the day, while *H. striatum* and *H. aurolineatum* feed on benthic invertebrates at night. In the lab, strike kinematics from each species feeding on small fish prey were captured from a lateral view with high-speed video recorded at 1000 Hz. Feeding sequences of juvenile specimens were recorded from 7 *H. vittatum*, 10 *H. striatum*, and 10 *H. aurolineatum* specimens (270 sequences total). Eleven landmarks from the video sequences were tracked digitally to measure timing, strike distance, and cranial kinematics during prey capture. Preliminary data from 57 sequences suggest that *H. aurolineatum* and *H. striatum* share similar feeding kinematics, while the planktivorous *H. vittatum* differs only in having greater jaw protrusion coupled with a faster jaw protrusion speed. Greater jaw protrusion projects the predator's mouth and suction field closer to the prey without increasing the disturbance caused by forward body motion. Therefore, the strike pattern of *H. vittatum* may be adaptive by decreasing the time during which evasive zooplankton can detect movement and escape. Morphology and feeding performance on zooplankton prey will also be discussed.

46.5 GADANI, A.P.*; ALFARO, M.; University of California, Los Angeles; *agadani@ucla.edu*
All I Ever Learned About Macroevolution I Learned in Fifth Grade
Uneven patterns of biodiversity are one of the most striking patterns in the natural world yet macroevolutionary explanations for these patterns are not commonly presented to students until high school or even college. To investigate whether these ideas can be learned by elementary school students we developed a workshop involving an interactive three-dimensional coral reef model. Following a presentation about biodiversity, adaptive zones, and coral reefs, students participated in several activities (evolving fish-puppet lineages and matching fish-puppets to reef habitats on the coral model) illustrating explanations of why species richness might differ among lineages. We presented the workshop to multiple fifth grade classrooms in the Los Angeles area and used surveys to compare their general knowledge of biodiversity patterns before and after our workshops. The results of the study will be discussed.

This workshop represents an experimental collaboration between an evolutionary biologist and a visual artist working as an artist in resident in the lab.

12.3 GAGNON, Yakir*; SPEISER, Daniel; SWEENEY, Alison; Duke Univesity, University of California, Santa Barbara; *12.yakir@gmail.com*
The visual function of the fluorescent lenses of Greeneye fish
The deep-sea environment is home for a variety of unique and strange animals all adapted to the dim-light environment. Many complex adaptations have developed in response to these unique conditions. Among these are transparency, cryptic coloration, mirrored body, and counter illumination. Counter adaptations for breaking these camouflage strategies include polarization vision, colored ocular filters, and offset visual pigments. The Greeneye deep-sea fish, *Chlorophthalmus*, is typically found at depths of 50-1000 m. While it is known to have green lenses, the function of these unique lenses is not well understood. To better understand the physiology and visual system of the Greeneye fish, specimens were collected from the Sea of Cortez at depths of 800 m during June 2008. A spectral analysis of the lenses demonstrated strong fluorescence with an excitation peak at 410 nm and emission peaks at 480 and 530 nm. Microspectrophotometry recordings from the retina revealed that the fish’s photoreceptors have a well-correlated maximum absorbance wavelength of about 480 nm. In addition, preliminary results indicate the lens can create an image from photons originating from this fluorescence, blue (410 nm) images are converted by the lens to green (480-530 nm) ones, preserving the spatial information of the images. The spatial integrity of signals at the excitation wavelength (410 nm) is thus preserved and the signal is converted to the maximum absorbance wavelength of the retina (480 nm). We therefore believe that the Greeneye's visual system achieves an exceptionally broad spectral sensitivity (400-500 nm) using only one photoreceptor type, allowing the fish to be visually sensitive to a wide range of differently colored bioluminescent animals as well as the downwelling light.

41.7 GARCIA, M.J.*; STANLEY, S.; VAUGHN, S.; EARLEY, R.L.; TAYLOR, DS; University of Alabama, Brevard County Environmentally Endangered Lands Program; *mjgarcia@crimson.ua.edu*
Evidence for Local Adaptation of Life History Traits in the Mangrove Rivulus (Kryptolebias marmoratus)
Variation in life history traits can be observed both within and between populations. This variation can result from individuals exhibiting phenotypic plasticity in response to local conditions, adaptation, or a combination thereof. The aim of this study was to evaluate genetic contributions to life history variation (fecundity and reproductive investment) using a powerful, genetically tractable model, the mangrove rivulus. This hermaphroditic fish possess the unique ability to self fertilize; isogenic strains can result from extensive inbreeding through selfing. Thirty-three isogenic strains were derived from field caught individuals collected from seven geographic locations on the east and west coasts of mainland Florida and the Florida Keys. Seven individuals of the F2 generation were collected from each strain and were raised under standard common garden conditions. At three months individuals were monitored daily for viable egg production (age of maturity) and subsequent clutches of eggs (inter-clutch interval) were collected. Eggs were measured (diameter in mm) to determine egg size; a proxy from gamete investment. Fecundity and reproductive investment were then examined to determine differences within- and between-lineages, populations, and geographical scales. Information gleaned from this study may shed light on how variable selection pressures across multiple scales might shape life history traits.

34.2 GAREY, JR*; WU, T; AYRES, E; BARDGETT, RD; WALL, DH; University of South Florida, Colorado State University, Lancaster University, Colorado State University; *garey@usf.edu*
The global distribution and diversity of soil invertebrates
The distribution of soil invertebrates and the relationship of below-ground biodiversity to above-ground biodiversity are not well studied at the global scale. We analyzed approximately 18,000 environmental 18S rRNA gene sequences representing 20 phyla of soil invertebrates from samples at 11 locations that spanned a wide range of biomes and latitudes. No globally cosmopolitan taxa were found and only 14 of 2,259 Operational Taxonomic Units (OTUs) were common to 4 or more locations. A comparison of diversity and community structure data to environmental factors reveals a possible inverse relationship between above and below ground invertebrate diversity. Our analyses suggests that the low below-ground biodiversity at locations of high above-ground biodiversity could be explained by differences in soil inorganic N and pH. Our locations could be characterized as being dominated by microarthropods or dominated by nematodes and we found significant differences in soil pH, root biomass, mean annual temperature, soil inorganic N and C:N, litter, and moisture in microarthropod dominated locations compared to nematode dominated locations. Our study suggests that small soil animals have distinct biogeographical distributions and provides new evidence of the link between above-ground and below-ground biodiversity at a global scale.

55.4 GARRETT, Sandra/C*; ROSENTHAL, Joshua/JC; University of Puerto Rico, Institute of Neurobiology; *sandracoralgarrett@gmail.com*

RNA editing underlies temperature adaptation in K+ channels from polar octopuses

Early studies with squid giant axons showed that K^+ channels, and the action potential phases they underlie, are especially temperature sensitive suggesting that in polar cephalopods they could be targets for adaptation. To look for evidence of cold adaptation, we compared orthologs of the squid delayed rectifier K^+ channel from a tropical and an Antarctic octopus. The two genes encoded channels that differed at only 4 positions, and when the channels were expressed in a heterologous system they had nearly identical electrophysiological properties. Since we found no evidence of gene level adaptation in the Antarctic channel, we next considered A-to-I RNA editing, which is known to generate substantial diversity in squid K^+ channels. Twelve RNA editing sites were identified in the octopus channels, four of which were edited differently between the two species. Among these, the site I321V appeared cold adaptive: it was almost completely edited in the Antarctic channel but mostly unedited in the tropical channel, and it dramatically accelerated channel closing. Models based on single channel and macroscopic currents suggested that I321V doubled the rate of the open state to closed state transition, thereby speeding closing kinetics with little effect on open probability, or opening kinetics. If I321V were truly used for cold adaptation, then we would expect the level of editing at this site to correlate with ambient temperature for other octopus species. We measured I321V editing in six additional species and found high levels in Arctic species, low levels in tropical species, and intermediate levels in temperate species. In conclusion, octopus K^+ channels do have cold adaptive structural changes, but these changes are coded at the level of RNA processing, not in the gene.

91.4 GARRETT, J.N.*; FISH, F.E.; West Chester Univ., Pennsylvania; *jg754235@wcupa.edu*

Kinematics of terrestrial locomotion in phocid seals: Importance of spinal flexion by an amphibious mammal

Pinnipeds are amphibious mammals that retain limbs to function on land and in water. The evolution of the limbs as flippers has placed constraints on the terrestrial locomotion of pinnipeds. Phocid seals cannot draw their hindlimbs under the body and must move over land by undulatory movements of the body in concert with the forelimbs. Previous examinations of terrestrial locomotion were limited to gross descriptions without consideration of terrain as an influence on performance. The purpose of this study was to detail the kinematics of terrestrial locomotion of phocid seals. For video analysis, grey seals (*Halichoerus grypus*) and harbor seals (*Phoca vitulina*) were recorded in captivity on level ground and in the wild on rocky beaches. Grey and harbor seals exhibited dorsoventral undulations with the sternum and pubis serving as the main weight bearing points. Forward movement was accomplished in an inchworm manner by a combination of spinal flexion and foreflipper protraction. An anteriorly directed wave of flexion by the spine positioned the foreflippers, which served as a pivot and aided in lifting the sternum off the ground. The foreflippers were retracted to pull the body forward. In some cases, the foreflippers were not used and forward progression was accomplished solely by spinal flexion. The seals traveled across a level platform with and without the use of the foreflippers. The seals could move on land at about 0.4 m/s. The amplitude of the spine decreased with increasing speed while the frequency of the undulatory wave in the body increased. This reliance on spinal flexion with reduced participation of the limbs incurs reduced performance for movement on land as aquatic locomotion is enhanced in phocids.

32.4 GEERINCKX, Tom*; HUYSSEUNE, Ann; BOONE, Matthieu; CLAEYS, Myriam; COUVREUR, Marjolein; DE KEGEL, Barbara; MAST, Peter; VAN HOOREBEKE, Luc; VERBEKEN, Kim; ADRIAENS, Dominique; Ghent University; *tom.geerinckx@ugent.be*

Soft dentin results in unique, naturally bendable teeth in scraping catfish

The teeth of vertebrates are used for biting, grasping, crushing, cutting and chewing, actions in which teeth experience mainly compressive forces acting mostly downward. Teeth are wonderfully adapted for this, with an ordered microstructure of hydroxyapatite crystals and organic components of the enamel(oid) and the dentine tissues contributing to the compressive, but also shear and tensile strengths, directing forces and preventing cracks. Some vertebrates, however, use their teeth for scraping or filtering, with teeth experiencing strong sideward forces, and some scraping suckermouth catfishes (Loricariidae) appear to have flexible teeth. Considering the mineralised nature of tooth tissues, the notion of flexible teeth seems paradoxal, though. We confirmed and quantified the extreme bending performance of single teeth (up to 180°), and show that reorganizations of the tooth (micro)structure and local hypomineralisation of the dentine are adaptations allowing flexibility and preventing breaking. In the dentine of the flexible zone, tubuli are absent, mineral elements are locally near-absent, and collagen is mostly longitudinally oriented. Tooth shape and internal structure appear to be optimised for bending in one direction, probably naturally occurring numerously during scraping feeding, but teeth can bend in the opposite direction as well. Not all Loricariidae possess flexible teeth, with the trait perhaps having evolved more than once. In view of the often unexpected mechanical properties of mineralised biological materials and the interesting process of actively biomediated dentine formation and mineralisation, the flexible tooth appears to be the finest illustration hitherto known.

74.5 GEFEN, E*; KALRA, B; University of Haifa- Oranim, Israel; *gefene@research.haifa.ac.il*

Desiccation stress triggers a switch to exclusive carbohydrate catabolism in scorpions

The scorpion hepatopancreas serves as an essential storage compartment considering the often unpredicted availability of prey. During desiccating stress water is mobilized from the hepatopancreas to replenish hemolymph volume in order to retain its hydration and osmotic stability. Carbohydrate oxidation is advantageous under these conditions as it results in high metabolic water production rate per unit of ATP formed, as well as the release of glycogen bound water. We therefore hypothesized that scorpions switch to exclusive carbohydrates catabolism during desiccation stress. Laboratory acclimated scorpions were kept for 48h without feeding, and respiratory gas exchange rate ratios and hepatopancreas metabolic fuel content were determined following additional 0-5 weeks of desiccation at 30˚C. Hepatopancreas water stores of the mesic *Scorpio maurus fuscus* (Scorpionidae) decreased significantly ($p<0.05$) following 1-week desiccation, consistent the species' high water loss rate. This response was delayed in the xeric subspecies *S. m. palmatus*. In contrast, the desiccation-resistant *Buthotus judaicus* and *Leiurus quinquestriatus* (Buthidae) maintained their initial fraction of hepatopancreas water for 4 weeks. Calculated RQ values indicate initial catabolism of a mixture of lipid, protein and carbohydrates (RQ~0.9) in all studied species. However, exposure to stressful conditions triggered a switch to exclusive carbohydrate catabolism (RQ not different from 1.0; $\alpha=0.05$). The timing of this event correlated with the respective species' susceptibility to desiccation as manifested in depletion of their hepatopancreatic water stores. Determination of hepatopancreas metabolic fuel content reiterated the delayed switch to exclusive carbohydrate catabolism in the more resistant Buthidae.

54.3 GEIST, N.R.; HILLENIUS, W.J.*; FREY, E.; JONES, T.D.; ELGIN, R.A.; Sonoma State Univ., College of Charleston, Staatl. Mus. Naturkunde Karlsruhe, Cal. State Univ. Stanislaus, Staatl. Mus. Naturkunde Karlsruhe; *hilleniusw@cofc.edu*

Breathing in a box: constraints on lung ventilation in giant pterosaurs

The evolution of large size among pterosaurs was usually accompanied by selection for a light yet strong skeleton, presumably to withstand the dynamic forces associated with flight, and most giant pterosaurs exhibit extensive fusion of the bones of the trunk. However, this process also added mechanical constraints on the mobility of the thorax that likely limited the options available for lung ventilation. Despite recent suggestions of an avian-like mechanism of costosternal pumping as the primary means of aspiration, an analysis of the lever systems associated with joints between the ribs, vertebrae, sternum, and pectoral girdle indicates limited mobility of the ribcage and sternum that is incompatible with that model. Rather, comparisons with modes of lung ventilation in extant amniotes suggests that the stiffened thorax, coupled with mobile gastralia and prepubic bones, was most consistent with an extra-costal mechanism for lung ventilation in large pterodactyloids, perhaps similar to a crocodile-like visceral displacement system

10.4 GERVASI, Stephanie S.*; GONDHALEKAR, Carmen; BLAUSTEIN, Andrew R.; Oregon State University, Corvallis, OR; *gervasis@science.oregonstate.edu*

Physiological responses of amphibians after exposure to the fungal pathogen, Batrachochytrium dendrobatidis

Emerging infectious diseases of wildlife are a threat to species and populations. For example, the emerging fungal pathogen, Batrachochytrium dendrobatidis (Bd), has been implicated as a driver of worldwide amphibian population declines and extinctions. Although we have learned a great deal about the ecology and distribution of Bd, less is known about how Bd affects physiological responses of amphibian hosts. Both lethal and sublethal effects may occur when hosts are exposed to Bd. Sublethal effects may include various physiological responses including those related to host immunity. We investigated responses of different amphibian host species after short-term or longer-term exposure to Bd. Variation in physiological responses to the pathogen may underlie interspecific variation in susceptibility to disease. Further, differences among hosts in response to exposure and infection with Bd may place certain species or groups of species at disproportionate risk of disease-induced population declines and species extinctions.

31.1 GIBBS, Victoria K.*; CUNNINGHAM, Adele C.; WATTS, Stephen A.; Univ. of Alabama at Birmingham; *victoria.gibbs@villanova.edu*

Enigma of the sea urchin gut: Abiotic and biotic conditions influence form and function

Seasonal reproductive cycles and factors influencing gonad production have been studied for a number of sea urchin species; however, the digestive system of the sea urchin is not well understood. Gross structure and cellular composition of the regular echinoid digestive tract have been described, but study of digestive physiology is limited. We present data describing biotic factors, such as reproductive cycle, diet, and dietary lipid type, and an abiotic factor, temperature, that influence the structure and function of the gut in the regular sea urchin *Lytechinus variegatus* from the northern Gulf of Mexico. Seasonal changes in gut size were inversely correlated to changes in gonad size, suggesting nutrient translocation from gut reserves to gonad production. Proximate composition of the gut also changed seasonally. Gut lipid content relative to carbohydrate content was higher during winter, and gut carbohydrate content was higher relative to protein and lipid during summer. Corroborative lab studies indicate water temperature is a significant factor affecting proximate composition of the gut, gut size, and nutrient absorption efficiency. These abiotic effects may be unrelated to reproductive state. Sea urchins fed nutrient dense diets had larger guts than urchins collected from wild populations, and the quantity of lipid in the diet was positively correlated with gut size. In juveniles, gut size was larger for those fed diets containing high levels of n-3 long chain polyunsaturated fatty acids (LC-PUFA) than those fed diets containing high levels of n-6 PUFA. These data suggest both intrinsic and extrinsic factors affect gut size and composition, the consequence of which is not fully understood.

S3-1.7 GIBSON, G D; Acadia University; *glenys.gibson@acadiau.ca*

Poecilogony in the polychaete Polydora cornuta: A potential polyphenism that requires decisions, decisions, decisions.

Poecilogonous species are wonderful organisms with which to investigate the mechanisms that underlie developmental decisions leading to phenotypic divergence. For example, broods of the spionid *Polydora cornuta* contain eggs that develop to one of three morphs. Most become non-developing nurse eggs, some develop into embryos that ingest nurse eggs (i.e., adelphophagy) and have accelerated development, and some develop into non-adelphophagous embryos that hatch as small, planktotrophic larvae. Thus eggs spawned within a single egg capsule have three potential fates: death (as a nurse egg), the fast-track (as an adelphophagic larva) or a slower course of development as a planktotrophic larva. Each path appears to involve an active developmental decision. Nurse eggs are activated at spawning but immediately enter apoptosis (e.g., TUNEL, Annexin V). Apoptosis was not detected until much later in embryos, suggesting a decision that involves an early onset of a common developmental process in nurse eggs. Adelphophagy begins in gastrulae suggesting an early onset of the ability to capture food by mouth in some young, versus the use of ciliary bands by planktotrophic larvae. Preliminary work suggests this divergence is influenced by histone modifications. Providing females with methyl releasers decreased histone methylation (e.g., H3K9me2) in maternal tissues, increased variance in nurse egg production and increased the percentage of adelphophagous young per capsule. Although preliminary, these results suggest that epigenetic processes, such as histone modifications, provide a mechanistic link between the environment and developmental decisions leading to alternate phenotypes of young.

32.3 GIDMARK, NJ*; TARRANT, JC; BRAINERD, EL; Brown University; *njg@brown.edu*

Pharyngeal jaw function in three cyprinid fishes

Cyprinids process food with highly specialized pharyngeal jaws. These jaws bear blade-like teeth in herbivores, molariform teeth in molluscivores, and heterodont dentition in omnivores. We studied food processing in grass carp (*Ctenopharyngodon idella*; herbivore), black carp (*Mylopharyngodon piceus*; molluscivore), and common carp (*Cyprinus carpio*; omnivore) using XROMM, an in-vivo skeletal imaging technique. The pharyngeal jaws have no bony articulations; they are suspended from the pectoral girdle and skull in a muscular sling. In all three species, only two jaw muscles have appreciable mass and appropriate lines of action to adduct the chewing surfaces: the pharyngeal jaw levator and retractor. Previous research has shown that both muscles are electrically active during the chewing stroke. Of those two muscles, we observed lengthening of the retractor and shortening of the levator during occlusion in all three species. We conclude that the levator functions as the primary driver of mechanical food breakdown, while the retractor acts primarily as a jaw positioning muscle. Despite these similarities in muscle actions, the jaws of the three species move differently. Grass carp use rotations and translations (>20 degrees and 4 mm summed across the two primary axes of motion) to abduct the jaws, pulling their ridged teeth laterally across the chewing pad. This shearing motion in grass carp contrasts starkly with the simple, translational movement in black carp, which show less rotation but similar translation. This contrast in jaw kinematics parallels their respective diets: grass carp shear vegetation while black carp crush their snail prey. The morphologically and trophically intermediate common carp shows intermediate movements, and in all three species, the magnitude levator muscle strain parallels the amount of jaw motion.

75.2 GIGNAC, P.M.*; ERICKSON, G.M.; Stony Brook University, Florida State University; *paul.gignac@stonybrook.edu*

Assessing biomechanical performance in extinct crocodylians: a neontological model of bite-force generation and tooth pressures in fossil forms

Crocodylians have dominated predatory niches at the water-land interface for over 85 million years. Like their ancestors, living species show substantial variation in their body sizes, jaw proportions, and dental forms, the latter of which stand in contrast to their strongly conserved post-cranial anatomy. As a result, it is thought that variation in crocodylian dental, cranial, and musculoskeletal characters has tracked available niche space within a narrow range of ecomorphology and has been the driving engine of their diversification. One critical aspect to understanding the evolution of this feeding system is its biomechanical performance in living and fossil forms. However, the ecological and evolutionary import of feeding capacities such as bite forces and tooth pressures has remained elusive. Two recent studies focusing on the development and diversification of bite forces and tooth pressures in living taxa have shed new light on this issue. Here we add to these advancements with a recently developed mathematical model of the crocodylian jaw-adductor system, which can be used to assess biomechanical performance in the crocodylian fossil record. We validated the bite-force model by testing it against a diversity of known-bite-force, adult crocodylians and showed that we can accurately predict these values. We then derived jaw-muscle reconstructions for extinct crocodylian taxa and, along with measurements of their dental form, produced bite-force and tooth-pressure estimates. These were also successfully tested against our performance data from extant taxa. Together insights from these developmental, evolutionary, and paleontological analyses now make it possible to address further questions about crocodylian evolutionary niche transitions and the mechanisms of their subsequent diversification.

65.3 GILBERT, P.S.*; CHANG, J.; FAIRCLOTH, B.; ALFARO, M.E.; Univ. of California, Los Angeles; *ps.gilbert@ucla.edu*

Genome-wide ultraconserved elements exhibit higher phylogenetic informativeness than traditional fish markers

We have recently developed a phylogenomic approach for fishes based upon sequence capture of regions flanking ultraconservative elements (UCEs) that enables the generation of data matrices with hundreds or even thousands of loci. Although it might seem reasonable to assume that the resolving power of a data matrix of this size would exceed that of traditional approaches which are often based upon 10-20 protein coding genes, the relative performance of these two approaches have never been assessed. Here we compare the phylogenetic informativeness (PI) of these two types of data matrices by analyzing the resolving power of UCEs and their flanking regions against protein-coding genes developed for high-level fish phylogenetics. Per base pair (bp) and net PI was calculated across shallow, medium and deep time epochs for the euteleost phylogeny. We also calculated and compared PI for each data matrix type. UCEs with 200bp flanking regions outperformed the protein-coding genes at every time epoch (PI = 43x, 46x and 43x higher at shallow, medium and deep time epochs respectively). However the average per site PI for protein-coding genes was two orders of magnitude higher than UCEs with 200bp flanking region at shallow and deep time epochs. Our findings support using UCEs and their flanking regions in euteleost phylogenetics as this approach massively increases the phylogenetic resolving power of our data set.

77.3 GILLESPIE, JL*; FRANKLIN, RB; Virginia Commonwealth University; *gillespiejl@mymail.vcu.edu*

A comparison of microbial community structure and function in tidal freshwater wetlands of the Chesapeake Bay watershed in Virginia

Wetlands provide billions of dollars in ecosystem services to the United States each year. In an era of great concern for global climate change, a wetland's ability to sequester carbon is one of its most important features. Understanding wetland function at the microscopic level can provide great insight for the preservation and restoration of this crucial ecosystem. Here, we examine and compare microbial community structure and function of tidal freshwater wetlands dominated by *Peltandra virginica*. Bacterial and archaeal community DNA was extracted from each wetland, and the 16S gene was amplified via PCR and analyzed with terminal restriction fragment length polymorphism (T-RFLP). Community composition was analyzed within each wetland and between wetlands at increasing scales. In addition, extracellular enzyme activity was measured to assess community function. Microbial community composition and enzyme activity was correlated among sites, and also to measured environmental parameters at each site. We found bacterial and archaeal communities are strongly correlated to each other and environmental factors. For instance, archaea showed a strong correlation to above-ground biomass, temperature and redoximorphic characteristics. Further, bacterial and archaeal communities strongly correlate to the enzyme Phenol Oxidase, a key regulator of soil organic matter decomposition. This work shows that bacterial and archaeal community structure are related to important ecosystem services such as carbon sequestration.

60.1 GILMAN, C.A.*; IRSCHICK, D.J.; University of Massachusetts Amherst; *cgilman@bio.umass.edu*
Foils of flexion: the effects of perch compliance on lizard locomotion and perch choice in the wild
For arboreal animals, the interaction between individuals and their habitat can be complex due to variability in perch characteristics, such as diameter, length, angle, and compliance. Perch compliance may be of particular concern for arboreal animals that use jumping as a means of moving through their habitat because of the high forces generated during takeoff, and the potential for loss of energy from the jump to the flexion of the perch. The arboreal lizard *Anolis carolinensis* ranges throughout the southeastern United States, and occupies a wide range of perches. Many of these perches, like leaves and small diameter branches, are highly compliant. Prior studies have shown that perch height and diameter are important habitat characteristics for this species, but the effects of perch compliance on performance and behavior in the wild are unknown. We recently performed lab trials on the effects of perch compliance on jumping kinematics and performance in *A. carolinensis*, and found that increased compliance resulted in significantly decreased jump distances and takeoff velocities in the largest animals. Because these lizards occupy habitats in which they must jump to and from unsteady perches, these results suggest that perch compliance may be an important structural variable that influences how this species negotiates its habitat. In this study we observed the jumping behavior of a Florida population of *A. carolinensis* and quantified the compliance of perches found in their habitat, those randomly occupied by the green anole, and those used for jumping by this population. Here we present the effects of perch compliance on perch choice and locomotion in a natural population of male and female *A. carolinensis*.

6.2 GILMORE, L. A.*; NISHIKAWA, K. C.; Northern Arizona University; *leslie.gilmore@nau.edu*
Length, force and changes in the elastic behavior of active muscle.
Previous studies have examined how muscle force and shortening velocity change with length changes in active muscle. However, few studies have examined how elastic behavior changes with muscle length. Using mouse soleus muscle in load clamp experiments, we examined the elastic behavior of actively shortening muscle at optimal length and at lengths 2.5%, 8% or 13% greater than optimal length. All length changes were made prior to activating the muscle. In each load clamp experiment, the muscle was maximally stimulated prior to a period of rapid unloading. By examining the changes in force and length during this period of elastic recoil we were able to describe the elastic behavior at each length. Our results show that elastic behavior is length dependent, but is not predicted by the active, passive or total force alone. Muscles were more compliant at 13% above optimal length, although there was no difference in total force at this length and at optimal length. At 13% above optimal length the ratio of passive and active force changes, however, there was no correlation between the elastic behavior and passive or active force. This suggests that neither a passive elastic element nor the cross-bridge action alone can describe the observed elastic behavior. Instead, these results suggest an internal, length-dependent spring which experiences changes in stiffness during activation. A similar mechanism has been proposed to explain force enhancement during active stretch. Our results are consistent with the winding filament model of muscle contraction, in which titin is engaged mechanically during Ca++ influx, and then winds upon the thin filaments as force develops. Supported by NSF IOS-1025806, IOS-0732949, II5-0827688, TRIF Fund for Biotechnology and Science Foundation Arizona.

15.7 GLAZER, Lilah*; WEIL, Simy; MITTELMAN, Benjamin; ROTH, Ziv; KHALAILA, Isam; TOM, Moshe; SAGI, Amir; Ben-Gurion University, Beer Sheva, Israel Oceanographic and Limnological Research, Haifa; *lilahg@bgu.ac.il*
Novel molt-related hemocyanin family proteins from extracellular matrix of crustacean gastroliths
Other than oxygen carrying, the crustacean hemocyanin family of proteins is known to be involved in several aspects of the molt cycle, particularly in the synthesis and hardening of the new postmolt exoskeleton. Gastroliths are extracellular structures formed by the crayfish *Cherax quadricarinatus* during premolt, serving as transient calcium deposits. Like the crustacean exoskeleton, gastroliths are made of a chitinous organic matrix within which calcium carbonate ($CaCO_3$) is deposited. Both the construction of the chitin scaffold and the precipitation of the $CaCO_3$ involve proteins. Although gastroliths are cuticular elements, therefore sharing many characteristics with the exoskeleton, they are much simpler in structure, relatively homogenous in composition and lack pigmentation. In search for molt-related proteins involved in gastrolith formation we have isolated several novel proteins from the extracellular matrix of the gastrolith. Among those proteins is a prominent set of bands at ~75kDa, identified by mass spectrometry as several different subunits of hemocyanin and also cryptocyanin. These identifications were validated against pyro-sequencing results of *C. quadricarinatus* transcripts. In addition, the protein bands cross-reacted with anti-hemocyanin antibodies. We are studying the specific roles of the hemocyanin-family members found in extracellular matrix, using the gastrolith as a unique and relatively simple model for cuticular assembly.

48.3 GOESSLING, J.M.*; LUTTERSCHMIDT, W.I.; REINERT, H.K.; ODUM, R.A.; Sam Houston State University, Sam Houston State University and the Texas Research Institute for Environmental Studies, The College of New Jersey, Toledo Zoological Society; *goessling@auburn.edu*
Comparative metabolic rate and assimilation between an endemic rattlesnake and an invasive boa: implications for invasive species success
Islands are often limited in resource availability and niche space. Thus, islands represent ideal models for studying the ecological relationships between native and invasive species. We investigated a potential mechanism by which invasive species may demonstrate a competitive advantage over native species. We examined the comparative energetics between an endemic rattlesnake (*Crotalus durissus unicolor*) and an invasive boa (*Boa constrictor constrictor*) on the island of Aruba. Differences in metabolic rate were tested across three treatments (rest, digestive-lizard, and digestive-mouse) and assimilation efficiency across two treatments (digestive-lizard and digestive-mouse); we also examined relative digestive tract morphology to identify possible correlates with potential energetic differences. We found both an effect of species and treatment on the metabolic rate of snakes (repeated two-way ANOVA: effect of species $P < 0.001$; effect of treatment $P = 0.005$), with boas having a lower metabolic rate than rattlesnakes. Using calorimetry, we found that boas have a higher assimilation efficiency than rattlesnakes with both food types (lizard and mouse; two-way ANOVA: $P = 0.003$). The analysis of relative digestive tract morphology showed no differences between species. Our results suggest that *B. c. constrictor* may be more energetically conservative than *C. d. unicolor* and we therefore discuss how physiological efficiency may be a mechanism by which *B. c. constrictor* has been able to rapidly expand its range and population on Aruba.

S1-2.4 GOLDBOGEN, Jeremy; Cascadia Research Collective; *jgoldbogen@gmail.com*
Using high-resolution acoustic tags to determine the kinematics and maneuverability of the world's largest whales.
The advent of digital tags has revolutionized the study of animal movement in their natural environment, particularly for cetaceans which are difficult to study in both the lab and the wild. A class of acoustic, suction-cup attached tags represents the most common approach for studying the fine-scale movement of cetaceans during diverse locomotor behaviors. Present day tags equipped with pressure transducers, hydrophones, and tri-axial accelerometers and magnetometers enable the determination of 4 of 6 kinematic degrees of freedom. Here I quantitatively describe three-dimensional body kinematics for rorqual whales (Balaenopteridae) engaged in a variety of maneuvers, and analyzed the extent to which rotations about three orthogonal body axes were coupled with the forward speed of the body. These data represent a first approximation for quantifying the large repertoire of maneuvering behaviors exhibited by rorquals, and also characterize maximum performance during extreme maneuvers (i.e. lunge feeding). These kinematic data have revealed new mechanisms of engulfment, provided estimates for the energetic cost of feeding, and prompted investigations into the bizarre morphological adaptations that facilitate this unique feeding behavior.

S7-2.4 GOLDMAN, Daniel I.; Georgia Institute of Technology; *daniel.goldman@physics.gatech.edu*
The secrets of swimming in sand
I will summarize our progress in biological and robotic experiments, and numerical and theoretical models of the locomotion of a sand-swimming lizard, the sandfish (*Scincus scincus*). We use high speed x-ray imaging to study how the 10 cm-long sandfish swims at 2 body-lengths/sec within sand, a granular material that displays solid and fluid-like behavior. Below the surface the lizard no longer uses limbs for propulsion but generates thrust to overcome drag by propagating an undulatory traveling wave down the body. To predict the sandfish swimming speed in the granular ``frictional fluid", we develop an empirical resistive force model by measuring drag force on a small cylinder oriented at different angles relative to the displacement direction and summing these forces over the animal movement profile. The model correctly predicts the animal's wave efficiency (ratio of forward speed to wave speed) as approximately 0.5. The empirical model agrees with a more detailed numerical simulation: a multi-segment model of the sandfish coupled to a multi-particle discrete element method (DEM) simulation of the granular medium. We use the principles discovered to construct a sand-swimming physical model (a robot) which, like in our empirical and multi-particle numerical model, swims fastest using the preferred sandfish wave pattern. The models predict that motor activation force is independent of swimming speed and increases with increasing depth below the surface. Electromyographic (EMG) measurements of epaxial musculature activity in the swimming lizard are in accord with the model predictions.

34.4 GONG, S.Y.*; TSUKIMURA, B.; California State University Fresno; *stevengong0083@yahoo.com*
Environmental Effects on Native and Non-Native Copepod Populations in San Francisco Bay
Plankton distribution patterns are important to study due to their potential influences on food web dynamics as predator and prey contributors. Copepods are among the most numerous aquatic microorganisms and are critical to energy flow between trophic levels. Introduced species can potentially create additional competitive pressure to native species over resources and predation, which could translate into altered community assemblages. San Francisco Bay is among the most invaded habitats, making it ideal for studying invasive species impacts. Plankton samples from fixed sites around San Francisco Bay from 1998 to 2009, taken at monthly intervals, were collected and sorted for three copepod species: an established species (*Eurytemora affinis*) and invasive species (*Pseudodiaptomus forbesi* and *Tortanus dextrilobatus*). These copepods were identified to species and their relative abundances determined by catch-per-unit-effort. Results over the 12 year period showed a positive correlation between water temperature and *P. forbesi* ($r=0.902$) and *T. dextrilobatus* abundances ($r=0.948$). *E. affinis* abundances had a positive correlation ($r=0.798$) with dissolved oxygen levels, which indicate a preference towards regions with high mixing that resulted in decreased secchi depth ($r=-0.776$) and less primary productivity ($r=-0.867$). The invasive *T. dextrilobatus* and *P. forbesi* populations were directly related to each other over time ($r=0.946$) but were inversely related per site ($r=-0.749$) which might indicate a predator-prey relationship. The overall population differences were indicative of environmental selection on community assemblages by abiotic and biotic factors which can be used towards developing an assessment model.

77.2 GOSNELL, J.S.*; DIPRIMA, J.B.; GAINES, S.D.; Univ. of California, Santa Barbara; *gosnell@lifesci.ucsb.edu*
Variation in habitat structure impacts responses to biotic and abiotic factors in an intertidal snail
Habitat structure often varies within and among communities and may influence the distribution of species and species interactions, yet studies of species interactions seldom consider the impact of habitat structure or complexity. To understand the importance of habitat structure, we examined how the structure of mussel beds influenced responses of whelks (*Nucella emarginata*) to abiotic (wave action) and biotic (predators (ochre sea stars, *Pisaster ochraceus*) and prey (*Mytilus californianus*)) factors. Results indicate that habitat structure increases the ability of whelks to survive in an area and influences habitat selection, mortality rates, and feeding in whelks in the presence of a predator. Habitat structure also has direct effects on feeding and growth rates in whelks. This suggests habitat structure can have complex impacts on species and species interactions in intertidal communities and may influence the distribution of whelks within sites. To better understand forces structuring ecological communities or potential responses to changing environments, studies should strive to incorporate habitat complexity instead of removing it for experimental clarity.

9.2 GRAHAM, Sean*; FREIDENFELDS, Nicole; MCCORMICK, Gail; LANGKILDE, Tracy; The Pennsylvania State University; *grahasp@auburn.edu*

The impacts of invaders: Basal and acute stress glucocorticoid profiles and immune function in native lizards threatened by invasive ants.

As anthropogenic stressors multiply exponentially in the coming decades, native vertebrates will likely face increasing threats from these novel challenges. The success or failure of the primary physiological mediator of these stressors—the HPA axis—will likely involve numerous and chaotic outcomes. Among the most challenging of these new threats are invasive species. These have the capacity to simultaneously challenge the HPA axis and the immune system since they are often associated with, or the cause of, emerging infectious diseases, and energetic tradeoffs with the HPA response can have immunosuppressive effects. To determine the effects of invasive species on the vertebrate GC response to a novel stressor and immunity, we examined the effects of invasive fire ants on native lizards, comparing lizards from sites with long histories with fire ants to those outside the invasion zone. We demonstrated higher baseline and acute stress (captive restraint) CORT levels in lizards from within fire ant invaded areas; females are more strongly affected than males, suggesting context-specific effects of invasion. We found no effect of fire ant invasion on the immune parameters we measured (complement bacterial lysis, antibody hemagglutination) with the exception of ectoparasite infestation. Mites were far less prevalent on lizards within fire ant invaded sites, suggesting fire ants may actually benefit lizards in this regard. This study suggests that invasive species may impose physiological stress on native vertebrates, but that the consequences of this stress may be complicated and unpredictable.

43.8 GRAVISH, N*; SALDANA, L; JANKOVSKY, N; GOODISMAN, M.A.D.; GOLDMAN, D.I.; Georgia Tech; *nick.gravish@gmail.com*

Climbing and falling in confined environments

Subterranean animals must rapidly navigate unpredictable and perilous underground environments. Nests of the fire ant *Solenopsis invicta* (average body length 0.39 cm) consist of a subterranean network of large chambers and tunnels which can reach 2 meters into the earth and house up to 250,000 workers. Laboratory investigations of *S. invicta* reveal that digging workers typically climb up and down tunnels slightly wider than the largest ant hundreds of times per hour. However the principles of locomotion within confined environments such as tubes have been largely unexplored. We conducted laboratory experiments to monitor upward and downward tube climbing of isolated S. invicta workers and compared the performance to upward and downward vertical-plane climbing (like that found during foraging outside the nest). In both treatments for upward climbing, speed increased linearly with stride frequency with slopes that were not significantly different (ANCOVA; $p = 0.31$), despite changes in gait and attachment mechanics. Average speeds were approximately 2 BL/sec. On planes the ants used ventral limb surfaces (like tarsal claws) to engage the substrates while in tubes, both ventral and dorsal surfaces of limbs were used. The range of frequency used in the tubes was not significantly different (t-test; $p = 0.28$) than that for climbing on vertical planes. Compared to upward climbing, animals were able to access a larger range of speeds when climbing downward on planes and in tubes. The fastest downward climbing speeds (8 BL/sec) were achieved in tubes. To reach these speeds ants executed short falls during each step. Falls were arrested through limb and antenna contact with the tube walls, effectively acting as brakes.

28.2 GREENWOLD, MJ*; SAWYER, RH; Univ. of South Carolina, Columbia; *greenwold@biol.sc.edu*

Characterization and expression profiles of beta (β)-keratins in the American alligator (Alligator mississippiensis) and their molecular evolution in archosaurians

Extant archosaurians are comprised of crocodilians and birds. Epidermal appendages of archosaurians, including scales, claws, and feathers, are largely composed of beta (β)-keratins. In birds, β-keratins form a multigene family that can be divided into distinct subfamilies (scale, claw, feather-like, feather and keratinocyte β-keratins) based on expression profiles of epidermal appendages. While all β-keratins contain a well conserved central filament domain, the avian β-keratin subfamilies show the highest amount of diversity in the C-terminus. Previous studies on crocodilians have isolated five unique β-keratin transcripts from three crocodilian species (*Crocodylus niloticus*, *Crocodylus palustris*, *Crocodylus intermedius*), but these transcripts demonstrate little diversity, especially in the C-terminus. Searches of preliminary genome builds of the saltwater crocodile (*Crocodylus porosus*) and American alligator (*Alligator mississippiensis*) show a much greater amount of β-keratin diversity than previously reported. Phylogenetic analyses demonstrate that 1:1 orthologous relationships exist between crocodilian β-keratins and basal avian β-keratins. Using specific primers to β-keratins of the American alligator, we utilize real-time quantitative PCR (qPCR) to compare the relative expression of β-keratins in different tissues of the alligator embryo. Results from qPCR demonstrate that the β-keratins of the American alligator are variably expressed in different embryonic tissues. Our results indicate that basal β-keratins in present day birds are more closely related to β-keratins in crocodilians than to the avian specific feather β-keratins that form the feathers in today's birds.

S1-2.1 GREENWOOD, A.K.*; WARK, A.R.; PEICHEL, C.L.; Fred Hutchinson Cancer Research Center; *akg@stanfordalumni.org*

Mechanisms underlying the evolution of schooling behavior in sticklebacks

Schooling behavior is a strategy commonly used by fishes for predator avoidance. Like other social grouping behaviors, schooling has numerous benefits for participants, such as increased vigilance and predator confusion. However, schooling is also associated with costs, including increased competition for food and mates. As a result of these costs and benefits, schooling varies as a function of ecological context. We have identified variation in schooling behavior among two populations of threespine stickleback fish: an anadromous marine population and a freshwater benthic population. Marine fish school very strongly whereas benthic sticklebacks show a significantly reduced tendency to school. We developed an assay to rigorously measure the schooling behavior of individuals from these populations in the laboratory. This assay consists of a motorized "school" of artificial sticklebacks, and it elicits strong schooling behavior from marine fish. The model school assay can quantify two separable features of schooling behavior: the tendency to associate with the models as well as the maintenance of a parallel body position with the models. Marines spend substantially more time with the models than benthics and have a significantly more parallel body position. We are now using the model school assay to dissect the proximate genetic and neural mechanisms contributing to divergence in schooling behavior. We have used quantitative trait locus (QTL) analysis in benthic-marine F2 hybrids to identify the genetic basis for differences in schooling behavior. This approach has led us to identify both a candidate gene and a candidate neural substrate mediating the difference in body position when schooling found between marines and benthics.

102.2 GROSS, Joshua B.*; WILKENS, Horst; University of Cincinnati, Cincinnati, Ohio, USA, Zoological Institute and Zoological Museum, University of Hamburg, Hamburg, Germany; *grossja@ucmail.uc.edu*

Evolution of albinism in a captive population of cavefish

One of the most common traits shared among cave-dwelling animals is the loss of pigmentation. This form of phenotypic regression evolves through diverse modes, including decreased numbers of pigment-producing cells (melanophones), decreased melanin content within melanophores, or the complete absence of melanin pigmentation (albinism). Collectively, populations of the blind Mexican cavefish demonstrate all three modes of pigmentation regression. Not all cave populations, however, harbor the same combination of defects. For instance, the Molino population demonstrates albinism, but not melanin reduction (the *brown* phenotype) while the Piedras population is *brown*, but not albino. Two critical genes, *Mc1r* and *Oca2*, have been identified as the causative regulators of the *brown* mutation and albinism, respectively. The order through which these changes evolve in nature remains unknown. Thus, it is unclear if the destructive phenotype (albinism) precedes mutations in other hypostatic genes, or alternatively if albinism evolves rapidly in populations demonstrating other reduced pigmentation phenotypes. This study investigates a population of lightly pigmented cavefish collected in the early 1970s. Remarkably, over the last several decades albinism has spontaneously arisen within this captive stock. We present results of a molecular analysis of the albino locus in which phenotype, coding sequence and expression levels are compared between the derived albino and "ancestral" pigmented individuals, along with representative individuals drawn from other surface and cave populations. In the context of cave-dwelling animals, which frequently experience population bottlenecks, this study provides direct evidence that cave-associated phenotypes can arise remarkably quickly in small populations.

30.1 GUGLIELMO, C.G.*; GERSON, A.R.; Univ. of Western Ontario; *cguglie2@uwo.ca*

The effects of high carbohydrate versus high protein diet on body composition, endurance flight capacity and fuel mixture in a migratory songbird

Migratory birds eat a wide variety of diets, and some switch diets during migration. A typical pattern is for insectivorous birds to switch to fruits when they are abundant. Previous studies, based on plasma metabolite analysis, suggest that diet may influence the mixture of fuels in flight; eating high protein insects may increase the use of protein and eating high carbohydrate fruits may enhance fat metabolism. High carbohydrate diets also typically increase body fatness and refueling rate. We acclimated yellow-rumped warblers (Dendroica coronata) to synthetic diets containing dry mass ratios of either 60:15:10 or 15:60:10 carbohydrate:protein:fat while they were in fall and spring migratory states. Body composition was measured non-invasively by quantitative magnetic resonance and endurance flight performance was tested at 7.8 m/sec flight speed in a climatic wind tunnel at 15 C and 70% RH. High carbohydrate diet increased body mass by 8% and body fatness by 50%, but did not affect lean mass. The likelihood of completing a flight of greater than 45 min was doubled by the high carbohydrate diet. Voluntary flight duration lasted up to six hours and was not affected by fat load, but was nearly double in the high carbohydrate group. The percent of energy derived from the catabolism of lean mass (protein) was negatively related to flight duration, but not diet. Our results indicate that dietary variation can influence body composition and endurance flight performance, but does not affect fuel mixture.

117.3 GUINDRE-PARKER, S.*; GILCHRIST, H.G.; DOUCET, S.M.; LOVE, O.L.; Biological Sciences, University of Windsor, National Wildlife Research Centre, Environment Canada; *guindre@uwindsor.ca*

Male quality in an Arctic passerine: what are the links between plumage and reproduction

Theory predicts that an individual's quality and fitness are closely linked; high-quality individuals are expected to have high reproductive success. While the link between quality-mediated traits and reproductive output has been shown in many taxa, the mechanism by which this relationship holds is less often assessed. We are using an Arctic-breeding population of Snow Buntings (*Plectrophenax nivalis*) to assess physiological traits that may mediate the relationship between plumage quality and reproductive output in males. By combining ecological (timing of arrival, territory size) and physiological (arrival condition, testosterone, immunoglobulins) traits within an evolutionary framework, we hope to elucidate the mechanisms by which plumage quality drives reproductive success. Specifically, we are undertaking the following: 1-Assessing male plumage quality by measuring plumage colouration, growth rates and patterns of colouration on easily displayed regions of the body (tail, wings) 2-Measuring plasma testosterone levels and stress-mediated traits (immunoglobulin and oxidative stress levels) 3-Assessing the reproductive success of each male. This project is one of the first attempts to examine endocrine and immunological mechanisms that may drive the link between male phenotypic traits and breeding. We are using multi-year correlative data to obtain a holistic understanding of how phenotype and physiology can drive fitness. Selected results will be presented providing information on (1) the relationship between plumage and reproduction and (2) the physiological mechanisms that link male quality and reproduction.

116.4 GUNDERSON, A.R.; Duke University; *arg12@duke.edu*

The evolution of thermal physiology in the lizard genus Anolis.

Greater Antillean *Anolis* lizards are a classic example of an adaptive radiation, in which rapid speciation was accompanied by adaptive phenotypic divergence. Forty years ago, Ernest Williams hypothesized that the *Anolis* radiation occurred along two primary ecological axes: structural habitat (i.e., perch selection) and climate. The importance of the structural niche axis has been extensively evaluated and corroborated. However, the degree to which thermal physiology has diverged in response to the occupation of different thermal niches, and thus the possible contribution of thermal physiology to the radiation of this clade, is still relatively unexplored. I evaluate this hypothesis in Puerto Rican anoles by correlating aspects of the thermal sensitivity of locomotor performance with features of their thermal habitat.

42.5 GUTMANN, Anne K.; University of Moscow, ID; *agutmann@uidaho.edu*

A mechanical basis for bilateral deficit and facilitation

Using two limbs, as opposed to one limb, to perform a task can affect single-limb performance. Both bilateral deficit (reduction of single-limb performance during bilateral tasks) and bilateral facilitation (enhancement of single-limb performance during bilateral tasks) have been observed for a number of tasks including simple, static tasks such as isometric hand grip exercises and complex, dynamic tasks such as jumping. Such differences in bilateral versus unilateral performance are commonly attributed to neural mechanisms – e.g. decreased or increased neural drive. However, in principle, mechanics alone can often explain such differences. Here I show how the mechanical requirements of a task and the mechanical capabilities of the limbs can interact to produce either bilateral deficit or bilateral facilitation. I also describe the general mechanical conditions that will produce bilateral deficit or bilateral facilitation and discuss how these results pertain to real-life examples.

102.5 HABER, Annat; University of Chicago; Tel Aviv University; *annat22@gmail.com*

The Role of Morphological Integration in Ruminant Diversification

Differences between clades in their diversification rates and patterns result from a combination of extrinsic and intrinsic factors. In this study I focus on the intrinsic factors as reflected in the covariation between morphological elements, i.e., morphological integration. I use the overall degree of integration as a measure of the intrinsic potential of populations to respond to a wide range of selective pressures. The long-term potential to evolve and diversify should be higher for populations with lower integration, assuming that selection is random with respect to the covariation structure and is not likely to continue along the same lines throughout the history of a lineage. Here I compare this potential with the observed rates and patterns of ruminant diversification. I use 3D landmarks and geometric morphometrics to generate the ruminant morphospace based on 2857 skulls, representing 132 out of the 200 extant ruminant species. I quantify the integration structure for 47 of these species. I use phylogenetic comparative methods to reconstruct the rates and pattern of morphological diversification, and to demonstrate a non-random association between the degree of integration and diversification. Clades with high integration have a more constrained diversification while those with lower integration have diversified into a wider range of directions in morphospace. However, Species with an intermediate degree of integration have the highest anagenetic morphological rates. This association suggests that the degree of integration, rather than its pattern, is the aspect of covariation that affects evolution in the long run. My study on intrinsic factors complements studies on extrinsic factors and provides a more complete view of ruminant diversification.

22.1 HAGEY, Travis; University of Idaho; *thagey@vandals.uidaho.edu*

Variation in Stickiness: Using the Weibull Distribution to Quantify Adhesion across Geckos

Adaptation is a major process in the diversification of life on earth. Studies of adaptation often rely on patterns of correlated morphology, performance, and habitat preferences. Gecko lizards are an excellent system to study these patterns of adaptation, as they are a species rich group with highly variable morphology. Well known for their climbing ability, geckos have unique adhesive toe pads. The shape and size of these adhesive pads vary across genera. Unfortunately, statistical measurements of geckos' adhesive capabilities can be difficult. To estimate and compare adhesion between species, we suggest using a failure analysis technique relying on the Weibull distribution. The generation of adhesion relies on the amount of friction a gecko's toe pad generates, and measuring the angle of toe detachment is a proxy for the efficiency with which a gecko can translate frictional forces into adhesion. We can estimate the most likely angle of toe detachment with the Weibull analysis. Using this method, we have evaluated the adhesive capabilities of nearly 40 species, sampling across the phylogeny. Establishing standard methods to quantify performance and significant variation between and within species is a valuable first step in examining how geckos have adapted to a wide array of habitat types across the globe.

36.3 HAHN, D.A.*; CLEMMENSEN, S.F.; University of Florida, University of Tennessee; *dahahn@ufl.edu*

Indian summer: photoperiod alters thermally induced plasticity in life history and morphological traits.

It is well known that temperature can have substantial effects on morphological and life history traits, like body size and growth rates, especially in ectotherms. Photoperiod covaries seasonally with temperature in temperate regions, and photoperiod is often a reliable cue for inducing seasonal plasticity. Yet the effects of photoperiod on thermally induced reaction norms are often not considered. We highlight examples of how photoperiod can alter thermal reaction norms for body size, body composition, and thresholds for life history transitions from our own work on dormancy responses in moths and flies, as well as work on other ectotherms from the literature. We provide a framework for including photoperiodic effects in thermally induced reaction norms and discuss cases where this approach may be most useful for uncovering mechanisms that favor the evolution of adaptive seasonal plasticity in temperate environments.

78.7 HAHN, D. Caldwell*; IGL, Lawrence; BURNETT, James; ERF, Gisela; US Geological Survey - Patuxent WRC, US Geological Survey - No. Prairie WRC, University of Arkansas, University of Arkansas; *chahn@usgs.gov*

Evidence of parasite-mediated selection favoring evolution of more effective immune defenses: more immune constituents in eggs of avian brood parasites

Parasite-mediated selection should favor the evolution of more effective immune defenses in organisms whose life history entails exposure to a heightened diversity of parasites and foreign microbes. Good study species for examining how evolution shapes the design and function of the immune system in response to elevated exposure to parasites are the New World cowbirds (Icteridae, Molothrus spp), obligate brood parasites that include extreme host-generalist species. Two cowbird species lay their eggs in the nests of 200+ species and are thus exposed to the diverse parasites of their diverse foster parent species. We have previously shown several aspects of enhanced adult immunity in cowbird species and here report on greater maternal investment of immune factors in eggs of the brown-headed cowbird. We found that the eggs of this cowbird species have both higher lysozyme content and higher immunoglobulin content than do the eggs of a closely-related species, red-winged blackbird, that is not a brood parasite.

103.1 HALE, M. E. *; WILLIAMS IV, R.; Univ. of Chicago; *mhale@uchicago.edu*

Pectoral fins as sensors: Spatial distribution of sensory input to the pectoral fins of the bluegill sunfish.

Pectoral fins function in many behavioral contexts for fishes including in locomotion, feeding and social interactions. In some unusual species, such as the gurnards, the pectoral fin rays are adapted to act as sensors, probing the sea floor for prey. The role of less specialized pectoral fin rays in mechanosensation has not been explored in depth. We have found extensive sensory innervation of the pectoral fins in more typical ray-finned fishes including bluegills and zebrafish. Fin rays and membranes are invested with nerve fibers that run nearly parallel to the rays, branching along their lengths with the rays. Endings of these afferent nerve fibers are positioned along the proximodistal axis of the rays and concentrated at the leading edge and distal tips of the fin. In the bluegill, we have demonstrated that populations of afferent nerve fibers fire during fin ray bending. A fundamental question about fin ray mechanosensation is how sensory nerve fiber input contributes to spatial resolution along the proximodistal axis of the rays. We investigate the spatial organization of fin ray mechanosensation by regionally bending fin rays and determining the physiological response through extracellular recordings of fin ray nerves. We use spike-sorting algorithms to tease apart the firing of neuron populations projecting to distal and proximal regions of the ray. Our data indicate that bending is sensed at multiple locations along the fin ray and that the input from points along the ray is likely independent, suggesting that the fish may discern the location where bending is occurring along the length of the fin ray. Mechanosensation may be a fundamental role of the pectoral fins and should be considered in studies of fin function and evolution.

17.1 HAMLET, C. L.*; MILLER, L. A.; North Carolina State University , University of North Carolina at Chapel Hill; *clhamlet@ncsu.edu*

Numerical simulations and laboratory experiments of the upside-down jellyfish with background flow

The upside-down jellyfish (*Cassiopea spp.*) is an ideal organism for examining the effects of jellyfish kinematics on the flow of the surrounding fluid due to its relatively sessile nature. Previous experiments and numerical simulations have shown that the secondary structures such as the oral arms play an important role in directing flow around the bell from the substrate. Here we present laboratory experiments and numerical simulations that examine the interaction of the effects from ambient flow and the pulsation of the bell. Dye visualization and PIV techniques are used to observe the fluid flow around laboratory specimens. The immersed boundary method is used to numerically solve the fluid structure interaction problem for an idealized two-dimensional organism. Of particular interest is the influence of the speed and direction of the ambient flow as well as the effect of the presence of a secondary structure in the general region of the oral arms structure. We show that at low velocities the secondary structures direct flow across feeding regions. In addition for variable directional flows, the secondary structure change the overall structure and direction of the flow around the bell. Implications of these effects on particle exchange and feeding will be explored.

85.1 HANES, S. D.*; KEMPF, S. C.; Auburn University, Auburn, AL; *hanessd@auburn.edu*

Autophagic degradation and bleaching in the symbiotic anemone, Aiptasia pallida

Over the past few decades, coral reefs have dramatically declined as a result of mass mortality bleaching events that have been linked to elevated sea surface temperatures and global climate change. Coral bleaching involves the loss of essential, photosynthetic dinoflagellates (*Symbiodinium*) from host gastrodermal cells in response to temperature and/or light stress conditions. Although numerous potential cellular bleaching methods have been proposed, there remains much uncertainty regarding which mechanisms occur during early stages of host stress. In this study, multiple techniques were utilized to determine specific cellular events that occur during the early bleaching process, including 1) transmission electron microscopy (TEM), 2) biochemical induction, and 3) immuno-labeling. Bleaching was induced by exposing both symbiotic and aposymbiotic symbiotic anemones, *Aiptasia pallida*, to heat-light stress conditions of ~32.5ºC at 120 µmols irradiance for 12 hrs followed by 12 hrs in the dark at 24 ºC daily for 2 days. Ultrastructural examinations revealed numerous autophagic structures and associated cellular degradation in tentacle tissues after ~12 hrs of stress treatment or after 12 hrs of exposure to the known autophagy inducer, rapamycin. Additionally, symbionts were observed detaching from highly degraded gastrodermal cells in an apocrine-like manner. Autophagic activity was then monitored using immunofluorescence, resulting in positive labeling with the autophagy marker, MAP LC3B. This study provides the first ultrastructural evidence of host autophagic degradation during thermal stress in a cnidarian system and also supports earlier suggestions that autophagy is an active cellular mechanism during early stages of bleaching.

41.3 HANNINEN, AF*; DAVIS, AG; LEE, EA; WONG, SC; EARLEY, RL; University of Alabama; *amanda.hanninen@gmail.com*
Endocrine and life history plasticity in an amphibious fish
Populations of the mangrove rivulus (*Kryptolebias marmoratus*), a self-fertilizing hermaphroditic fish, consist of a diverse set of heterozygous and homozygous, isogenic lineages. Natural populations often occupy terrestrial habitats during prolonged tidal recessions with limited food availability. We explored within- and between-genotype variation in cortisol, androgens [11-ketotestosterone (KT)], and estradiol along tidal and food availability gradients using a reaction norm approach. Given age-dependent differences in fecundity we expected animals to adjust their endocrine response according to future reproductive prospects. We employed 3 age groups (3-9;10-15;>15 mo.) in 2 isogenic lineages divided among 3 tidal treatments [low/high/alternating (every 6h)] under fed or fasted conditions. Hormones were collected before and after treatment using a water-borne method and tissues were stored for future assay of metabolic enzymes and reproductive investment. Initial analyses show that prolonged exposure to low tide trigger marked cortisol elevations in only young animals. There was no change in estradiol in high tide (control) animals following treatment however, low and alternating tide animals showed a significant decrease in estradiol relative to control animals. There was a significant decrease in KT in fasted animals of the alternating tide condition. Body mass and residual gonad mass also decreased significantly in fasted animals. Gonadosomatic index (GSI) was greater in control animals and young animals regardless of tidal regime. These results reveal environmentally driven, age dependent changes in hormones and reproductive investment through a powerful and genetically tractable model system.

100.3 HANSEN, B. K.*; KRIST, A. C.; MARTINEZ DEL RIO, C.; University of Wyoming; *bhanse11@uwyo.edu*
How do invasive species maintain dominance in nutrient limited environments? A comparison of behavioral and physiological mechanisms between an invasive and a native snail.
Resource competition can shape species composition. In environments where nutrients are limited in either quantity or quality, the organisms best equipped to exploit these resources may gain a competitive advantage. The New Zealand mudsnail (*Potamopyrgus antipodarum*), a world-wide invader that can dominate secondary productivity, may benefit from such an advantage. *Potamopyrgus antipodarum* is a parthenogenetic snail, with high growth rates, and a high percent of somatic phosphorus (P). Consequently, these snails should have a high demand for P. Because freshwater ecosystems are often limited in P, successful animals like *P. antipodarum* must be exceptionally efficient at acquiring P from their food, either through effective foraging or digestive efficiency. However, previous work suggests that *P. antipodarum* consumes less food per unit biomass than the native snail *Fossaria* sp. To determine whether *P. antipodarum* gain an advantage in P limited environments, we compared preference, feeding rate and gut retention time for food containing low and high P content for *P. antipodarum* and the native snail, *Fossaria*. Relative to food with high P content, we predicted that low P food would not be preferred, would be consumed at a higher rate (compensatory feeding) when diets were presented alone, and would be maintained in the gut for more time. Consistent with our prediction, *P. antipodarum* consumed low P food at a higher rate than high P food. In contrast, the native snail *Fossaria* consumed high P food at a higher rate. Ongoing experiments will reveal whether differences persist between the invasive and native snail when faced with diets differing in P.

95.1 HANSON,, A.M.*; SHERIDAN,, M.A.; North Dakota St. Univ.; *andrea.m.hanson@my.ndsu.edu*
Environmental Estrogens Inhibit the Expression of Insulin-like Growth Factors 1 and 2 in the Liver and Gill of Rainbow Trout in vitro.
The increasing production, use, and disposal of an expanding array of chemicals that enter the environment pose a serious threat to terrestrial and aquatic animals, as well as to humans. Fish in aquatic habitats are exposed to an increasing array and concentration of environmental contaminants, including environmental estrogens (EE). Previously, we observed that *in vivo* exposure of juvenile rainbow trout (ca. 50 g) to varying concentrations of 17β-estradiol (E2), β-sitosterol (βS), and 4-n-nonylphenol (NP) for 28 days (14 C; 12L:12D) depressed growth and altered the expression of various elements of the growth hormone (GH)-insulin-like growth factor (IGF) system. In this study, we assessed the direct effects of EE on GH sensitivity as assessed by mRNA expression of GH receptors (GHR) and on IGF production as assessed by expression of IGF-1 and IGF-2 mRNAs in selected tissues. None of the EE tested affected the expression of GHRs in either liver or gill. By contrast, E2, βS and NP inhibited the expression of both IGF-1 and IGF-2 in a time- and concentration-related manner in liver. Although the response evoked by all of the EE was similar for hepatic IGF-1 and IGF-2 mRNA expression, the potency and efficacy varied with EE; the rank order of potency/efficacy was as follows: E2=NP> βS. E2, βS and NP also inhibited the expression of IGF-1 and IGF-2 mRNAs in a time- and concentration-related manner in gill; patterns for efficacy and potency similar to those in liver also were observed in gill. These findings indicate that selected EE can directly influence the growth of post-embryonic rainbow trout by inhibiting the synthesis of IGFs (Supported by NSF IOS 0920116 to MAS).

82.5 HARDEN, L.A.*; WILLIARD, A.S.; UNC Wilmington; *lah4492@uncw.edu*
Using a Spatially-Explicit Predator-Prey Model to Investigate Bycatch Risk of Terrapins in Crab Pots
Trends in diamondback terrapin *Malaclemys terrapin* abundance and demography suggest that crab pot bycatch mortalities may be contributing to population declines of this estuarine turtle. Designing effective regulations to minimize terrapin-crab pot interactions requires information on the spatial ecology and seasonal behavior of terrapins. Thus, our goals are to 1) identify spatial and temporal aspects of terrapin-crab pot overlap and 2) assess the likelihood of encounters (bycatch risk) based on densities and distribution of crab pots and terrapins as well as terrapin behavior in North Carolina. We radiotracked 29 terrapins and documented their locations and behavior, as well as the locations of nearby crab pots, in sounds where crabbers have observed terrapin bycatch. Terrapin and environmental temperatures were also recorded using micro-dataloggers to provide a more detailed profile of activity and habitat use. Spatial and temporal interactions between terrapins and crab pots were determined using GIS to calculate their seasonal distributions and densities and then using a spatially-explicit predator-prey model to assess their spatial overlap. This model has been used in previous studies to predict areas of high bycatch by comparing the density and distribution of fishing effort (predator) to that of the marine bycatch species (prey) and describes the degree to which the spatial correlation of predator and prey deviates from the random expectation under uniform spatial distributions. Results indicate that spatial overlap is greater in warm months when terrapins are swimming in the same shallow, near shore habitat as blue crabs. Moreover, when seasonal and semi-aquatic behavior of terrapins is incorporated into the spatial model, bycatch risk is reduced.

113.3 HARDY, A.R.*; MERZ, R.A.; Swarthmore College, PA; *arhardy7@gmail.com*

Flippin' out: inverted sand dollars actively orient themselves in flow to maximize lift for righting

The fact that sand dollars are often dislodged and inverted is an inescapable consequence of living at or slightly below the sediment-water interface. Once inverted however, how do sand dollars effectively right themselves given their lack of sizable appendages? In the current study we considered the effects of the inherent asymmetrical morphology of *Mellita quinquiesperforata* and *Dendraster excentricus* on their ability to right in flow. Based on flow tank observations, the critical velocity required to flip an inverted sand dollar varies with orientation and increases with test size. In both species, inverted sand dollars were least likely to be flipped by the current when oriented so that their posterior edge faced directly upstream. In order to test whether inverted sand dollars would actively rotate into a more advantageous position, we exposed each inverted individual to the minimum flow expected to induce flipping and compared their response in three orientations – with their posterior edge upstream (the least favored position), downstream and perpendicular to flow. Time-lapse photography showed that within one hour, individuals of both species regardless of initial orientation remained stationary or rotated into positions that were not statistically different from the downstream orientation. These results for *D. excentricus* were further confirmed in the field at Argyle Lagoon, WA. Taken together these data suggest that inverted sand dollars are able to recognize flow direction, respond behaviorally and modify their orientation to maximize lift and drag for righting.

106.4 HARPER, C.J.*; SWARTZ, S.M.; BRAINERD, E.L.; Brown University, Providence; *caroline_harper@brown.edu*

How nectar-feeding bats lap: nectar uptake and ingestion in Glossophaga soricina

In nectar-feeding bats, the tongue tip resembles a brush because it is covered with long filamentous papillae. In *Glossophaga soricina*, these hairlike papillae are organized in discrete rows on the dorsolateral surface of the tongue tip. The goal of this study is to describe how these hairlike papillae are used to collect nectar during feeding. Live *G. soricina* (n=3) were trained to feed from a small acrylic feeder and their tongues were filmed with monochrome and color high-speed video cameras. The high-speed videos show that these hairlike papillae are dynamic during feeding. During the initial phases of tongue protrusion, the papillae are proximally oriented and lie flat against the tongue. As the tongue tip enters the nectar, the hairlike papillae become engorged with blood and project from the tongue's surface. In their erect state, the papillae extend perpendicular to the long axis of the tongue and nectar is trapped between the rows of papillae. The hairlike papillae remain in their erect posture throughout tongue retraction and nectar is carried into the mouth for ingestion. These observations provide the first evidence for a hemodynamically-powered specialization of the tongue. Nectarivores have been noted for their specialized feeding adaptations, such as the fluid trap recently described in hummingbirds. The novel fluid capture system in nectar-feeding bats described here, however, is different from that of hummingbirds because the papillae are actively controlled by blood flow and do not rely on passive tongue-fluid interactions.

72.4 HARRIS, BN*; PEREA-RODRIGUEZ, JP; SALTZMAN, W; Univ. of California, Riverside; *bharr002@ucr.edu*

Acute effects of corticosterone injection on paternal behavior in California mouse (Peromyscus californicus) fathers

In the face of stressors, both acute and chronic, a trade-off between self-maintenance and reproductive behavior (both sexual and parental) has been documented, and glucocorticoids (GCs) are thought to mediate this effect. Studies implementing long-term GC elevation support a role of these hormones in disrupting paternal behavior in response to chronic perturbations, but no study has experimentally tested the effects of acute glucocorticoid elevation on paternal behavior. We tested the hypothesis that an acute corticosterone (CORT) increase would decrease paternal behavior in fathers and would lead to longer-term effects on reproductive success, as even short-term increases in CORT have been shown to produce lasting effects on the hypothalamic-pituitary-adrenal axis. First-time fathers were injected with 30mg/kg CORT, 60 mg/kg CORT, or vehicle, or left unmanipulated; however, groups were analyzed as control (unmanipulated + vehicle, n=15) and CORT (30mg/kg + 60mg/kg, n=16) following plasma CORT determination. Approximately 1.5-2h following injection two behavioral paradigms were used to access both paternal and non-paternal behaviors. CORT treatment increased the latency to contact a pup during the second behavioral test, but this effect was no longer significant after controlling for alpha inflation. CORT treatment did not alter any other measured behavior during either testing scenario, nor did it affect any long-term parameters (male body mass or temperature, pup growth rate, pup survival, interbirth interval, number or mass of pups born in the second litter). Regardless of treatment group, however, fathers showed a significant rise in body mass at day 30 postpartum, followed by a decrease in body mass after the birth of the second litter.

61.3 HARRISON, J.F.*; WATERS, J.S.; HEINRICH, S.M.; SOCHA, J.J.; Arizona State University, Virginia Polytechnical Institute; *j.harrison@asu.edu*

Effects of rearing oxygen level on the anatomy of the adult tracheal system in Drosophila

Insect tracheal systems are known to respond in a compensatory manner to rearing oxygen level, but the functional extent of compensation remains unclear, as does whether compensation extends from the larval to the adult stage. In this study, we investigated the structure, and phenotypic plasticity of the tracheal system of *Drosophila melanogaster*. Flies were reared from egg to adulthood in 10, 21 or 40% oxygen atmospheres, and their tracheal system assessed on the fourth day of adulthood. The tracheal system of the whole body was assessed with a 3D tomographic technique using synchrotron x-rays at Argonne National Laboratory. In addition, tracheoles in the flight muscle were imaged using confocal microscopy. We did not detect changes in the branching structure (or number of branches) in the major, large-diameter tracheae of the thorax. However, there was strong compensatory variation in the number and density of tracheoles in the flight muscle. In addition, we were surprised to find that the diameter of the terminal tracheoles decreased for flies reared in hypoxia. These results contrast to observations in larvae, which can show increases in diameter in hypoxic-reared animals. Perhaps the decreased tracheal diameters benefit oxygen diffusion into muscle by increasing surface/volume ratios of these tubes. This research was supported by NSF 0938047to JJS and JFH.

38.5 HART, Mary K; Univ. of Kentucky, Lexington; *mkhart0@yahoo.com*
Flexible sex allocation in a group-living simultaneous hermaphrodite
Phenotypic plasticity can be helpful for maximizing mating success in variable environments and thus may generate different sex allocation patterns among populations. For Serranus tortugarum, a simultaneously hermaphroditic fish, proportional male allocation (testis mass/total gonad mass) is greater where local density and sperm competition are higher. In the present study, I used reciprocal transplants among four high and low density reefs to test whether adult S. tortugarum show phenotypic flexibility in sex allocation when transplanted from high-density to low-density sites and vice versa. For controls, I included marked residents from each study site in the experiment, and I also tested whether transplants across similar densities would maintain similar sex allocation patterns. After four months, transplants between low density and high density reefs were very similar in proportional male allocation and body sizes to individuals from resident populations at their new reefs. Male allocation was increased through a reduction of relative ovary mass for Low to High density transplants and was decreased through a reduction in relative testis mass for High to Low density transplants. Respective increases in relative testis mass or relative ovary mass with shifts in male allocation, which would indicate the trade-off assumed by theory, were not clearly shown.

39.4 HARVEY, A.*; WHITFORD, G.; DELORENZO, S.; Georgia Southern Univ., Statesboro, GSU, Statesboro; *aharvey@georgiasouthern.edu*
Hunger-mediated phototaxis in adult brine shrimp
Nauplii of brine shrimp (*Artemia* spp.) are known to be strongly attracted to light, but information about the photoresponse of adults is strikingly inconsistent. For example, Aiken and Hailman (1978) found that adults were strongly photopositive, whereas Bradley and Forward (1985) reported equally strong **negative** phototaxis. The design of their experiments differed in numerous ways, but we found that the contradictory outcomes were not artifacts of these differences: individual adults that were photopositive in the Bradley design were also photopositive in the Aiken design; likewise, photonegative adults were consistently so in both setups. Over 90% of our adults were negatively phototactic, as found by Bradley and Forward. However, the two earlier studies differed not only in their experimental apparatus, but also in the source of their animals: Aiken and Hailman bought theirs from a pet shop (pet shops do not feed adult brine shrimp), whereas Bradley and Forward reared theirs from cysts (which requires regular feeding). Thus, we tested the hypothesis that hungry adult brine shrimp are more attracted to light than are well-fed adults, and found this in fact to be the case: only 14% of individuals from a well-fed stock tank showed a positive photoresponse, but this proportion gradually rose to 60% by the fourth day without food. These results provide a likely resolution for the contradictory results of previous studies: Aiken's photopositive shrimp were hungry, whereas Bradley's photonegative shrimp were not. This hunger-mediated phototaxis may be explained by the ecology of brine shrimp in the wild: light levels are highest at the surface of the water, where both phytoplankton (food for hungry brine shrimp) and birds (primary predators of brine shrimp) are in greater abundance.

107.3 HATTON, R. L.*; DING, Y.; MASSE, A.; MALADEN, R. D.; GOLDMAN, D. I.; CHOSET, H.; Carnegie Mellon University, Georgia Institute of Technology; *rlhatton@cmu.edu*
Principles of Sand-swimming Revealed by Geometric Mechanics
Many animals move within granular media such as desert sand. Models of an undulatory sand-swimmer, the sandfish lizard, reveal that the grains around the organism form a frictional fluid in which inertial effects are small and kinematics dominate. To understand the fundamental mechanics of swimming in granular media (GM), we examine a reduced system that has been well-studied in Newtonian fluids: the three-link swimmer. We model this system on several levels: a physical instantiation driven by servo-motors, a high-fidelity computational model using discrete-element methods (DEM) to represent the GM, and a resistive-force theory (RFT) approximation empirically derived from the DEM results.

By combining the RFT model with recent geometric mechanics theory, we construct intuitive visualizations of the system dynamics -- *connection vector fields* for differential motion, and *constraint curvature functions* that illustrate net motion over cycles. These visualizations allow us to directly predict optimal gaits for forward, lateral and rotational motion. Experiment and simulation are in accord with the theoretical predictions; thus geometric tools can be used to study locomotion in GM.

S5-1.6 HEATWOLE, Harold*; GRECH, Alana; MONAHAN, John; KING, Sue; MARSH, Helene; NC State Univ., Raleigh, James Cook Univ., Townsville, Eastern Kentucky Univ., Richmond; *harold_heatwole@ncsu.edu*
Ectothermy in the marine environment: new perspectives from the ecology and geography of sea snakes
"True" sea snakes (marine Oxyuraninae) are small, linear in shape with a high surface area to mass ratio, and have no morphological attributes that conserve body heat; their body temperatures track those of their surrounding medium. Their thermoregulatory repertory is entirely behavioral, and includes diving to cooler depths, or basking at the surface. The latter is relatively ineffective because of the high surface area to volume ratio of snakes and the high conductivity of water. Most species are bottom-feeders and spend little time at the surface. Sea kraits (Laticaudinae) that feed in the sea but come out on land to rest, digest, and reproduce, thermoregulate by selecting appropriate terrestrial shelter, but are influenced by sea temperatures. The banded sea krait (*Laticauda colubrina*) has a distribution that straddles the equator and is subjected sea temperatures symmetrically distributed around the equator. Its poleward limits of distribution are restricted by low sea temperatures as boundaries relate to specific isotherms, even on a local scale, such as where currents carry cool water into areas otherwise inhabited by kraits. Morphological features under thermal control during development, or with differential fitness under different thermal regimes would be expected to show convergences between northern and southern populations relative to central ones. For sea kraits multivariate analyses, incorporating latitude and sea temperatures as environmental variables, revealed a strong latitudinal component that varied from west to east but that was not linked strongly to specific thermal conditions. Future research should investigate intraspecific geographic variation in physiological attributes and tolerance limits in relation to temperature.

S7-2.2 HEDRICK, TL; Univ. of North Carolina at Chapel Hill; *thedrick@bio.unc.edu*

Separating behavioral and passive dynamics in the pitch maneuvers of hawkmoths

Flying animals are widely appreciated as having amazing capabilities of flight maneuverability and control. Some types of these maneuvers, especially those beginning in a hovering or slow forward flight state, are now regularly recorded in attempts to understand the basis for these capabilities. However, many factors contribute to the observed dynamics of the animal, complicating analysis of the recordings. These factors include sensory feedback which results in the animal making changes to its wing kinematics and body configuration to produce the maneuver or compensate for a perturbation, making the observed motions the result of a "closed-loop" feedback process. Additionally, passive effects such as drag and the passive damping due to the interaction of basic (i.e. hovering) flapping kinematics with body motion also produce forces which influence the dynamics of the animal. These "open-loop" or uncontrolled effects on the dynamics of the animal must be isolated and removed from the observations to assess the animal's active contribution to the observed movements. Because animals tend to respond to their environment or to imposed perturbations, open-loop properties are best measured by mathematical model, computational simulation or mechanical model. Here I use a comparison of two similar maneuvers or changes in state in the hawkmoth *Manduca sexta* to show how closed- and open-loop effects combine in different ways. The first of these cases is an animal initiated pitch maneuvers and the second a response to pitch perturbations. Despite the similarity of the maneuvers, the open- and closed-loop breakdown shows that the response to a pitch perturbation is not identical to the response of a moth stabilizing itself following an animal initiated pitch maneuver.

92.5 HEERS, Ashley M.*; DIAL, Kenneth P.; University of Montana; *ashmheers@gmail.com*

Locomotor ontogeny and the evolution of avian flight

Fossils with transitional morphologies are the record of major evolutionary transformations key to understanding life's history. Reconstructing these transformations requires interpreting functional attributes of extinct forms by exploring how similar features function in extant organisms. Yet extinct-extant comparisons are often difficult, because extant adult forms frequently differ substantially from fossil material. Here, we illustrate how postnatal developmental transitions in living birds can provide rich, novel insight into the evolution of avian flight. As developing birds acquire flight capacity, ontogenetic changes in feather and skeletal morphology tend to parallel evolutionary changes in the theropod ancestors of birds. Examining locomotor ontogeny may thus clarify potential locomotor capacities of extinct theropods, by elucidating relationships between form, function, and behavior during obligately-bipedal to flight-capable transitions. To document feather and skeletal ontogeny in the precocial chukar (*Alectoris chukar*), we (i) used a propeller apparatus to measure aerodynamic forces generated by dried chukar wings over a range of ages and Reynolds numbers, and (ii) used high resolution CT scans and biplanar x-ray videos (X-ray Reconstruction of Moving Morphology) of different aged chukars to quantify 3D skeletal kinematics during various behaviors. Our results show that juveniles and adults with highly disparate anatomies employ remarkably similar skeletal kinematics, possibly due to differences in aerodynamic force production. These findings are important for understanding flight ontogeny and evolution. Similarities between developing birds and extinct theropods are merely one of many parallels between ontogeny and evolution, and exploring the ontogeny of morphological form and functional capacity may thus provide rich insight into a broad array of evolutionary transformations.

55.5 HEINBOCKEL, T.*; WANG, Z.-J.; SUN, L.; Howard Univ. Coll. of Medicine, Washington, DC; *theinbockel@howard.edu*

Cannabinoid Receptor-Mediated Regulation of Neuronal Activity and Signaling in Glomeruli of the Main Olfactory Bulb

Glomeruli in the main olfactory bulb (MOB) are the initial sites of synaptic processing and contain at least three types of neurons collectively referred to as juxtaglomerular (JG) cells. JG cells include periglomerular (PG) cells, external tufted (ET) cells, and short axon (SA) cells. In glomeruli, PG cells form inhibitory GABAergic dendrodendritic synapses with ET cells. ET cells form excitatory glutamatergic dendrodendritic synapses with PG and SA cells. Neurons in the MOB express cannabinoid receptors, CB1R. The function of CB1R and their endogenous activators, endocannabinoids, for neuronal signaling in glomeruli is unknown. In mouse brain slices, we used whole-cell patch-clamp recordings to study the role of CB1R in regulating the activity and signaling of PG and ET cells. A CB1R antagonist evoked membrane depolarization and increased action potential firing in PG cells, while CB1R agonists inhibited PG cells. Blockers of synaptic transmission (ionotropic glutamate and GABA-A receptor antagonists) failed to block CB1R-evoked modulation of PG cell activity, suggesting that cannabinoids had direct effects on PG cells. In the presence but not in the absence of synaptic blockers, ET cells showed a response to CB1R activation similar to PG cells. A CB1R antagonist modestly activated ET cells and an agonist inhibited ET cells. A pulse of depolarizing current injected into an ET cell or a train of depolarizing pulses evoked suppression of IPSCs suggesting retrograde endocannabinoid signaling in the MOB, namely, depolarization-induced suppression of inhibition (DSI) in ET cells. We hypothesize that sustained burst firing of ET cells triggers the release of endocannabinoids which in turn directly control PG cell excitability and reduce GABA release from PG cells. This can result in a transient reduction of PG cell inhibitory input to other neurons such as olfactory nerve, mitral cells and ET cells. Support: Whitehall Foundation, U.S. PHS grants S06GM08016 (MBRS-SCORE, NIGMS/NIH), U54NS039407 (SNRP, NINDS/NIH), 2G12RR003048 (RCMI, NIH-NCRR).

78.1 HEINIGER, J*; VAN UITREGT, V; WILSON, R S; University of Queensland; *r.wilson@uq.edu.au*

Fine tuning anti-predator responses: are the costs of inducible predator defences proportional to the magnitude of the responses?

The threat-sensitive predator avoidance hypothesis predicts the magnitude of inducible defensive responses should reflect the degree of threat. This allows organisms to maximise the effectiveness of the defence whilst minimising the associated costs. Although we know prey can fine-tune their responses to the degree of predation risk, it is unclear if the magnitude of threat-sensitive defensive responses relate to their associated costs. We tested this assertion by examining the effects of increases in perceived predation risk on the expression of inducible defences and their associated costs in larvae of the cane toad, Bufo marinus. We reared larvae in varying concentrations of predation cue and quantified their growth, morphology and development, as well as metamorphic size, locomotor performance and oxygen consumption. We predicted the magnitude of inducible defensive responses of larvae would be proportional to the associated costs experienced by the metamorphs. Larvae responded to increases in perceived predation risk in a threat sensitive manner by gradually decreasing their activity. As a consequence, individuals metamorphosed later, smaller and with reduced endurance. Although no differences in maximum jumping distance were detected among treatments, the longer relative hind limbs of metamorphs that experienced high predation cues allowed them to jump further for their overall body size. In support of our predictions, we found the costs of producing an inducible defensive response were proportional to the magnitude of the response. Thus, our data support the hypothesis that prey can fine tune their anti-predator responses to the intensity of threat, allowing prey to balance the costs experienced against the benefits to predator avoidance.

117.1 HEISS, Rebecca S. *; SCHOECH, Stephan J.; University of Memphis; *rsheiss@memphis.edu*

Experimental supplementation with antioxidants reduces reproduction-associated oxidative damage in breeding male Florida Scrub-Jays

Oxidative damage results from the inability of an organism to cope with reactive oxygen species. Previously, we found that male Florida Scrub-Jays (*Aphelocoma coerulescens*) with elevated oxidative damage levels during the pre-breeding period had lower reproductive effort. A significant increase in oxidative damage levels from pre-reproduction to post-reproduction was also found exclusively in males. We experimentally assessed these correlations through supplementation with antioxidants. Thirty male breeders were equally divided and either supplemented with an antioxidant enhanced cat food, a non-antioxidant enhanced cat food, or were not supplemented. Plasma was collected for males in each treatment group, both prior to, and post reproduction. Oxidative damage to DNA and proteins was assessed in each bird. Plasma was further subjected to an oxidative attack to determine total antioxidant capacity (TAC). Supplemented males demonstrated significantly higher levels of reproductive effort relative to control males, however, there was no statistical difference between the effort of males in either of the supplemented groups (antioxidant enhanced or not). Similarly, when controlling for reproductive effort, antioxidant supplemented males had significantly lower levels of oxidative damage to proteins post-reproduction than males in either of the other treatment groups. Relatively higher levels of damage to DNA prior to breeding, predicted higher reproductive effort independent of treatment group. For control groups, reproduction significantly lowered resistance to an oxidative attack, however, birds supplemented with antioxidants had similar TAC levels prior to, and post reproduction.

120.3 HELM, BR*; DAVIDOWITZ, G; University of Arizona; *bhelm@email.arizona.edu*

Do resource thresholds play a role in the onset of maturation--a key life history transition?

Within the life history of a single organism, the onset of maturation marks a significant shift from the juvenile stage of life to the reproductive adult form. For a wide taxonomic sampling of organisms, this transition has been found to occur upon the attainment of a critical threshhold size near the end of larval growth after which hormonal and developmental mechanisms control maturation to the adult form. The internal physiological conditions that are assessed at the critical weight are, however, unresolved. An implicit assumption of life history theory is that the role of the juvenile stage acquire resources for growth and development. This pattern and theory lead to the hypothesis that the critical weight is triggered by the attainment of a resource threshold late in larval development. In this study, we use the model organism Manduca sexta to test two key predictions derived from this hypothesis: first, experimental augmentation of resources should move the critical weight forward in ontogeny, and 2.) environmentally-induced plasticity of the critical weight can be explained by differential rates of resource allocation to storage.

35.1 HELMUTH, B*; KEARNEY, MR; MATZELLE, A; University of South Carolina, Columbia, University of Melbourne, Victoria; *helmuth@environ.sc.edu*

Forecasting the sublethal impacts of climate change: no more lizard lovin' and mussel beaches?

Despite an emphasis on measuring and predicting patterns of mortality and species range boundaries, recent studies have begun to point to the importance of sublethal effects of climate change on organisms and populations and the ensuing consequences to ecosystem services. The emerging field of mechanistic niche modelling aims to link the functional traits of organisms to their environments to predict growth, survival, reproduction, distribution and abundance. Here we use biophysical heat budget models combined with Dynamic Energy Budgets to examine the effects of weather on two very different organisms, the sessile mussel *Mytilus californianus* and the behaviorally thermoregulating terrestrial lizard *Sceloporus undulatus*. Using input data of different temporal resolutions (calculated using daily data or calculated from monthly means) we show that fine-scale temporal resolution (daily) data can be critical for unbiased inference of climatic impacts on survival, growth and reproduction. This is especially so for organisms with little capacity for behavioural buffering, either because of behavioral or habitat constraints, and for detecting temporal trends. Specifically, results suggest markedly different predictions of the physiological responses of *S. undulatus* to long-term (30 yr) trends in warming at sites throughout the U.S. depending on the temporal resolution of environmental data used.

57.4 HENNIN, H.L.*; BÊTY, J.; GILCHRIST, H.G.; LOVE, O.P.; University of Windsor, ON, UniversitÃ© du QuÃ©bec Ã Rimouski, National Wildlife Research Centre, Environment Canada, Ottawa, ON; *hennin@uwindsor.ca*

Do state-mediated hormones predict reproductive decisions in Arctic-nesting common eiders?

Individual state and the abiotic environment are predicted to influence the reproductive decisions and therefore reproductive success of migratory species. Previous studies have shown that body mass and arrival date on the breeding grounds explain some of the variation seen in the reproductive success of Arctic-nesting, migratory species; however a substantial amount of variation is still unexplained. Using a state-dependent approach, our goal is to use physiological traits to enhance our ability to explain the variation seen in reproductive decisions and hence, reproductive success of individuals. We are studying a colony of Arctic-nesting common eiders (*Somateria molissima*) at East Bay Island, Nunavut, Canada. From 2006-2009, we collected blood samples from approximately 1000 pre-breeding females and assayed them for plasma baseline hormones (corticosterone and leptin), energetic metabolites (triglycerides), and oxidative stress levels, and recorded both the reproductive decisions (e.g. whether to reproduce, when to reproduce) and reproductive success (e.g. ability to hatch ducklings) of these individuals. We aim to determine the influence of these physiological traits in explaining the variation in reproductive decisions and reproductive success via correlative analyses and experimental manipulations in the field to test the causal relationships between individual state (physiology) and reproductive success. These results will provide insight into the evolution of mechanisms linking individual state and fitness in long-lived, migratory organisms.

8.2 HENNINGSEN, Justin P.*; LANCE, Stacey L.; IRSCHICK, Duncan J.; Univ. of Massachusetts Amherst, Savannah River Ecology Lab, Univ. of Georgia; *justin.henningsen@gmail.com*

How do signal size and performance capacity affect reproductive success in male green anole lizards (Anolis carolinensis)?

In many animal species, males compete aggressively for control of territory and access to females. The outcome of such aggressive interactions is influenced by whole-organism performance traits. In some species, performance traits are consistently correlated with some aspect of a signal (e.g., size, color, behavior). These reliable signals are displayed to rivals and may resolve agonistic disputes without resorting to potentially costly physical aggression. However, in such cases the correlation between the signal and the other trait can obfuscate the relationship between these two characteristics and the results of interactions with conspecifics. In male green anole lizards, the size of the throat fan, or dewlap, is positively correlated with maximum bite force capacity. Bite force, in turn, is a trait that is known to influence the outcome of aggressive interactions. However, the relationships among bite force, dewlap size, dominance, and reproductive success remain unclear. We paired males in large, semi-natural enclosures with females present and manipulated the size of the dewlap of one male in order to decouple the relationship between dewlap size and bite force. We observed and recorded behavior, and collected and genotyped offspring in order to determine how performance and signals affected reproductive success.

119.4 HENNINGSSON, Per*; BOMPHREY, Richard/J; University of Oxford; *per.henningsson@zoo.ox.ac.uk*

How aerodynamic induced power scales with body mass and wing span in British dragonflies and damselflies

The efficiency with which a flying animal generates lift has wide ranging implications and impacts upon its maximum flight range, peak load lifting capacity, flight duration, accelerations during manoeuvres and other performance metrics that are dependent on energy budget. Some measures of aerodynamic efficiency can be directly measured using flow diagnostic techniques. Measuring the flow around insects in flapping flight presents an exciting challenge because they are typically small, have high wingbeat frequencies, and the aerodynamics can be highly time variant and complex. Nevertheless, if the flow fields they generate can be measured then the efficiency of the process can be assessed using well-established aerodynamic theory. We used high-speed stereo Particle Image Velocimetry (repetition rate 1 kHz) to measure the distribution of induced flow of freely flying species of damselflies and dragonflies flying in a wind tunnel and calculated the efficiency of lift production at many intervals during the stroke cycle. The species included in the study covered a three-fold range of wingspan, and a forty-fold range in mass. We present how time-varying span efficiency scales with size and mass in British Odonata over these ranges.

15.10 HENRY, RP*; SERRANO, L; Auburn University; *henryrp@auburn.edu*

Molecular basis of low salinity limits in euryhaline decapod crustaceans

Euryhaline crustaceans make the transition from osmoconformity to osmoregulation at about 26 ppt salinity, and this ability allows them to survive in very dilute estuarine waters. But even these organisms have a lower limit of salinity tolerance, and it varies among species. Blue crabs, Callinectes sapidus, can survive direct transfer down to fresh water (0 ppt); but green crabs, Carcinus maenas, have a lower lethal salinity limit near 5 ppt and are rarely found in nature below 7 pp. To test the molecular basis of extreme low salinity tolerance, we measured acute and acclimated changes in carbonic anhydrase (CA) gene expression and enzyme induction in response to multiple step-wise reductions in salinity in both species. Blue crabs survived all transfers down to 5 ppt but showed the maximum increases of both CA gene expression and enzyme induction in posterior, ion-transporting gills at 15 pp. Neither value increased in the lower salinities. Interestingly, at 5 ppt, there was a dramatic increase in CA gene expression in anterior gills, but this was not accompanied by an increase in CA activity. Green crabs also showed maximal CA gene expression and enzyme induction at 15 ppt, but both values then decreased as salinity was progressively lowered. Direct transfer to 5 ppt resulted in 50% mortality at 4 days (acute) and 100% mortality at 7 days (chronic) exposure. In the acute phase, there was a significant increase in CA gene expression in anterior gills but no increase in enzyme induction. Furthermore, there was no significant CA induction in posterior gills at 4 days post-transfer to 5 ppt. These results suggest that the molecular mechanism of transport-related protein induction breaks down near the lower lethal salinity limit, and fails to confer adequate systemic physiological adaptation for continued survival.

44.4 HERREL, A*; CORNETTE, R; UMR 7179 C.N.R.S/M.N.H.N., DÃ©partement d'Ecologie et de Gestion de la BiodiversitÃ©, 57 rue Cuvier, Case postale 55, 75231, Paris Cedex 5, France., UMR 7205 C.N.R.S/M.N.H.N., DÃ©partement SystÃ©matique et Evolution, Origine, Structure et Evolution de la BiodiversitÃ© (OSEB), plateforme de morphomÃ©trie, 45 rue Buffon, 75005 Paris, France.; *anthony.herrel@mnhn.fr*

The evolution of form and function in the greater white–toothed shrew.

Many small vertebrates on islands grow larger, mature later, lay smaller clutches or litters, and are less sexually dimorphic and aggressive than their mainland relatives. The intensity of this insular syndrome is thought to be linked to the different ecological characteristics of islands compared to the mainland. Here we study the mandible of the greater white toothed shrew, *Crocidura russula*, on the French Atlantic islands and compare it to individuals from populations on the mainland to quantify potential effects of insularity. We used both traditional and geometric morphometric analyses to quantify differences in size and shape between populations. Moreover, we describe shape co-variation in skull and mandible shape using 3D surface geometric morphometric tools. Finally, we explore the functional consequences of shape co-variation in skull and mandible using both modelling approaches and in vivo bite force measurements. Our data show that whereas specimens from island populations are not different from adjacent continental populations in mandible size, they are clearly different from continental populations by their shape. Among islands, the shape of the mandible shows various types that can be linked with both the distance from the coast and island surface area. The co-variation between the skull and mandible in *C. russula* is dominated by the variation in attachment sites of the temporalis muscle which has clear and significant effects on the mechanics of biting.

7.1 HEWS, D.K.*; OSSIP-KLEIN, A.; OYOLA-MORALES, J.; CAIN, P.; MARTINS, E.P.; Indiana State Univ., Terre Haute, Indiana Univ., Bloomington, Indiana Univ., Bloomington and Cornell Univ., Ithaca, NY; *diana.hews@indstate.edu*

Multiple color traits: can they signal body condition or size in male Sceloporus lizards

In males, secondary sexual traits may signal aspects of the phenotype that are important to potential mates and/or to competing males. For example, different elements of color signals correlate with different steroid hormones or nematode loads in some lizards. Adult male *Sceloporus merrami* are unusual for this lizard genus because the abdominal coloring, which is typical of males in this genus, involves several color and shape components, instead of being a simple blue oval that is often partially outlined in black. We assessed the potential for multiple color signals in breeding-season male *S. merrami* and *S. undulatus* by first assessing associations among the color and shape elements we measured. We then used multivariate approaches to assess associations between the independent components of abdominal coloring and several variables including 1) body size, as measured by snout-to-vent length (SVL) and mass; 2) body condition, as measured by residuals from a regression of mass on SVL, 3) fluctuating asymmetry in some individual patch elements, and the body size and body condition measures. Future analyses also will assess these relationships, but use additional display modalities including motion (frequency and cadence of display elements) and chemical signals (lipid and protein composition of secretions from femoral glands known to have a social signaling function in *Sceloporus*.

71.9 HICKMAN, Carole S.; Univ. of California, Berkeley; *caroleh@berkeley.edu*

Why Marine Mollusks don't require larvae for dispersal

Dispersal modes in marine mollusks are linked classically to larval life history. Taxa that lack a planktonic larval stage and larvae that do not feed in the plankton allegedly lack exposure to currents and prolonged opportunity for long-distance travel and establishment of broad geographic ranges. Because lecithotrophic larvae are characterized as poor dispersers, it has been difficult to explain how so many molluscan taxa with this mode of development have achieved broad geographic distributions. Rafting, transport on the feet of birds and successful passage through the guts of motile predators are entrenched in dispersalist folklore. However there are other dispersal mechanisms consistent with otherwise enigmatic distribution patterns. The following biological phenomena are proposed as a charter for an alternative body of biogeographic theory: (1) re-entry of adults into the water column to form pelagic spawning aggregations (2) byssus drifting of juveniles, (3) mucus thread kiting of juveniles and adults, (4) midwater metamorphosis, (5) gas flotation at the air-water interface, (6) adhesion to surface films, and (7) pelagic egg capsules and egg masses. Two additional phenomena that merit greater attention with respect to dispersal are ontogenetic migration of lecithotrophic larvae of deep-sea taxa and transport of larvae entrained in mesoscale parcels of water that form “dispersal units” during turbulent disturbance events. There are observational reports of all these phenomena in the literature and opportunities for rigorous study of the underlying structural, functional and behavioral biology.

22.12 HICKS, R.; MACESIC, L.J.; GILLIS, G.B.*; Mount Holyoke College; *ggillis@mtholyoke.edu*

Horizontal and vertical landing in the Cuban tree frog, Osteopilus septentrionalis

Recent work focused on what happens after takeoff in frogs and toads is revealing that Anurans approach landing in different ways. Specifically, the use and movements of both the forelimbs and hindlimbs differ radically between species that land with varying degrees of coordination. Tree frogs are known for inhabiting a complex arboreal environment and because of their toe pads are capable of landing on diverse surfaces that can be at just about any orientation (consider the leaves and branches on which we often see tree frogs photographed). The goal of this study was to determine whether Cuban tree frogs, *Osteopilus septentrionalis*, prepare for landing differently depending on the orientation of the substrate. High-speed video recordings indicate that, indeed, the patterns of movement of the forelimbs and hindlimbs during horizontal hops differ from those in which the animal leaps to a vertical surface. When performing horizontal hops, the tree frog rapidly moves its forelimbs after takeoff to be in a position to absorb the impact of landing while the hindlimbs are rapidly folded back into a flexed position. In contrast, after takeoff toward a vertical surface, the hindlimbs remain extended until impact and the forelimbs are rarely the first part of the animal’s body to make contact. Instead, it is generally the head or trunk that first makes contact with a vertical surface, after which the forelimbs are quickly moved to a position that allows the toepads to adhere, and the legs are pulled in. Our preliminary data suggest that when approaching a landing surface this species varies its limb movements depending on the orientation of that surface.

1.5 HIGGINS, B.A.*; HORN, M.H.; California State Univ., Fullerton; *higgins.ben@gmail.com*

Suction among pickers: Jaw mechanics and dietary breadth in the beach-spawning grunion sisters (Leuresthes) compared to their relatives (Teleostei: Atherinopsidae)

We compared jaw mechanics and dietary breadth in the sister atherinopsids *Leuresthes tenuis* (California grunion) and *L. sardina* (Gulf grunion) along with three other members of the Atherinopsini to test whether the two grunion species have evolved a novel jaw protrusion that might be associated with feeding narrowly on abundant prey near spawning beaches. Quantitative comparison of cleared-and-stained specimens of five members of the atherinopsine clade showed that, compared to *Colpichthys regis* (false grunion), *Atherinops affinis* (topsmelt), and *Atherinopsis californiensis* (jacksmelt), *L. tenuis* and its sister *L. sardina* have longer (5.1% vs 0.9%), more downwardly directed (-37 vs. +0.1 degrees) premaxillary protrusion, expanded dentary and premaxillary bones, greater lower jaw rotation (65.3 vs 13.8 degrees), and greater premaxillary-vomer spacing (36.6% vs 20.9%). *L. tenuis* showed the most divergence in these features. High-speed video analysis indicates that *L. tenuis* protrude their jaws faster than *A. affinis*. For dietary analysis, adult *L. tenuis* and *A. affinis* were collected offshore, simultaneously with zooplankton samples to represent prey availability. *L. tenuis* fed heavily on mysid crustaceans, and, as predicted, had a narrower diet than *A. affinis* in the same habitat, as shown by higher L selectivity (0.5 vs. 0.1) and lower H’ diversity (0.81 vs. 1.58), and J evenness (0.48 vs. 0.80) values. Information available on *As. californiensis* and *C. regis* indicate that these species have broad diets associated with benthic feeding. The diet of *L. sardina* remains largely unstudied. *L. tenuis* appears to have evolved a method of jaw protrusion unlike close (cyprinodontiform) and more distant (perciform) relatives.

2.6 HIGHAM, Timothy E.*; RUSSELL, Anthony P.; Univ. of California, Riverside, Univ. of Calgary; *thigham@ucr.edu*
Dancing with the tails: Comparative dynamics of caudal autotomy in geckos
Autotomy, the voluntary loss of an appendage in response to mechanical and/or visual stimulation, is common among diverse groups of vertebrates and invertebrates. Tail autotomy in lizards is important for distracting a predator, providing a window of time for the lizard to escape by providing the would-be predator with a dissociated source of visual stimulus. Although autotomized gecko tails can move in rhythmic and complex ways, few species of gecko have actually been examined with regard to the pattern of movement that they display, and how this might relate to ecological and morphological circumstances. To begin to explore how the tails of disparate groups of geckos move, we obtained high-speed video (250 - 500 Hz) from original autotomized tails representing five genera (*Rhoptropus*, *Eublepharis*, *Tarentola*, *Hemidactylus* and *Chondrodactylus*) spanning three families (Eublepharidae, Gekkonidae, and Phyllodactylidae). The initial 24 seconds of tail movement following autotomy was observed. Tail movements investigated include tail-swinging rate, tail acceleration, amplitude of tail bending, and frequency of complex flips and jumps (relative to rhythmic swings). Results reveal interesting differences between genera. All species exhibited jumps, flips, and swings. A rolling behavior, particularly when in contact with the arena wall, was observed in *Chondrodactylus*. Species differed in the rate of movement immediately following autotomy, and the proportion of complex movements within the initial 24 seconds following autotomy also differed between species. Finally, the magnitude of the flips was considerably greater in *Eublepharis* compared to the other species. The inter-specific differences are discussed in relation to differences in ecology and morphology.

38.3 HILL, G. E.; Auburn Univ.; *ghill@auburn.edu*
Condition-dependent display traits as signals of the functionality of vital cellular processes
Condition is a nearly ubiquitous term in the behavioral, physiological, and evolutionary literature, yet existing definitions are incomplete or ambiguous. Too often in the literature, condition is defined in terms of nutrient reserves. This poor conceptualization has led to confusion regarding what is being signaled by condition-dependent traits and how to interpret links between ornamentation and individual characteristics such as nutrient reserves, oxidative state, and immunocompetence. I propose that the combined effects of the somatic state, epigenetic state, and genotype of an organism determine condition. I define condition as the relative capacity to maintain optimal functionality of vital systems within the body. A condition-dependent trait is a conspicuous feature of an organism that enhances perception of condition. If the honesty of ornamental traits derives from connections to vital cellular processes then there is no need to invoke a resource tradeoffs to insure signal honesty.

7.5 HOBBS, N.J.*; FERKIN, M.H.; University of Memphis; *nhobbs@memphis.edu*
Reproductive state of female voles affects males' responses to same- and mixed-sex over-marks
Many mammals use scent marks and over-marks to signal their condition and willingness to mate with conspecifics. Animals may encounter over-marks in which the scent donors are the same sex (same-sex over-marks) or the scent donors differ in sex (mixed-sex over-marks). During the breeding season, the condition of female meadow voles, *Microtus pennsylvanicus*, may vary. Females may be in a heightened state of receptivity known as postpartum estrus (PPE). Alternatively, females that are neither pregnant nor lactating may be in a more moderate state of sexual receptivity (REF females). We conducted three experiments that determined whether males exposed to over-marks containing the scent marks of PPE and REF females respond preferentially to females based on either the position of their scent mark in the over-mark or their reproductive state. In experiment 1, we tested the hypothesis that how males respond to the two female scent donors of a same-sex over-mark is affected by the females' reproductive states. Experiments 2 and 3 tested the hypothesis that the reproductive state of a female in a mixed-sex over-mark affects how males respond to her scent mark relative to that of a novel female. Our results suggest that males use both the position of a female's scent mark as well as her reproductive state when evaluating the scent donors of same- and mixed-sex over-marks as potential mates.

S10-1.4 HOEG, JT*; CHAN, BKK; GLENNER, H; MARUZZO, D; OKANO, K; University of Copenhagen, Academia Sinica, Bergen University, University of Padova, Akita Prefectural University; *jthoeg@bio.ku.dk*
Metamorphosis in balanomorphan, pedunculated and parasitic barnacles: A video based analysis
All barnacles pass a profound metamorphosis between the larval phase and the attached juvenile. We use video microscopy to study metamorphosis in both suspension feeding thoracicans and in parasitic rhizocephalans. The morphology of the cirripede cyprid is incompatible with that of the ensuing juvenile form, whether suspension feeding or parasitic. Therefore, the reorganization involved in metamorphosis can only commence after permanent attachment, but must then proceed rapidly because the attached cyprid has limited energy resources and faces external dangers such as desiccation, predation, or removal by the host animal. In all cirripedes the metamorphic moult is initiated by a slight separation of the integument from the cyprid cuticle, and antennular muscles participate in the ensuing process. In balanomorphans a rotation of the body assures the correct orientation of the cirri, and pulsating movements of the prospective juvenile results in elimination of the cyprid carapace. The compound eyes are shed just before this event. Metamorphosis lasts from a few hours (Balanomorpha, Rhizocephala) to several days (pedunculates). The free balanomorphan juvenile is rather shapeless, with very thin cuticle and continues its pulsating movements, but it quickly assumes the volcano shape of a barnacle with incipient shell plates and beating cirri. Pedunculated forms have a more gradual metamorphosis. In rhizocephalans, female cyprids moult into a kentrogon, which after two days use a stylet to penetrate into the host and enter as a simplified vermigon stage, the injection lasting seconds only. Elimination of the cyprid carapace is essential in thoracicans but not in all rhizocephalans.

S10-1.5 HOLM, E.R.; Naval Surface Warfare Center, Carderock Division; *eric.holm@navy.mil*

Barnacles and biofouling - a brief history and summary of current research approaches and results

Biofouling, the accretion of organisms on submerged surfaces, has been the bane of ship operators for at least 2500 years. Accumulation of biofouling increases the frictional resistance of ship hulls and propellers, resulting in increased fuel consumption and decreased speed. Although the great diversity of biofouling organisms is well recognized, barnacles have, for better or worse, come to serve as both the phenomenon's popular symbol and its indispensable research tool. Initial studies on barnacles and biofouling focused on documenting the extent of the problem, but later progressed to addressing aspects of larval attachment, metamorphosis and subsequent adhesion. With the development of relatively simple, portable, culture protocols, as well as clever assays, biofouling research with barnacles now often focuses not on biological aspects of the organism, but instead on the development of materials to maintain clean, smooth, hulls and propellers. These include evaluations of novel strategies for reducing the initial attachment of biofouling or its adhesion. I review the recent use of barnacles in the development of new antifouling and fouling-release hull coating materials. The process can be turned on its head – these new materials can be used as probes to further our understanding of, for example, the control of barnacle larval settlement or adhesion of adults.

76.2 HOLT, A.L.*; GAGNON, Y; SWEENEY, A.M.; MORSE, D.E.; Univ. California, Santa Barbara, Duke University; *amanda.holt@lifesci.ucsb.edu*

A monte-carlo model of photon transport in symbiotic giant clams

Giant clams of the genus *Tridacna* have a complex photonic system combining photosynthetic and absorbing brown algae with single cell reflectors, the functions of which are currently poorly understood. To explore the functionality of the iridocyte cells in this unique photonic system, we developed a novel, detailed model of light scattering in the tissue using a stochastic Monte Carlo photon transport method. Using optical and transmission micrograph data, we replicated *in silico* the organization of algae and iridocyte cells in three-dimensions and many levels of spatial hierarchical organization. Monte Carlo ray tracing was then used to explore photon transport in this biologically realistic three-dimensional space. Our model used fixed cell positions and probability-weighted scattering functions for algal cells and iridocytes to then calculate the scattering of thousands of photons based on these probabilities. The computational efficiency of our method is high because the code has been vectorized in Matlab, allowing us errors of <1% of these tracked parameters. We used our model to track the values of total absorption and individual cell absorption by algal cells in the 3D tissue with a high degree of realism and accuracy. By systematically changing the scattering probabilities of the iridocytes and determining which ones most accurately describe reflectance, optical, and transmission micrograph data, we learned that the iridocytes are organized on multiple spatial scales to scatter light into the tissue in a way that optimizes photosynthetically active irradiance in both wavelength and intensity, according to the physiological abilities of the algae.

94.6 HOLZMAN, R*; COLLAR, D.C.; MEHTA, R.S.; WAINWRIGHT, P.C; Tel Aviv Univ, UC Santa Cruz, UC Davis; *holzman@post.tau.ac.il*

Suction Induced Force Field: An integrative model of aquatic feeding performance

Research on suction feeding performance has focused on measuring individual underlying components of performance such as suction pressure, flow velocity, ram, or the effects of suction forces on prey movement. Although this body of work has contributed to our mechanistic understanding of aquatic feeding, no consensus has emerged on how to best estimate suction feeding performance. We developed the Suction Induced Force Field model (SIFF) to integrate effects of morphology, physiology, skull kinematics, ram, and fluid mechanics on suction feeding performance. SIFF treats the aquatic predator-prey encounter as a hydrodynamic interaction between a solid particle (the prey) and the unsteady suction flows around it. SIFF combines the underlying suction feeding components by numerical simulation to predict the probability of prey capture as an integrated metric for performance. We parameterized SIFF with data from 18 species of centrarchid fishes, and asked what morphological and functional traits underlie the evolution of feeding performance on three types of prey. Analysis of SIFF output revealed that different trait combinations contribute to the ability to feed on each prey type (attached, evasive, or zooplanktonic prey), such that high performance on more than one prey was sometimes observed in the same species. SIFF yielded estimates of feeding ability that performed better than kinematic traits in explaining natural patterns of prey use. When compared to a principal components analysis on suction feeding kinematics, performance estimates from SIFF explained greater variation in centrarchid diets, suggesting that the inclusion of more mechanistic hydrodynamic models holds promise for gaining insight into the evolution of aquatic feeding performance. The use of SIFF, available as MATLAB code, will be demonstrated and explained for different prey types.

67.2 HOMBERGER, D.G.*; DUBANSKY, B.H.; Louisiana State Univ., Baton Rouge; *zodhomb@lsu.edu*

Functional morphology of the crocodilian and avian integument: Implications for the evolutionary origin of feathers in dinosaurs

The integuments of crocodilians and birds differ fundamentally in their structure. Crocodilian skin resembles fossilized dinosaur skin in having non-imbricating plate-like or tuberculate scales. Hence, the skin of alligators with its hard-cornified plate-like scales, expandable interscale skin that is rich in elastic fibers, a subcutis (Fascia superficialis) that is composed of obliquely helical collagen fibers, and a complete absence of dermal musculature is an appropriate extant model for the skin of dinosaurs. In contrast, the skin of birds has a very thin, scale-less epidermis, and the adipose dermis and subcutis, which are separated by an elastic membrane, form a hydraulic skeleton for the follicles of contour feathers. A complex layer of dermal musculature underlies the entire skin and forms feather muscles that move contour feathers and sheets of apterial muscles that adjust the tension and placement of feather tracts. Furthermore, the feather muscles comprise not only arrector muscles (like those that move the hairs of mammals and the imbricating scales of lepidosaurians), but also stronger depressor muscles that are derived from the arrector muscles. Biomechanical models and experiments have shown that contour feathers perform their aerodynamic function only if they are integrated into a hydraulic skeleto-muscular apparatus. Hence, feathers could obviously not have evolved from a scaly integument that is devoid of dermal musculature and is moved only passively and by elastic resilience as in alligators and probably dinosaurs.

112.3 HORNER, Angela M*; ASTLEY, Henry C; ROBERTS, Thomas J; Brown University; *angela_horner@brown.edu*
Analysis of rat hindlimb muscle and tendon mechanics using x-ray videoradiography
Biomechanical scaling principles have shaped our understanding of mammal locomotion for decades, but our understanding of tissue level function is biased toward taxa 1 kg or larger. For example, although rats are commonly used in muscle physiology research, few studies have measured muscle and tendon function in vivo. This bias in data is due in part to the technical challenges imposed by instrumentation of small mammal tissue in vivo. In this study we apply a novel methodology for the study of small mammal muscle and tendon function utilizing high speed, biplanar videoradiography (as used in X-Ray Reconstruction of Moving Morphology, or XROMM). In this system, movements of bone and markers can be tracked accurately (± 0.1mm) with minimal invasiveness. We surgically implanted rats with small (< 1.0mm) radio-opaque beads; two beads were implanted into the medial gastrocnemius muscle fascicles and one into the shared tendon of the triceps surae. In vivo muscle and tendon length changes were recorded with videoradiography during locomotion on level, inclined and declined trackways, as well as during short jumps. Following locomotor measurements, animals were anesthetized and the length-tension (LT) and force-velocity (FV) properties of the muscle were measured in situ via videoradiography. The measurements revealed typical LT and FV behavior, confirming that radio-opaque markers can accurately track muscle length. These data demonstrate the wider applicability of videoradiography to soft tissue mechanics and hold promise for further study of muscle and tendon mechanics in smaller animals.

79.6 HSIEH, S. Tonia*; FISHER, Rebecca E.; KUSUMI, Kenro; Temple University, Philadelphia, PA, University of Arizona College of Medicine-Phoenix, AZ; Arizona State University, Tempe, AZ, Arizona State University, Tempe, AZ; *sthsieh@temple.edu*
The effect of tail autotomy on locomotor stability in the green anole lizard
Having a tail in the animal kingdom is common; yet, the function of such a prevalent structure is not entirely understood. Recent work has shown that tails can be important for counteracting perturbations, and can affect maneuverability on level ground. The goals of this study were to quantify how tails are used during rapid locomotion and to determine how tail autotomy and regrowth subsequently affects locomotor mechanics. Regeneration was of interest because unlike the segmented, articulated vertebrae that compose the original tail, the regenerated tail comprises a single cartilaginous endoskeleton. We also have found that reorganization of musculoskeletal tissues in the tail stump takes place within days of autotomy in preparation for tail regeneration, which may affect its function. Data were collected from 10 adult male green anole lizards (*Anolis carolinensis*) running along surfaces of different diameters: flat (i.e., infinite diameter), 19.0 mm, 15.9 mm, and 9.5 mm, while tracking their body, limbs, and tail motions. Runs were filmed with a six-camera high-speed system (Motion Analysis, Corp) pre-, immediately after, and one week post-autotomy. We expected to find signatures of increased instability when running on narrow surfaces post-autotomy. Surprisingly, preliminary results show very few kinematic differences between pre- and post-autotomy running, with the greatest changes limited to the tail. Furthermore, the greatest differences were observed on the narrowest surfaces, which offer the greatest stability challenges to the running lizard. Together, these results suggest that the tail plays an important role in minimizing perturbations to the center of mass when running on narrow surfaces.

S2-2.2 HSU, Yuying*; CHANG, Ching; National Taiwan Normal University, Taipei, Taiwan; *yuyinghs@ntnu.edu.tw*
The relationship between aggressiveness and boldness, tendency to explore and learning performance in Kryptolebias marmoratus: the influence of recent contest experiences and the roles of hormones
In some species, correlations have been found between individuals' aggressiveness and their boldness, their tendency to explore their environment actively or their performance in certain learning tasks. Researchers have suggested that a cause for the correlation between these behaviors might lie in the neuroendocrine system. In this study, we examined the relationships between aggressiveness and each of boldness, tendency to explore and learning performance in a mangrove killifish, *Kryptolebias marmoratus*. We tested the stability of the relationships by using a winning or losing experience to alter individuals' aggressiveness. We also explored the possibility that the relationships arise because these behaviors are modulated by common physiological mechanisms (i.e. levels of cortisol and testosterone). The results showed (1) that aggressiveness was positively correlated with boldness but not with tendency to explore or learning performance, (2) that recent contest experience influenced individuals' aggressiveness, tendency to explore and learning performance but not their boldness, (3) that contest experience did not, however, influence the relationship between aggressiveness and boldness and (4) that both aggressiveness and boldness were positively correlated with an individual's baseline testosterone level measured prior to its contest experience. The results suggest that there is a stable aggressiveness-boldness syndrome in *K. marmoratus* and that testosterone might be involved in mediating this.

119.2 HU, David*; DICKERSON, Andrew; MILLS, Zack; Georgia Institute of Technology; *hu@me.gatech.edu*
Wet mammals shake at tuned frequencies to dry
In cold wet weather, mammals face hypothermia if they cannot dry themselves. By rapidly oscillating their bodies for fractions of a second, hirsute mammals can shed water droplets in a manner similar to the spin cycle of a washing machine. High-speed film and fur particle tracking are used to characterize the shakes of over twenty zoo animals ranging in size from mice to bears. We here report a wet-dog-shake rule for shaking frequencies according to body size, and test this rule using experiments with a wet-dog simulator and predictions from capillarity. We find the frequencies observed are roughly consistent with those required for drop ejection, found by considering the balance of surface tension and centripetal forces on drops adhering to the animal. We also find a novel role for loose mammalian skin: by whipping around the body, it increases the speed of drops leaving the animal and the ensuing level of dryness relative to tight skin. The tuning of mammalian shakes to shed water demonstrates an inability to shed contaminants such as crude oil.

39.2 HUANG, H.-D.*; WU, C.-H.; LIU, H. C.; National Museum of Natural Science, Taiwan, National Chung-Hsing University, Taiwan, Providence University, Taiwan; *hdhuang@nmns.edu.tw*
Magnetic orientation for larval release migration by the land crab Metasesarma aubryi in Kenting National Park, southern Taiwan
The terrestrial sesarmid crab *Metasesarma aubryi* inhabit in burrows under maritime forest of Hengchun Peninsula, southern Taiwan. Ovigerous females migrate to surf for larval release during the last quarter of lunar cycle from May to November. Preliminary study showed that ovigerous crabs orient seawards when no visual and chemical cue presented. This study aims to test the hypothesis that ovigerous *M. aubryi* utilize geomagnetic signals for orientation in larval release migration. Animal collection and experiments were conducted in Sitzkou area, Kenting National Park. Crabs were tested with magnetic treatments in a circular arena; their responses and orientation in the arena were examined. In natural geomagnetic field, crabs oriented toward the seaward direction. When attached a magnet on crab carapace, or placed an isometric rubber magnetic plate under the arena, ovigerous females performed random movement. In artificial magnetic fields with designated directions, crabs oriented to the "seaward directions" corresponding to the new magnetic fields. We conclude that *M. aubryi* may equip biological compasses inside the body; geomagnetic signals may be employed as primary orientation cues for larval release migration.

49.2 HUBEL, Tatjana Y*; USHERWOOD, James; Royal Veterinary College, London, UK; *thubel@rvc.ac.uk*
Walking in children – the story of an additional gait
Observations of walking in small children show that they move quite differently from what one would expect from downsized adults. Human adults are able to drive their legs actively with a frequency about 2-3 times of its passive swing frequency, walking at 4/3rds of the speed achievable with passive swing legs. In contrast, small children – like birds – appear restricted to their passive swing leg frequency, and are limited to lower maximum walking speeds (for their size). Progressing in age, children develop the capability to swing their legs at higher frequencies. In addition, they are able to switch to running in order to achieve higher speeds. Ground reaction forces from children (age 1-5), show typical walking and running profiles, but also a consistent range of intermediates depending on age and speed. We consider these traces in the light of an economical third gait predicted by computer optimization and explore the possibility of powering based on torques, contrasting with adults, and precluded from point mass models.

8.1 HUGHES, M.*; WILLIAMSON, T.; HOLLOWELL, K.; VICKERY, R.E.; College of Charleston, SC; *hughesm@cofc.edu*
Oh snap! Sex, weaponry and aggression in snapping shrimp
Sexual dimorphism in weaponry is often attributed to intrasexual selection, wherein one sex maximizes reproductive success through competition. In snapping shrimp (*Alpheus spp*.), sexual dimorphism in snapping claws – a deadly weapon – is common, with males having larger claws than females. If larger weaponry in male snapping shrimp results from selection on males for greater ability to compete for access to mates or resources necessary reproduction, we would predict that (1) males are more aggressive than females; (2) males exhibit more sex-specific aggression than females; and (3) species with more pronounced sexual dimorphism will exhibit greater aggressive behavior. To test these predictions, we staged competitive and pairing interactions in 2 species: *A. heterochaelis* and *A. angulosus*. Although they have proportionally smaller weapons, females of both species are more aggressive than males in competitive interactions, and in both species, females but not males exhibit sex-specific aggression. Finally, although sexual dimorphism is greater in *A. angulosus*, *A. heterochaelis* is more aggressive regardless of context. Female reproductive success is limited by body size; males, but not females, use claws as visual signals of size, suggesting that males may benefit from larger claws for functions other than their use as a weapon. Thus sexual dimorphisms in weaponry may result from differential advantages of investment in body vs. weapon size, rather than intrasexual selection for greater competitive ability in males.

22.8 HULSEY , C.D.; Univ. of Tennessee; *chulsey@utk.edu*
Rates of Trophic Evolution in Lake Malawi Cichlid Fishes
The cichlid fishes of Lake Malawi may represent the most rapidly diverging adaptive radiation of vertebrates on earth. The mbuna, or rock-dwelling, Lake Malawi cichlids are the most species rich component of the Lake Malawi radiation. Using a novel phylogeny constructed from SNPs (single nucleotide polymorphisms), I recontruct the phylogeny of 40 members of the Lake Malawi Cichlid Flock. Then, I test whether 10 trophic characters show enhanced rates of evolution in the mbuna as compared to the remainder of the Lake Malawi species. Finally, using a new method of estimating phenotypic rates, I examine if the single fastest rate of evolution of single traits for the entire flock is nested within the mbuna. These results should shed light on whether the mbuna have experienced the most rapid rate of trophic evolution within the Lake Malawi cichlid radiation

115.5 HUSAK, J.F.*; LOVERN, M.B.; Univ. of St. Thomas, Oklahoma State Univ.; *jerry.husak@stthomas.edu*

Variation in circulating steroid hormones among Caribbean Anolis ecomorphs

The evolutionary processes leading to adaptive radiations have been intensely studied, yet the proximate mechanisms leading to phenotypic change during these speciation events have received less attention. *Anolis* lizards of the Caribbean are a classic example of an adaptive radiation, with each Greater Antillean island having independently evolved similar sets of coexisting ecomorphs. In addition to the well-documented convergence of morphology within ecomorphs, ecomorphs also appear to have convergently evolved similar mating systems and social organizations, though this remains poorly studied. A likely mediator for this behavioral variation is testosterone. Testosterone affects a range of male attributes, including rates of behavior and intensity of physical engagement with rival males. We predicted that ecomorphs would differ in testosterone consistent with social behavior differences. We also predicted that species of the same ecomorph category on different islands would have relatively similar testosterone levels. That is, trunk-ground anoles should have high testosterone levels compared to twig anoles on an island, with other ecomorphs being intermediate, and this pattern should be repeated across islands. We compared eight species within five ecomorphs from the Bahamas and Jamaica, finding significant differences among species in male and female testosterone levels. Even though the rank order of testosterone levels for the ecomorphs was not as we predicted, the order among ecomorphs was consistent across islands. When looking across species, we found no correlation between testosterone levels and corticosterone levels for males or females, but we did find a significant correlation between male and female testosterone levels across species. We further examined evolutionary relationships between testosterone levels and sexual dimorphism in size, shape, and performance.

28.4 HUTCHINS, ED*; STAPLEY, J; ECKALBAR, WL; KULATHINAL, RJ; HSIEH, ST; DENARDO, DF; FISHER, RE; WILSON-RAWLS, J; RAWLS, A; HUENTELMAN, MJ; BERMINGHAM, E; KUSUMI, K; Arizona State Univ, Smithsonian Tropical Research Inst, Temple Univ, Univ Arizona College of Med-Phoenix and Arizona State Univ, Translational Genomics Research Inst; *kenro.kusumi@asu.edu*

Comparative analysis of genomic sequence and myogenic pathways regulating muscle mass in the green anole, Anolis carolinensis, and the Panamanian slender anole, A. apletophallus

Anole lizards are a spectacular example of adaptive radiation in vertebrates, with morphological adaptations for specific ecological niches. A key divergent feature between anole species is the distribution of muscle group mass. From vertebrate developmental models, in which the genetic pathways regulating myogenesis are well defined, we were able to identify orthologs of muscle regulatory genes in the green anole, *Anolis carolinensis* – a trunk-crown ecomorph – whose complete genome was recently sequenced. We are currently carrying out next generation whole genome sequencing of a second anole species, the slender anole (*A. apletophallus*), which is found primarily in Panama and, unlike *A. carolinensis*, occupies a trunk-ground niche. In addition to global de novo assembly, we have generated localized assemblies of coding and 2kb flanking non-coding sequences for 20 key myogenic regulatory factors in *A. apletophallus*. Functional anatomical and histological studies are being performed to quantify the tail and hindlimb muscle groups of *A. apletophallus* compared to *A. carolinensis*. We expect that these anatomical data combined with comparative analysis of coding and regulatory sequences will allow us to identify the divergent alleles associated with changes in anole myogenesis.

104.5 HUTCHINSON, D.A.*; MORI, A.; SAVITZKY, A.H.; BURGHARDT, G.M.; NGUYEN, C.; MEINWALD, J.; SCHROEDER, F.C.; Coastal Carolina University, Conway, SC, Kyoto University, Sakyo, Japan, Utah State University, Logan, UT, University of Tennessee, Knoxville, TN, Cornell University, Ithaca, NY; *dhutchin@coastal.edu*

Sequestration of Defensive Toxins by the Asian Snake Rhabdophis tigrinus: Effects of Local Prey Availability and Maternal Diet

Rhabdophis tigrinus (Colubridae: Natricinae) is an Asian snake that possesses defensive glands known as nuchal glands on the dorsal side of its neck. The fluid from these glands contains bufadienolide steroids, which are cardiotoxic to many predators. Bufadienolides are also found in the skin glands of toads, and presumably individuals from most populations of *R. tigrinus* consume toads as part of their diet. By performing feeding experiments, we demonstrated previously that *R. tigrinus* sequesters the defensive bufadienolides in its nuchal glands from consumed toads. Snakes from a toad-free island (Kinkasan, Miyagi Prefecture) were found to lack bufadienolides in their nuchal gland fluid, reflecting the absence of toads in their native habitat. However, when *R. tigrinus* from Kinkasan were fed toads in captivity, they were able to sequester bufadienolides in their nuchal glands. Hatchling snakes from an island with a dense population of toads (Ishima, Tokushima Prefecture) possessed large quantities of bufadienolides in their nuchal gland fluid. We demonstrated that female *R. tigrinus* are able to provision bufadienolides to their embryos through deposition of those compounds in yolk and by late-gestational transfer, presumably across shelled eggs. Maternal provisioning explains the presence of bufadienolides in hatchlings from Ishima, and these snakes can sequester additional bufadienolides from toads that they consume after hatching.

37.2 HUYGHE, K.*; SAN-JOSE, L.M.; PEñALVER ALCáZAR, M.; FITZE, P.S.; University of Antwerp, Belgium, CSIC-MNCN, Spain, UNIL, Switzerland; *katleen.huyghe@ua.ac.be*

The lizard's tail: size matters! Determinants of mating success in the common lizard.

Sexual selection has been demonstrated to mould traits that help to increase the probability of a successful outcome of a male's reproductive strategy. Previous work has suggested a primary role for body size, the main feature that determines the outcome of territorial conflicts between males and/or the result of female mate choice. However, recent studies focusing on performance traits suggest that these may be as, or even more, important in determining male mating success. Here we tested this hypothesis and determined the traits predicting mating success in males of a colour polymorphic population of the common lizard, *Lacerta vivipara*. Size-matched males of three morphs were staged together with one female, and the importance of a series of traits (morphology, colour, sprint speed and bite force capacity, and mating behavior) was investigated. Contrary to what we expected from the theoretical rock-paper-scissors models, neither colour nor performance affected mating success. Tail length on the other hand was a male's most important key to success.

61.9 HYKIN, SM; Univ. of California, Berkeley; *smhykin@berkeley.edu*

Cardiac morphology of Dermophis mexicanus through ontogeny

Caecilians are a little-known and understudied clade of limbless, often fossorial amphibians restricted to tropical regions around the globe. Heart development and function, especially regarding the extent of separation of oxygenated and deoxygenated blood within the heart, has been much speculated on but little explored. In the hope of shedding light on the dominant respiratory mode, development, and evolution of this clade, I examined histological sections of the heart in an ontogenetic series of the viviparous *Dermophis mexicanus*. At 8 mm TL, heart looping has commenced in a counterclockwise direction. By 10 mm TL, heart-tube looping is complete and interatrial septation commences via an extension of anterior myocardial cells through the atrial chamber. At 15 mm TL the valves of the atrioventricular funnel and conus begin to form from endocardial cushions. In the conus, what will become two sets of semilunar valves progress through a spiral configuration. At 20 mm TL the interatrial septum is complete at its right limit, but remains incomplete through the majority of the chamber. The valves of the atrioventricular funnel and the conus remain asymmetrical; however, the conus valves appear to be transitioning out of the spiral configuration. Finally, the newborn and adult forms are similar to one another, but dramatic changes have taken place between the 20 mm stage and parturition. From my observations, I conclude that heart-tube looping occurs approximately one month into the 11-month gestation period and differs from heart-tube looping seen in anurans. The interatrial septum commences development shortly after heart-tube looping completes. No evidence of vestigial interventricular septum development is seen, but it is noteworthy that some vestigial development of the spiral valve (seen in anurans) appears to be a component during early development of the semilunar valves in the caecilian.

66.4 INFANTE, CR*; LOSOS, JB; MENKE, DM; University of Georgia, Harvard University; *cinfante@uga.edu*

The developmental basis of an adaptive radiation: the evolution of limb diversity in Anolis lizards

The lizard genus *Anolis* comprises over 300 described species and has undergone an extraordinary radiation on the islands of the Greater Antilles. On each of these islands, species of *Anolis* can be categorized into sets of habitat specialists or "ecomorphs", defined by similarities in morphology, behavior, and ecology. Phylogenetic analyses support the independent evolution of these specialists on each island, and not the single origin of a specialist type followed by dispersal. Therefore, the diversification of *Anolis* lizards on the islands represents at least four independent ecomorph radiations, creating natural replicates for the study of the evolution of morphology and the developmental process. To investigate the developmental component of this radiation, we are establishing tools and techniques for studying limb morphogenesis in *Anolis*. The goal of this research is to identify the genetic basis of the divergence in limb morphology. By using a comparative approach, this research tests whether shared or unique developmental mechanisms underlie the repeated evolution of similar ecomorph morphologies. Additionally, it will enhance our knowledge of the evolution of limb development among tetrapods by providing an additional phylogenetic data point.

75.3 IRIARTE-DIAZ, J*; TERHUNE, C.E.; ROSS, C.F.; University of Chicago, Duke University; *jiriarte@uchicago.edu*

Mandibular helical axis during feeding in non-human primates

Teeth trajectories are often used for the study of mandibular movement. These trajectories, however, depend on the location of the reference point and their interpretation can be equivocal. In contrast, the finite helical axis (FHA) is a mathematical model that completely describes the movement of a rigid body. Previous studies have shown that the FHA is located inferior to the mandibular condyle and that it varies continually through the gape cycle. In humans, the position and orientation of the FHA varies primarily during the closing phases, with little fluctuation of the FHA during the opening phases. Few data are available regarding the position and/or orientation of the FHA in non-human primates and it remains unclear to what extent the paths of FHA during mastication in other taxa are similar to or different from those documented for humans. Here we present data on the rigid-body kinematics of three species of primates (*Cebus*, *Macaca* and *Papio*) obtained by measuring the three-dimensional position of mandibular and cranial markers during feeding using high-speed, high-resolution video recordings. Similar to humans, the location of the FHA in these primates was below the mandibular condyle. FHA orientation, however, changed throughout the whole gape cycle, with substantial changes during both closing and opening phases. Differences in mandibular movement during feeding between human and non-human primates, as well as differences among non-human primates species are expected to reflect differences in morphology of the temporomandibular joint and differences in patterns of muscle activation.

46.6 IYENGAR, E.V.; Muhlenberg College; *iyengar@muhlenberg.edu*

Writing across the curriculum: Explorations in nature and first year seminars

First-Year Seminars (FYS) at my liberal arts institution are small (typically limited to an enrollment of 15), writing-intensive discussion-oriented courses required of all beginning students that promote intellectual discussion and critical thinking, reading, and writing skills. Faculty from across the college teach these courses, with the idea that the basic skills are accessible and applicable to any major. The course topic is chosen by the instructor, does not need to be in the instructor's area of academic expertise, and must be of interest to a wide range of students, not merely ones majoring in the instructor's field. In Fall 2011 I taught my first FYS, entitled Explorations in Nature. We concentrated on three general locations as topics for discussion: Alaska, Antarctica, and open ocean exploration. A wide variety of assignments, involving various mediums (including poetry, art, music, and field explorations of a stream) complemented our typical readings and promoted active discussions of a wide range of approaches to nature. Course components, in particular the use of jigsaw techniques for class discussions and writing assignments and the use of portfolios as a component of the rewriting and grading process, are discussed.

92.4 JACKSON, Brandon E*; TOBALSKE, Bret W; DIAL, Kenneth P; Field Research Station at Fort Missoula, The University of Montana; *brandon.jackson@mso.umt.edu*

Ontogeny of contractile behavior in the flight muscles of birds

Flight is the defining characteristic of birds yet the mechanisms through which flight ability develops are virtually unknown. Recent efforts focused on pre-flight flapping behaviors (wing assisted incline running and controlled flapping descent) in chukar chicks (Alectoris chukar) have described the ontogenetic progression of morphological, kinematic and aerodynamic characteristics that permit very young (20 days) birds to achieve adult-like aerial locomotor performance. In this study we use these behaviors, which are ubiquitous in developing birds, as a stage to investigate the developmental trajectory of neuromuscular control and function in the pectoralis muscles of precocial chukar and semi-altricial pigeon (Columba livia). 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. Pigeon chicks demonstrate similar trends, including force production that correlates with increasing EMG amplitude, but much later in development (5-8 weeks after hatching) and at larger relative sizes (50-70% adult mass). Muscle performance coincides with the development of external morphology and whole-body locomotor performance in both species. NSF grants IOS-0923606 and IOS-0919799.

30.4 JACKSON, Alexander/G.S*; HICKS, James/W.; University of California, Irvine; *agjackso@uci.edu*

Energetics of reproduction in the oviparous squamate, Lamprophis fuliginosus

The goal of this study was to quantitatively determine whether or not gravidity poses a significant energetic fitness cost on the oviparous squamate, *Lamprophis fuliginosus*. We chose *L. fuliginosus* due to several life history traits, including high fecundity, lack of a hibernation period, tractability in the laboratory setting, and large clutch sizes relative to total body mass. To encompass multiple possible energetic fitness costs associated with gravidity, we also examined peak oxygen consumption during exercise and during a large meal (20% body mass). We asked whether the costs of exercise and digestion were affected by gravidity, and if so, by what degree? Our results indicate that this particular species incurs little to no additional energetic cost for being gravid, and that neither digestion or exercise are affected in terms of peak oxygen consumption. At least in this species, the energetics associated with gravidity are most likely not associated with a potential fitness cost during rest, digestion, or exhaustive exercise. Therefore we conclude that further research on different aspects of the physiology of reproduction is required if one seeks to discover where in its life history, reproduction might be influencing the fitness of this species. Funding was provided by NSF grant IOS 0922756 to JWH.

97.1 JAFARI, F.*; SOCHA, J.J.; Virginia Tech; *jafari@vt.edu*

A theoretical investigation of static stability in gliding snakes

Flying snakes undulate while gliding, using their entire body as a continuously morphing ‘wing’ to produce flight forces. Studies of static 2D airfoils using the snake’s aerial cross-sectional shape have demonstrated that this shape maintains high lift at angles of attack as large as 35&deg. However, the unsteady effects of undulation on gliding in flying snakes has never been studied. In particular, the role of the highly dynamic postural reconfiguration in the control system is unknown; how the snake remains stable in the pitch, roll and yaw directions is not understood. Whereas the simplest hypothesis posits that the snake is passively stable in all directions, active control may indeed be required about all axes. Here, we developed a theoretical model to investigate the transient motions and stability characteristics of an airborne flying snake. This two-dimensional model was developed in a way to simulate dynamics in the configuration space resembling the behavior of an aerially undulating snake. Previously obtained experimental aerodynamic data were incorporated into the model, and undulation was modeled by varying area and mass distribution. Bilateral symmetry was assumed to allow decoupling of the motions in the longitudinal and lateral directions. Stability (considered quasi-statically) in the pitch axis was examined by testing the proposed model against the static stability criterion. Additionally, we used this model to test the hypothesis that, given enough time, equilibrium gliding could be achieved.

56.4 JAGNANDAN, K.*; SANFORD, C. P.; Hofstra University, Hempstead, NY; *kevin.m.jagnandan@hofstra.edu*

Ribbon Fin Kinematics in the Bowfin, Amia calva

The use of an elongated dorsal or anal fin (a ribbon fin) in producing forward and backward propulsion is utilized by a variety of phylogenetically distinct fish species. Fishes that employ this mode of swimming move individual fin rays that generate a series of waves used to drive propulsion. To date, there is no published data on the use of the dorsal ribbon fin in the basal freshwater bowfin, *Amia calva*. To understand how the ribbon fin is used for propulsion in this basal fish, differences in frequency, amplitude, and wavelength of the waves produced along the fin in *Amia* were measured in individuals swimming at various swimming speeds (0 to 1.0 body lengths/sec). In addition, wave properties of the ribbon fin were recorded and analyzed to determine if regional specialization occurs along the fin. Wave properties were also compared between swimming with sole use of the ribbon fin, and swimming with combined use of the ribbon fin and pectoral fins influencing forward propulsion. Statistical analysis reveals that regional specialization does not occur along the ribbon fin, and that forward propulsive speed is primarily controlled by the frequency of the wave in the ribbon fin irrespective of the contribution of the pectoral fin. Funding provided by NSF IOS#0444891 and NSF DBI#0420440.

S10-1.1 JARRETT, JN; Central Connecticut State University; *jarrettj@ccsu.edu*

Costs and benefits of alternative defensive morphologies and population variation in phenotypic plasticity of the barnacle Chthamalus fissus

The barnacle *Chthamalus fissus* resides in the high intertidal along the coast of Southern California and Northern Baja California. Juvenile *C. fissus* exposed to the spine feeding predatory snail *Mexacanthina lugubris lugubris* may develop either a narrow or bent defensive morphology which are both better defended against this predator compared to the conic morph. This appears to be the only reported case in which there exists more than one "plastic" morphological response within a species population to a single predator. Here I report costs and benefits associated with the three morphs, species specificity of the defensive response, variation among populations of this barnacle in the degree of plasticity, and population variation in spine morphology of the predator. The evidence suggests that populations of *C. fissus* north of the historic northern range limit of *M. l. lugubris* are less able to respond to predator cues thus making them more vulnerable to predation by this predator whose population continues to extend north.

68.5 JASZLICS, A.*; PARDO, J. D.; University of Texas at Arlington; *jaszlics@uta.edu*

Ontogeny and Modularity in the Crocodilian Skull

Variation in ontogenetic trajectories plays a critical role in shaping morphological diversity of the vertebrate skull. Crocodilians are a potentially informative group in which to study this phenomenon because they demonstrate a relatively large degree of morphological diversity in the skull, in spite of a relatively high degree of ecological and phylogenetic constraint. Previous studies of crocodilian skull morphology have shown that the majority of extant species occupy a contiguous morphospace, with the exception of the Indian gharial, *Gavialis gangeticus*. These studies demonstrate that variation in morphology largely reflects biomechanical constraint during feeding. In order to test whether the diversity of crocodilian skull morphologies is achieved through dissociation of ontogenetic modules, we sampled growth sequences representing each of the four major extant lineages (Alligatoridae, Crocodylidae, Tomistominae and Gavialinae). We then used a geometric morphometrics-based approach to compare ontogenetic trajectories in these taxa. Principle components analyses show a tight integration of the entire skull, specifically between rostral length and the width of the suspensorium relative to the braincase in crocodylids, alligatorids and tomistomines. Gavialines however, show a strong disintegration of the suspensory module from the rostrum. We hypothesize that this dissociation is the result of the slender rostrum and 'snapping' feeding mechanism of true gharials, which places unique constraints on adductor morphology. This suggests that variation along even highly constrained ontogenetic trajectories can produce diverse morphologies.

110.1 JAUMANN, Sarah; NAUG, Dhruba*; Colorado State University; *dhruba@colostate.edu*

Learning kills

While learning is generally considered only in terms of its substantial benefits, what is often overlooked is that there is a substantial energetic cost associated with it. However, past research has failed to demonstrate such a cost of learning in honeybees, leading to the argument that sociality might be able to buffer these costs. We re-examined the energetic cost of learning in the honeybee *Apis mellifera* by comparing the subsequent survival of bees that were made to undergo associative learning with those that were not. Bees that were made to learn died sooner than bees that were not made to learn, suggesting that bees indeed pay an energetic cost of learning and we further confirmed this by assaying the hemolymph carbohydrate levels of bees before and after they underwent the associative learning procedure. Based on our earlier finding that bees infected with a parasite show an energetic stress, the current results provide a possible novel link between parasitic disease and cognitive impairment, which has broad implications for a number of areas as well specific implications for the current phenomenon of disappearing bees.

79.4 JAYARAM, K*; MERRITT, C; FULL, R.J.; Univ. of California, Berkeley; *kaushikj@berkeley.edu*

Robust Climbing in Cockroaches Results from Fault Tolerant Design Using Leg Spines

Previously, we found that cockroaches, *Blaberus discoidalis*, maintain performance on flat and rough terrain even with the loss of tarsi (or feet) by relying on large spines at the tibia-tarsus joint. Here, we examined whether tarsi-less cockroaches could maintain performance on inclined surfaces. We compared running performance (average speed) on constant inclines of 0, 30, 45, 60, 75 and 90° before and after complete tarsi ablation. Loss of tarsi did not affect performance (<5% change in mean running speed) at 0, 30 and 45° inclines. Tarsi-less animals decreased speed at 60° (-54%), 75° (-87%) and 90° (-88%) relative to the intact animals. To uniquely identify the cause of failure, we ran the animals on a curved incline track (radius = 50 cm) using two surfaces, rough (700 µm beaded) and smooth (Plexi-glas), and measured failure angle. Intact cockroaches failed at 89.6±2.6° and 58.6±7.7° on rough and smooth surfaces, respectively. After tarsal ablation, animals failed at 79.0±7.9° (rough) and 21.7±6.2° (smooth). Animals with only claws ablated (rest of the tarsi intact) showed failure at 84.4±7.72° (rough) and 56.8±4.1° (smooth). Tarsi-less animals showed negligible loss in running speeds on rough surfaces. Passive spines effectively compensated for loss of tarsi or claws except at steep inclines, but on smooth surfaces contribute minimally. Probing the structure of the tarsus by isolating the heterarchical functional regimes of the different tarsal specializations is important because most engineering solutions to climbing in robots rely on a single structure and not a hybrid, robust design.

15.3 JAYASUNDARA, N.*; GARDNER, L.D.; TOWLE, D.T.; BLOCK, B.A.; Stanford University, Mount Desert Island Biological Laboratory; *nishadj@stanford.edu*

Warm fish with cold hearts: Cardiac thermal plasticity of Pacific bluefin tuna Thunnus orientalis

Bluefin tunas are renowned for their exceptional locomotory capabilities, elevated metabolic rates and unique endothermic physiology. Their hearts, operating at ambient temperature, sustain an enhanced cardiac performance across a thermal gradient to support this high energy demanding life style. However, little is known about the molecular processes underpinning the thermal plasticity of tuna hearts. In this study we investigated the transcriptomic response to temperature acclimation (14ºC, 20ºC and 25ºC) in atrial and ventricular tissues of Pacific bluefin tuna (PBFT) using quantitative PCR and a bluefin tuna specific microarray. qPCR data suggested that genes involved in Ca^{2+} induced Ca^{2+} release pathway are altered with cold (14ºC) and warm (25ºC) acclimation. We compared this data against cardiac gene expression of wild caught PBFT and two spatiotemporally co-occurring closely related tuna species (*T. alalunga* and *T. albacares*) with varying degrees of endothermic capacity. Transcriptomic analysis on PBFT acclimated to temperature indicated changes in genes associated with energy metabolism, protein bio synthesis, cellular stress response, apoptosis and oxidative stress. A principal component analysis revealed that thermal response is tissue specific, with gene expression in atrium at 25ºC showing the greatest difference. In the ventricle, compact layer appears to be more thermally labile compared to spongy layer. This study demonstrates that tuna heart function is optimized at 14ºC, potentially improving aerobic performance in the cold. Conversely the cardiac transcriptome at 25ºC is indicative of limitations in cardiac performance at warmer temperatures.

93.2 JIMENEZ, Ana G.*; KINSEY, Steve T.; University of North Carolina at Wilmington; *jimenez.102@osu.edu*

Nuclear DNA content variation associated with muscle fiber hypertrophic growth in fishes.

Muscle fiber hypertrophic growth can lead to an increase in the myonuclear domain (MND), leading to greater diffusion distances within the cytoplasmic volume that each nucleus services. We tested the hypothesis that hypertrophic growth in white muscle of fishes was associated with increases in the mean DNA content of nuclei, which may be a strategy to offset increasing diffusion constraints. DAPI stained chicken erythrocytes standards and image analysis were used to estimate nuclear DNA content in erythrocytes and muscle fibers from seventeen fish species. Mean diploid (2C) values in fish erythrocytes ranged from 0.78 to 7.2 pg. Erythrocyte 2C values were used to determine ploidy level in muscle tissue of small and large size classes of each species. Within each species, mean muscle fiber diameter was greater in the large size class than the small size class, and MND was significantly greater in larger fibers for 11 of the 17 species. Nuclear DNA content per species in muscle ranged from 2 - 64C. Fiber-size dependent increases in ploidy were observed in nine species, which is consistent with our hypothesis and indicates that endoreduplication is occurring during fiber growth. However, two species exhibited significantly lower ploidy in the larger size class, and the mechanistic basis and potential advantage of this ploidy shift is unclear. These results suggest that increases in ploidy may be a common mechanism to compensate for increases in MND associated with fiber hypertrophy in fishes, although it is likely that other factors also affect ploidy changes that occur in muscle during animal growth.

119.6 JING, F*; KANSO, E; Georgia Tech, Univ. of Southern California; *jing@math.gatech.edu*

Effects of Body Elasticity on Stability of Underwater Locomotion

We examine the stability of the ``coast" motion of fish, that is to say, the motion of a neutrally buoyant fish at constant speed in a straight line. The forces and moments acting on the fish body are thus perfectly balanced. The fish motion is said to be unstable if a perturbation in the conditions surrounding the fish results in forces and moments that tend to increase the perturbation and it is stable if these emerging forces tend to reduce the perturbation and return the fish to its original state. Stability may be achieved actively or passively. Active stabilization requires neurological control that activates musculo-skeletal components to compensate for the external perturbations acting against stability. Passive stabilization on the other hand requires no energy input by the fish and is dependent upon the fish morphology, i.e. geometry and elastic properties. In this paper, we use a deformable body consisting of an articulated body equipped with torsional springs at its hinge joints and submerged in an unbounded perfect fluid as a simple model to study passive stability as a function of the body geometry and spring stiffness. We show that for given body dimensions, the spring elasticity, when properly chosen, leads to passive stabilization of the (otherwise unstable) coast motion.

21.3 JOHNSEN, S. *; MARSHALL, N.J.; Duke Univ., Univ. of Queensland; *sjohnsen@duke.edu*

Through the looking glass: Are silvery fish safe from viewers with polarization vision?

Many coral reef and open-ocean fish have mirrored sides built from stacks of guanine crystals. Because the underwater light field is approximately symmetric around the vertical axis, vertical mirrors are an excellent form of camouflage. Mirrors of this orientation reflect light from the same angle of elevation (though from the opposite azimuth), so the reflected image matches what would be seen if the animal were transparent. However, most surfaces affect the polarization of light that is reflected from it. Smooth surfaces strongly affect on the polarization of the reflected light, and rough surfaces depolarize the light. Either effect can be seen by animals with polarization vision, thus breaking the camouflage. We examined how the silvery surfaces of fish affect the polarization of light in two ways. First, using a custom-built *in situ* polarization imaging system, we photographed various species of fish with mirrored sides on the Great Barrier Reef. Second, using transfer matrix theory, we modeled how the polarization of light reflected from stacks of guanine platelets depended on the number of plates and the distribution of platelet thicknesses and angles. The *in situ* imaging showed that many fish species were less conspicuous to animals with polarization vision than would be predicted. The optical modeling showed that, while stacks of 10 or 20 platelets strongly affected the polarization of light for most angles of incidence, stacks of 50 or greater platelets with a moderate amount of randomness in both platelet thicknesses and angles reflected nearly 100% of both polarization components. Thus, these structures acted as polarization-preserving reflectors that would provide camouflage to both animals with normal vision and polarization vision. To our knowledge, this is the first example of a polarization–preserving reflector in nature.

37.5 JOHNSON, M.A.*; SANGER, T.J.; SPARKS, M.N.; LOSOS, J.B.; Trinity University, San Antonio, TX, Harvard University; *michele.johnson@trinity.edu*

Sexual dimorphisms in Anolis lizard behavior and morphology: the result of niche partitioning or sexual selection?

Sexual dimorphisms in size and shape may result from ecological differences between the sexes or from sexual selection. Here, we examined the behavior and morphology of males and females of the two species of *Anolis* lizards that occur on Cayman Brac, *A. sagrei* and *A. maynardi*, to determine differences in traits of ecological importance (habitat use, foraging behavior, and limb dimensions) and traits potentially under sexual selection (social display, dewlap size, and body size). We also measured head dimensions, which could be associated with foraging and sexual selection, as biting is important in both prey capture and male-male conflicts. In both species, the sexes differed in display behavior and habitat use, but not foraging behavior, suggesting that sexual dimorphisms may be influenced by both sexual selection and some aspects of ecological niche partitioning. We found significant size and shape dimorphisms for the two species, with both more pronounced in *A. maynardi*. Variation in head length is the predominant morphological difference between the species and sexes. To more directly assess the potential roles of morphological traits in sexual selection, we used controlled behavioral trials to distinguish whether particular traits may be more strongly associated with male competition or female choice. Although the *A. sagrei* behavioral trials were largely inconclusive, in the *A. maynardi* behavioral trials, we found that longer-bodied males with shorter snouts were more likely to be dominant over other males, while males with longer snouts appeared to be preferred by females. This suggests the intriguing possibility that in *A. maynardi*, differing traits influence the two modes of sexual selection.

S10-2.2 JONES, D.S.; Western Australian Museum; *diana.jones@museum.wa.gov.au*

The biogeography of Australian barnacles

Two biogeographic provinces are distinguished for Australian waters, a northern tropical province and a southern temperate province. The barnacle fauna of the northern tropical province exhibits high species diversity, a high incidence of tropical species and a low species endemicity. In comparison, the barnacles of warm-temperate and temperate southern Australian waters show decreased species diversity, a lower incidence of tropical species and a higher species endemicity. General patterns can be demonstrated for the shallow-water biota of northern tropical and the southern temperate Australian provinces, with members of the balanomorph families Chthamalidae, Tetraclitidae and Balanidae dominant. However, in south-western Australia, a stronger tropical component than could be predicted by latitude occurs, due to the influence of the Leeuwin Current, a seasonal, poleward flowing, eastern boundary current on the western coast of Western Australia. Additionally, chthamalids are absent from south-western Australian shores and zonation shows a simpler tetraclitid-balanid trend, with archaeobalanids also prominent on sheltered shores. In both tropical and temperate Australia the pedunculate barnacle component is greater in the sub-littoral, the majority of species being epizoic on a variety of hosts. Pedunculate species diversity in the temperate littoral and sub-littoral is not as great as that occurring in corresponding zones in the tropics. Pelagic species in both provinces are pedunculate forms. Introduced species are identified from port localities in tropical and temperate provinces.

40.1 JOOSTE, E.*; SWANEPOEL, L.H.; PITMAN, R.T.; VAN HOVEN, W.; University of Pretoria, South Africa, University of Plymouth, UK; *esmarie.jooste@gmail.com*

Unusually high predation on Chacma baboons (Papio ursinus) by female leopards (Panthera pardus) in the Waterberg Mountains, South Africa

Leopards are the primary predator of baboons, but do not favor baboons, likely because their extreme aggressiveness and high mobility may limit leopard predation. Male baboons are particularly aggressive and retaliation often leads to the death of the leopard. However, leopards may learn to catch and kill certain dangerous prey. This study reports predation on Chacma baboons by female leopards in the Waterberg Mountains of South Africa. Potential leopard feeding sites were identified using global positioning system (GPS) location clusters obtained from GPS collars. Over a five month period we investigated 200 potential leopard feeding sites and located 96 leopard feeding/kill sites. Baboons constituted 18.7% of the leopards' biomass intake, considerably higher than previous studies which report the contribution of baboons to leopard diets seldom exceeds 5% of biomass. The majority of the baboons preyed upon were adults and 70% of the kills were diurnal, as determined by the time of the first GPS-location in GPS-clusters formed at confirmed baboon feeding/kill sites. There were no significant differences between the measured variables of feeding sites of baboons and those of other prey species, suggesting that leopards were hunting baboons opportunistically. The recurring predation on adult baboons by a sub-adult female, recently split from her mother, suggests that specialized hunting skills are possibly passed down from mother leopards to their cubs.

79.5 JUSUFI, A.*; LIBBY, T.; FULL, R.J.; Univ. of California, Berkeley; *ardianj@berkeley.edu*

Scales Assist Scaling in Lizards: Keeled, Subcaudal Scale Arrays Engage Substrate during Rapid Vertical Climbing

To explore substrate interactions between locomotor appendages such as feet and tails, we video recorded lizards *Iguana iguana, Acanthosaurus crucigera* and *Gonocephalus grandis* as they scaled substrates of varying traction (tree bark, sandpaper, wire mesh). In addition, we observed how Forest Dragons climb trees in their natural habitats in South-East Asian tropical rainforests and Green Iguanas in Central America. Analysis revealed that lizards are continuously perturbed by natural substrata and frequently experience foot displacement. Lizards held their tail tip in constant contact with the substratum. Previously, using a force platform embedded in wall, we showed that tails pushing against the substrate can stabilize the body against overturning during rapid, vertical running (Jusufi et al., 2008). The lizard species investigated here possess subcaudal scales that are keeled and therefore have the potential to anchor in the substrate. To experimentally determine whether these structures could arrest a fall to avoid climbing failure, we mounted cadaver tails from deceased lizards in a materials testing machine (Instron). We performed friction tests to determine the toughness of the subcaudal structures to a simulated fall by pulling the tail parallel to the substrate. We discovered that engagement of only one or a few caudal scales with the substrate allowed support of 1 to 2 times body weight. Using the passive attachment properties of scales increases fault tolerance from foot slippage and could significantly simplify the control of climbing. Robots could increase the robustness of dynamic climbing by using keeled scale arrays on their tails.

22.7 KA'APU-LYONS, C.; GIBB, A.C.*; Northern Arizona University; *alice.gibb@nau.edu*

Critical periods during teleost development: a case study of two cypriniform fishes

During early development, teleosts undergo intervals of extremely high mortality. These intervals, often termed "critical periods," have been attributed to various causes, including starvation and predation. However, the *proximal* mechanisms that underlie such periods of increased vulnerability have yet to be identified. We suggest that, at least for some teleosts, the ontogenetic transition from the embryonic, cartilage-based feeding mechanism to the juvenile/adult, bone-based feeding mechanism may compromise feeding performance and thereby increase the likelihood of death due to starvation. In fact, when feeding kinematics for two species of cypriniform fish (*Xyrauchen texanus* and *Gila robusta*) are examined across early development, the movements used to procure prey become absolutely slower during the time period when the bony elements of the cranium are forming; feeding movements become rapid again when juvenile cranial morphology has been attained. Slower feeding mechanics will likely decrease feeding rates of animals in the wild and make it difficult for them to acquire the resources necessary to support growth and morphogenesis; thus, functional demand may outpace structural capacity (*sensu* Galis) to generate a "critical period." However, this period of vulnerability may be avoided in teleosts that provision their young with sufficient endogenous (yolk) resources such that young fish can avoid exogenous feeding until the bony elements of the skull are fully formed.

47.3 KAISER, S/A*; WEBSTER, M/S; SILLETT, T/S; Cornell University, Ithaca, Smithsonian Migratory Bird Center, Washington, DC; *sak275@cornell.edu*

Population-level Variation in Endogenous Testosterone, Mating and Paternal Effort Across an Elevation Gradient

Climate change is causing temporal shifts in the environmental cues migratory birds and other animals use to synchronize breeding events with optimal foraging conditions, and these shifts potentially could have drastic consequences. Seasonal changes in circulating hormone levels can modulate avian reproductive behaviors that directly influence fitness, but we know surprisingly little about the environmental cues that signal the underlying endocrine mechanisms generating behavioral variation, nor how these will respond to changing conditions. At the population level, we examined the linkage between endogenous testosterone and investment in mating and parental behaviors by Black-throated Blue Warbler males breeding along a 600 m elevation gradient in New Hampshire. Birds nesting at high elevation experience cooler temperatures than those nesting at low elevation, however the caterpillar biomass is two times greater at high elevation. We found that testosterone levels were elevated during the fertile period compared to the parental period and greatest during the fertile period at mid and high elevations where males invested more effort in extra-pair mating and less in paternal care. These results suggest a testosterone-mediated trade-off between mating and paternal effort influenced by differences in environment across the elevation gradient. However, endogenous testosterone levels were variable among males within the same nesting stage across elevations. Therefore, an important next step to understand the extent to which plasticity in the hormone-regulated reproductive behaviors is adaptive is to examine these relationships at the level of the individual experiencing different environmental extremes.

112.6 KAMBIC, Robert E*; GATESY, Stephen M; ROBERTS, Thomas R; Brown University; *robert_kambic@brown.edu*

Walking With a Twist

Studies of tetrapod limb movement and muscle activity during steady locomotion often record data from only one side. This approach assumes that both members of a limb pair act symmetrically when the animal holds stable on a treadmill or moves overground along a linear path at a constant speed. But what if this assumption is violated? What happens when the body is yawed relative to the direction of travel? When the yaw and heading are not aligned, right and left limbs will need to move asymmetrically relative to the body. Our 3-D analysis of skeletal motion in walking helmeted guineafowl (Numida meleagris) reveals that asymmetry is quite common. Although birds move steadily on the treadmill, marker-based XROMM reveals pelvic yaw up to 15°. Such small deviations would not be detectable in lateral view by an external camera, yet have significant effect on joint kinematics. Long-axis rotation of the femur and tibiotarsus increases with yaw angle. By combining hip, knee, and ankle flexion/extension with these long-axis rotations, the feet translate diagonally with respect to the yawed pelvis. When the body yaws to the right, for example, the limb is set down more to the left. During stance, internal femoral and external tibiotarsal rotation shift the foot to the right. Simultaneously, the left limb is lifted more to the right and then shifts left using internal femoral and external tibiotarsal rotation during swing. As a result, long axis rotations of the striding limbs are in-phase while flexion/extension is out-of-phase. This complex pattern suggests that even during steady walking, the limbs require more than a simple pattern of alternating activation. In-phase long-axis rotations reveal a flexible motor control strategy that decouples this degree of freedom from out-of-phase fore-aft movements. Our next step is to use as inverse dynamics approach to contrast the kinetics of yawed and non-yawed locomotion.

33.2 KANE, Emily A.*; HIGHAM, Timothy E.; University of California, Riverside; *ekane001@ucr.edu*

How sculpin pectoral fin morphology changes with demand across habitat transitions

Aquatic organisms that occupy high-flow habitats often display traits associated with decreased drag and increased friction with the substrate. Sculpins (Scorpaeniformes: Cottoidea) have transitioned from deep-water marine habitats with low flow to shallow habitats with high flow, and likely exhibit changes in morphology for maintaining position in high flow habitats. We examined body and pectoral fin morphology of 9 species collected from deep, shallow, intertidal, and freshwater habitats; additionally, shallow subtidal and tidepool populations of *Oligocottus maculosus* were compared. Intact specimens and pectoral fins were measured, and multivariate techniques determined the morphological differences among habitat types. Principal components analysis (PCA) identified 4 functional groups, which were supported by a discriminant function analysis (DFA): pelagic *Blepsias cirrhosus* , deep forms, intermediate forms, and shallow forms. The transition from deep to shallow water is represented by two gradients: primarily, shallower forms had increased tail area and peduncle depth (specialization for acceleration) and larger pectoral fins with thicker, less webbed ventral rays (specialization for mechanical gripping); secondarily, shallower forms had more symmetrical fins with a greater aspect ratio and a reduced number of fin rays (specialization for negative lift generation). The function of sculpin pectoral fins likely shifts from primarily gripping in deep (low flow) habitats to an equal dependence on gripping and negative lift generation in shallow (high flow) habitats. Together, these morphological characteristics likely minimize drag and increase friction with the substrate to increase station-holding capability for species in high-flow habitats.

64.6 KAPPNER, Isabella; American Museum of Natural History, New York; *ikappner@amnh.org*

Paternal mitochondrial inheritance is widespread in dioecious bivalves and may have multiple origins

Unusual mtDNA inheritance is seen in some bivalve taxa, with male germlines inheriting paternal mitochondria genetically distinct from those in somatic cells and female germlines. The full extent of this divergence from a strictly maternal mitochondrial inheritance in Bivalves, one of the largest classes of marine animals, is still unknown. Absence of the trait has rarely been recorded. The phenomenon, Doubly Uniparental Inheritance (DUI), is widespread in Bivalvia: We report sex-associated sequence divergence in nine additional clam species, now extending detection across eight bivalve families. Also, we refute DUI in six species. We spawned sperm for pure germline samples, otherwise dissected testis, a mosaic of germ and somatic cells, requiring cloning. COI and 16S were routinely sequenced and, in several cases, entire mitogenomes were determined. Several ideas for the function and mechanisms of DUI have been proposed. Most bivalves lack sex chromosomes yet are dioecious. Thus, DUI is appealing for controlling sex determination and reproductive mode. We used our expanded dataset to show a highly significant correlation between DUI occurrence and patterns of reproduction. Reliable paternal transmission occurs only in dioecious bivalves (but not in all), and does not occur in hermaphroditic species. Phylogenetic character mapping of the ancestral state and diverse genetic properties suggest DUI arose at least twice with several losses. We discuss the implications for DUI function and whether the development of bivalves, including germline transmission of endosymbionts, predisposes them to this unusual evolutionary pattern.

82.6 KARSTEN, K.B.*; HALE, A.M.; California Lutheran University, Texas Christian University; *karsten@callutheran.edu*

Using Meteorological Data to Predict Bat Mortality at a Wind Facility in Texas

Bats are an important component to many ecosystems and are under increasing pressure from both White Nose Syndrome and wind facility related mortality. The growth of the wind industry in the last decade is considerable. Recent experimental approaches have attempted to reduce bat fatalities by manipulating operation procedures. Bats are most active during low wind conditions and these experiments have relied upon adjustment of when turbines are operational—shutting down turbines during low wind conditions has reduced mortality in previous studies sometimes by up to 70%. While these experiments have advanced the field and successfully reduced mortality, there is still room for improvement. We analyzed two years of mortality data collected at a wind facility in north-central Texas. We calculated a Daily Fatality Index (DFI) as the number of bats killed the previous night per searched turbine. We modeled the DFI as a function of the previous night's weather conditions to predict the weather conditions in which bat mortality is most likely to occur. Our results indicate that wind speed in combination with wind direction carry far more explanatory power in predicting bat fatality than does just using only wind speed as a predictor. We suggest curtailment strategies that not only incorporate wind speed, but also take into account the prevailing wind direction.

113.1 KATIJA, Kakani*; JIANG, Houshuo; COLIN, Sean P.; COSTELLO, John H.; Woods Hole Oceanographic Institution, Roger Williams University, Providence College; *kakani@whoi.edu*

Ontogenetic propulsive transitions from viscous to inertial flow regimes

Among marine organisms, the influences of flow regimes on swimming strategies are largely unknown. As an approach to examine this issue, we quantified how transitions from viscous to inertially dominated flow regimes, which commonly occur during the development of marine animals, relate to changes in swimming strategies. We used the hydromedusae *Sarsia tubulosa* as a model organism for this investigation because its morphology and propulsive actuation mechanism are radially symmetric. This feature allows for determination of three-dimensional fluid quantities from two-dimensional flow measurement techniques. Digital particle image velocimetry was used to quantify the flow fields created by free-swimming hydromedusae and calculate the impulse generated by their swimming pulses at different life stages. Swimming strategies were evaluated by quantifying the relationship between impulse production and hydrodynamic swimming efficiency. The use of impulse theory enables us to generalize our finding to the swimming strategies of other aquatic animals that swim in similar fluid regimes.

91.3 KAWANO, S.M.*; BLOB, R.W.; Clemson Univ.; *skawano@clemson.edu*

Force production by the forelimbs of salamanders and pectoral fins of mudskippers during terrestrial locomotion

Salamanders are often used to model the locomotor capacities of early tetrapods due to postural and morphological similarities. The fossil record provides evidence that terrestrial adaptations began in the anterior region of the body in tetrapodomorphs, but little data on salamander forelimb function is available to provide insights in this context. Three-dimensional ground reaction force (GRF) and kinematic data of isolated footfalls of the tiger salamander (*Ambystoma tigrinum*) forelimb were compared to similar data from the hindlimb to evaluate mechanical differences between these appendicular systems. Similar to reptiles, salamander forelimb and hindlimb force production exhibit both similarities and differences. For instance, the mean magnitude and orientation of the GRF is similar between the forelimb and hindlimb in salamanders, which may be due to the similar size and proportions of these limbs in the group. However, peak net GRF occurred much later in stance for the forelimb than the hindlimb. Comparison of salamander forelimb forces to preliminary GRF data from the pectoral fins of amphibious *Periophthalmus* mudskipper fish during terrestrial crutching suggest numerous similarities in mechanical performance between the pectoral appendages in these taxa, despite their drastically different morphologies. Further work on the locomotor biomechanics of the pectoral fin vs. limb for terrestrial locomotion of extant, amphibious fishes and salamanders will contribute towards our understanding of the locomotor capacities of tetrapodomorphs during the water-to-land transition in tetrapod evolution.

64.2 KAWAUCHI, Gisele Y.*; SHARMA, Prashant P.; GIRIBET, Gonzalo; Harvard University, Cambridge; *gykawa@gmail.com*

A new Sipuncula classification: reassessing and dating the sipunculan phylogeny using a six-gene dataset and fossil taxa

Sipuncula is a protostome phylum of contentious phylogenetic placement and an elusive internal phylogeny. Repeated attempts to infer sipunculan relationships have obtained discordant results. In this study we reassessed the internal phylogeny of Sipuncula using a six-gene dataset and larger target amplicons of nuclear ribosomal loci. We dated the molecular phylogeny, employing recently discovered fossil taxa to constrain node ages. Phylogenetic analyses using Bayesian inference, maximum likelihood, and parsimony approaches recover six major clades of Sipuncula across multiple analytical treatments. Some groups considered suspect in previous studies are vindicated, but most traditional sipunculan families were recovered as para- or polyphyletic groups. To redress the dissonance between the current classification and the phylogeny of Sipuncula, we provide a new and revised family-level classification of the group, which includes two new families that we erect herein: Siphonosomatidae and Antillesomatidae. Additional taxonomic action renders a total of six monophyletic families of Sipuncula. Barring the monotypic Antillesomatidae, we observe that the diversification of the revised families constitute ancient events that occurred in the Mesozoic or earlier.

65.4 KECK, BP; University of Tennessee; *bkeck@utk.edu*

Rates of hybridization, introgression, and formation of chimaeric lineages in Darters.

It is currently accepted that hybridization and introgression can influence the evolutionary trajectory of a lineage and affect patterns of diversification. Whether it is the capture of a heterospecific mitochondrial genome or the formation of a chimaeric (or hybrid) lineage with a mosaic genome, the novel combination of genetic material may allow an organism to exploit a novel environment. However, the rates at which hybridization, introgression, and formation of chimaeric lineages occur in nature are not often investigated in a phylogenetic framework. Darters are an excellent group in which to study these rates, because they are one of the most well researched clades of North American freshwater fishes. There are published studies on the number of darter species that hybridize (~25%), that have experienced some extent of introgression (~12.5%), and we have identified at least one chimaeric lineage. Using a recently published phylogenetic hypothesis for 98.8% of darter species that is time calibrated, I examine the timeframe for these events in a phylogenetic context.

S2-1.2 KELLEY, JL*; YEE, MC; LEE, C; LEVANDOWSKY, E; SHAH, M; HARKINS, T; EARLEY, RL; BUSTAMANTE, CD; Stanford University, University of Chicago, Stanford University, Life Technologies, Life Technologies, University of Alabama; *jokelley@stanford.edu*

Bringing genomics to non-model organisms: the promise of de novo genome assembly and population genetics of the fish Kryptolebias marmoratus

How organisms diverge and adapt to the range of environments they encounter is a fundamental question in biology. Elucidating the genetic basis of adaptation is a difficult task, especially when the targets of selection are not known. In this genomics era, emerging sequencing technologies and assembly algorithms facilitate the genomic dissection of adaptation and differentiation in a vast array of organisms with informative or unusual life histories. Here, we leverage genomic data to characterize the genome of *Kryptolebias marmoratus*, the only known self-fertilizing hermaphroditic vertebrate. *K. marmoratus* is an attractive genetic system and a model for behavioral genomics because long periods of inbreeding result in naturally homozygous fish and the fish can be easily reared in the laboratory. To date, microsatellite markers have been used to distinguish wild clonal strains. These populations have a remarkable variety of identifiable phenotypes and encounter a wide-range of environments, including fresh to brackish water. The naturally homozygous strains present distinct phenotypes that segregate between them, making this a tractable system to study both within- and among-population differentiation. High homozygosity improves the quality of de novo genome assembly and facilitates the identification of variants associated with phenotypes. Gene annotation is accomplished with RNA-sequencing data. By combining genomic information with extensive laboratory-based phenotyping we aim to map genetic variants underlying differences in behavioral traits and other potentially adaptive traits. This project highlights the use of emerging genomic technologies to create the required resources for establishing *K. marmoratus* as a new model organism for behavioral genetics and evolutionary genetics research.

83.6 KELLY, D.A.; University of Massachusetts, Amherst; *dianek@psych.umass.edu*

Functional morphology of penile erection in the American alligator (Alligator mississippiensis): indirect eversion and elastic retraction

The intromittent organs of mammals, turtles, snakes and lizards contain variable-volume hydrostatic skeletons that are stored in a flexible state and inflate with fluid before males attempt copulation. Here I present data that suggest crocodilians have evolved a mechanism for penile erection that does not require inflation and detumescence. Dissections of the cloaca in sexually mature male American alligators (*Alligator mississippiensis*) show that although the cross section of the proximal shaft of the alligator penis superficially resembles the inflatable mammalian corpus cavernosum, it contains dense collagenous tissues that do not significantly change shape when fluid is added to the central vascular space. The large proportion of collagen in the wall and central space of the alligator penis stiffens the structure so it can be simply everted for copulation and rapidly retracted at its completion. Because there are no muscles connecting the penis to the wall of the cloaca, I hypothesize that eversion and retraction are effected indirectly. The contraction of paired levator cloacae muscles around the anterior end of the cloaca rotates the penis out of the cloacal opening and strains tendons that connect the base of the penis to the ischium. When the cloacal muscles relax, the elastic recoil of these tendons returns the penis to its original position inside the cloaca.

62.2 KELLY, J.E.*; BLAIR, B.G.; MEADE, M.E.; MURDOCK, C.A.; Jacksonville State University, Alabama; *jsu1603e@jsu.edu*

Elevated growth rate and hepatic IGF-1 expression in Oreochromis niloticus (Nile Tilapia), the case for Eubacterium cellulosolvens 5494 as a possible aquaculture probiont

The use of probiotics has demonstrated the ability to increase growth rates in some aquaculture species. However, most studies have utilized facultative anaerobes. In this study, the effects of *Eubacterium cellulosolvens* 5494, a gram positive, cellulolytic, strict anaerobe isolated from bovine rumen was tested. Commercial feed was supplemented with *E. cellulosolvens* and presented to *Oreochromis niloticus* fry on three separate occasions over the course of the first 10 days of the experiment. Tilapia fry were maintained in 37.8 L tanks (at a density of 25 fish per tank) for a total of 45 days. Fish that received the *E. cellulosolvens* supplemented feed were significantly larger (3.66g ± 0.29g) than the control fish (2.76g ± 0.51g). Liver tissue samples were also collected from these fish for comparisons of insulin-like growth factor 1 (IGF-1) expression patterns, using quantitative real-time PCR methodology, in response to probiotic treatments. IGF-1 is an important hormone within the somatotropic axis and is essential for stimulating maximal growth. Treated tilapia had significantly higher expression (6.31 ± 0.22 pg/ug total RNA) than the control fish (4.85 ± 0.08 pg/ug total RNA). These data may help establish links between growth, molecular mechanisms of growth signals and anaerobic bacteria in the digestive tracts of aquaculture species.

81.2 KENALEY, Christopher/P; Harvard University; *cpkenaley@gmail.com*

A Device for Dampening Drag: A Novel Hypothesis for the Function of Enormous Fangs in Deep-sea Fishes

Many deep-sea fishes possess spectacular morphologies that enable the capture of large prey in a seascape devoid of biomass. Perhaps the most distinctive feeding morphologies of deep-sea teleosts are enormous fangs set on extremely long jaws. Although the functional significance of these phenotypes has long been assumed (e.g., caging or impaling devices), no single study has addressed what functional advantages enormous fangs confer. In recent years, a handful of studies have employed theoretical models to predict feeding performance and to describe the dynamic forces associated with jaw adduction in deep-sea fishes. These studies have demonstrated that the most important force opposing jaw adduction in long-jawed, deep-sea taxa, namely drag, differs substantially from that of shallow-water taxa, namely inertia of the lower-jaw system. As a corollary, any prey item put in motion by the jaws of a deep-sea predator might impose much greater negative forces associated with drag and that this might alter adduction performance considerably. Based on these insights and a series of feeding simulations for several species of the dragonfish family Stomiidae, a new hypothesis is proposed for the function of enormous fangs of deep-sea fishes. A theoretical model that accounts for mass and the hydrodynamic properties of typical dragonfish prey items predicts that fangs function to optimally position prey in such a manner that reduces negative forces acting on the lower jaw. These results demonstrate that without optimal positioning by long teeth, the capacity of dragonfishes to consume large prey items is severely diminished.

116.1 KENKEL, C.D.*; GOODBODY-GRINGLEY, G.; BARTELS, E.; DAVIES, S.W.; PERCY, A.L.; MATZ, M.V.; The University of Texas at Austin, Bermuda Institute of Ocean Sciences, Mote Tropical Research Laboratory; *carly.kenkel@gmail.com*

Evidence of local thermal adaptation in a Caribbean coral

The long-term persistence of coral reefs under global climate change scenarios depends largely on the ability of corals to track increasing temperatures with evolutionary adaptation. However, the patterns and mechanisms of coral adaptation to varying thermal environments remain poorly understood, particularly in the Caribbean. In the Florida Keys, nearshore corals are exposed to temperature extremes in both the summer and winter, while offshore corals experience a less variable thermal environment. We hypothesized that these spatial differences in temperature result in local thermal adaptation, with inshore corals exhibiting greater resilience to thermal stress than offshore corals. To test this prediction, we conducted a six-week common garden experiment with colonies of the mustard hill coral, *Porites astreoides*, from inshore and offshore reefs, using water temperature as a selective agent. Growth, bleaching and algal symbiont photosystem function were quantified as proxies of fitness. We also measured expression of genes implicated in stress response, metabolism, and immunity in the coral host to identify underlying molecular pathways affected by long-term thermal stress. We find significant genotype by environment interactions for symbiont related traits, suggesting that inshore corals are more resilient to thermal stress. Ongoing analysis of genotype data will provide insight into the relative roles of genetic and physiological mechanisms potentially driving local thermal adaptation in this system.

46.4 KERKHOFF, A.J.*; GILLEN, C.M.; HARTLAUB, B.A.; HOLDENER, J.A.; ITAGAKI, H.; Kenyon College; *kerkhoffa@kenyon.edu*

The mathematical biology of metabolic scaling: using a model insect as the basis for interdisciplinary undergraduate science training and research

Interdisciplinary training in biology and math is deemed essential for scientific progress, but it represents a challenge for undergraduate educators. Collaborative research involving faculty and students from both disciplines provides an authentic training opportunity while maintaining the rigor of disciplinary curricula. Here we summarize the results of an undergraduate research and training program investigating the mathematical biology of metabolic scaling using the tobacco hornworm, *Manduca sexta*, as a model system. Focusing on the role of the larval midgut, we have documented the allometric scaling of gut dimensions as well as ontogenetic changes in the expression of transport proteins and digestive enzymes. We have also tested existing theories relating metabolic scaling to growth and developed new models of how microvilli increase midgut surface area and allometric changes in the dynamics of assimilation. These projects have provided technical training to dozens of undergraduates in both mathematics and biology. More importantly, students have been able to participate in authentic, collaborative interdisciplinary research, resulting in the tangible products of science: knowledge shared via publications and presentations. The use of a common suite of questions centered on metabolic scaling has given a unified focus to student research while allowing them to find the topic that interests them most. Our approach requires that faculty mentors be willing to find common ground with their mathematical and biological collaborators, but the excitement and productivity of the project, in terms of both research products and student training outcomes, can more than offset this challenge

S3-2.3 KESäNIEMI, J.E.*; KNOTT, K.E.; University of JyvÃ¤skylÃ¤, Finland; *jenni.kesaniemi@jyu.fi*

Developmental mode polymorphism and population connectivity in the polychaete Pygospio elegans

The tube building polychaete *Pygospio elegans* is poecilogonous, producing both dispersive planktotrophic larvae and brooded lecithotrophic larvae released as benthic juveniles. Because these larvae have differing dispersal potential, variation in developmental mode both within and among populations can have a significant impact on population connectivity and distribution of genetic variation. An assessment of population connectivity is therefore interesting, since gene flow between populations will diminish potential divergence between populations. If developmental plasticity is an adaptation for coping with variable environmental conditions, dispersing offspring should fare well in many environments and resulting gene flow is expected to be high. If divergence is occurring between different populations (either via selection or drift) gene flow among populations will be reduced. I use data from microsatellite markers to estimate divergence and connectivity among 19 European *P. elegans* populations. A transition zone affecting marine species distribution is commonly seen between the Baltic and North Sea. In *P. elegans*, low but significant structure is seen between these regions, and preliminary analyses show asymmetrical gene flow among populations. Results also indicate high gene flow among the mainly planktonic North Sea and English Channel populations, and higher levels of differentiation among the Baltic Sea populations that have longer brooding. Highest allelic richness, an indication of larger effective population size, is observed in the North Sea, the English Channel and Germany. Correlations of genetic divergence and geographic distances are explored with a variety of methods.

12.5 KIKUCHI, DW*; PFENNIG, DW; Univ. of North Carolina, Chapel Hill; *dkikuchi@live.unc.edu*

MIMICRY AND THE PROXIMATE BASIS OF ADAPTATION

Mimicry is one of the classical examples of adaptation, yet we have much to learn about how mimetic phenotypes are produced. As an instance of convergent evolution, mimicry is an opportunity to study how different species respond to similar selective pressures. For example, do models and mimics use different developmental pathways to produce their phenotypes? Either alternative would have costs and benefits to mimics. Mimics using the same developmental pathway as their models might be able to produce very good mimicry, but at the same time might pay a pleiotropic or epistatic cost for doing so. Such mutations have also been considered highly unlikely. Alternatively, mimics using a different developmental system from their model would have to assemble their mimetic phenotype from scratch, and might never achieve very good mimicry. I present data showing that a Batesian mimic (the scarlet kingsnake) and its model (the coral snake) use very similar developmental mechanisms to produce the colorful signals that they present to predators. Both use melanin sequestered in melanophores to create black coloration, and both use drosopterin pigments sequestered in erythrophores to produce red coloration. Furthermore, although they obviously differ in the spatial patterning of their color patterns, I show that predators do not exert selection on that aspect of phenotype. This story illustrates how selection can drive mimicry to evolve via parallel mechanisms in some dimensions of phenotype, but other dimensions of what we might expect to constitute mimicry do not evolve in concert.

18.3 KIKUCHI, K.; CHATTERJEE, S.; LEE, W.-K.; STREMLER, M.A.; MOCHIZUKI, O.; SOCHA, J.J.*; Toyo U., Virginia Tech, Argonne National Lab.; *jjsocha@vt.edu*

Multi-modal pumping in drinking mosquitoes

Mosquito-related diseases such as malaria and dengue fever affect millions of people globally every year. Such diseases are transmitted through feeding, yet little is known about the internal mechanics of feeding in mosquitoes. Mosquitoes use a pair of serially-arranged cibarial and pharyngeal pumps in the head to generate forces that transport food from the source to the esophagus via the proboscis. We directly observed the action of these internal pumps using synchrotron x-ray imaging at Argonne National Laboratory. In two species (*Aedes vexans* and *A. cinereus*), we recorded x-ray videos of sugar water enhanced with an iodine contrast agent moving through the mosquito's head. Our footage revealed multiple modes of drinking in the mosquito. In the most commonly observed mode, the pharyngeal and cibarial pumps operated out of phase, cycling at a frequency of 2.9 ± 0.4 Hz, a mechanism of drinking that appeared to transport a continuous line of fluid into the gut. In a second mode of pumping, the cibarial and pharyngeal pumps expanded and contracted in phase, with both pumps distending to a greater volume than in the first mode, a form of pumping that transported a discrete bolus of fluid with each event. This second mode occurred only intermittently. To investigate the functional significance of these two modes of drinking, we created a new analytical model of pumping with system dimensions based on three-dimensional measurements of mosquito heads, obtained from synchrotron radiation microcomputed tomography. Dynamic similarity was maintained by matching dimensionless Reynolds, Womersley, Strouhal, and Stokes numbers. Our results demonstrate that mosquitoes can modulate aspects of feeding performance by changing the relative timing of pump expansion and contraction.

108.5 KILLPACK, TL*; KARASOV, WH; Univ. of Wisconsin, Madison; *tkillpack@wisc.edu*

Post-hatching ontogeny of adaptive antibody response to two distinct antigens in captive zebra finches

Immune function development has been studied extensively in poultry, yet analogous studies of altricial birds have been few until relatively recently. Altricial birds have the fastest growth rates among animals and some have such rapid development that the time from onset of egg incubation to fledging is less than 4 weeks. This raises questions about the vulnerability of small nestlings to infection, given that at least 4 weeks may be required to develop B-cell lineages with functional Igs against distinct antigens. We predicted that antibody responsiveness in altricial nestlings increases during the post-hatch period and reaches adult levels by fledging age (day 18-20 post-hatch in zebra finches), and that nestlings generate more robust antibody responses to larger injected antigens. Nestling zebra finches were injected at 7 days (7d group) or 14 days (14d group) post-hatch with keyhole limpet hemocyanin (KLH; antigen size ~400kDa) and West Nile Virus (WNV; antigen size ~50kDa) antigens, and boosted 7 days later. Adults were vaccinated in the same manner. Induced KLH- and WNV-specific IgG response was measured using ELISA. Adaptive IgG response to KLH boost significantly increased between the 7d and 14d nestling groups. However, there was no significant difference in adaptive IgG response to WNV boost between 7d and 14d groups. Adult adaptive IgG responses to KLH and WNV were at least 7 times higher than in nestlings, indicating that immunological competence continues to develop during the nestling and perhaps post-fledging periods. Lastly, adaptive IgG response to KLH was higher compared to WNV regardless of age, possibly indicating an important impact of antigen size on detection of antibody response. Support: NSF-GRFP, USDA-Hatch, AOU, GWIS, UW-Noland Fund.

80.1 KIM, K.S.; FUNK, D.H.; BUCHWALTER, D.B.*; NC State University, Stroud Water Research Center; *david_buchwalter@ncsu.edu*

Thermal and hypoxic gene expression in the mayfly (Centroptilum triangulifer).

Despite the widespread use of aquatic insects in biomonitoring programs, there are currently no established model organisms for ecophysiological studies of stream insects. The mayfly *Centroptilum triangulifer* has many attributes that make it promising as a laboratory model. Its thermal reaction norms are well established and relatively short life cycles (at laboratory temperatures) and high fecundity (typically >1,000 clonal and non-diapausing eggs/individual) allow for complete life cycle experiments with large sample sizes. Recent work in our lab has generated ~24,000 partial gene sequences which we are beginning to exploit to better understand how mayflies respond to thermal and hypoxic stress. To date, we have partially cloned 13 genes of interest related to heat shock, cellular oxygen status, and antioxidant enzymes. Larvae were subjected to 4 different sets of conditions for 6 hours each– controls (22 °C, 8 mg O2/L), hypoxia (22 °C, 2 mg O2/l), thermal stress (32 °C, 8 mg O2/l), and thermal stress combined with hypoxia (32 °C, 2 mg O2/l). Real-time PCR revealed both expected and unexpected results. Expected results included the elevated expression of HSPs 40, 70 and 90 by high temperature and the suppression of superoxide dismutases by hypoxia. Hypoxia inducible factor (HIF) mRNA levels were stimulated by hypoxia at 22 °C, but were surprisingly not different from controls at 32 °C. Interestingly, EGL9 mRNA levels were elevated by a combination of heat and hypoxia, but not hypoxia alone. EGL9 is an oxygen sensing gene that is reported to suppress HIF. Thus, EGL9 (and the influence of temperature on its activity) may play an important role in appropriate physiological response to thermally induced hypoxia.

106.5 KIM, Wonjung; GILET, Tristan*; BUSH, John W.M.; Massachusetts Institute of Technology, Cambridge, University of Liege, Belgium; *Tristan.Gilet@ulg.ac.be*

Nectar drinking

Nectar drinkers must feed efficiently due to the threat of predation. The sweetest nectar offers the greatest energetic rewards, but the sharp increase of viscosity with sugar concentration makes it the most difficult to transport. We show that the energy transport is optimized for a sugar concentration that depends exclusively on the drinking technique employed. We classify these techniques into three types: active suction, capillary suction, and viscous dipping. For each of them, we deduce the dependence of the volume intake rate on the nectar viscosity. Our results explain why suction feeders typically pollinate flowers with lower sugar concentration nectar than their counterparts that use viscous dipping.

26.6 KINGSOLVER, JG*; DIAMOND, SE; SEITER, S; HIGGINS, JK; UNC, Chapel Hill; *jgking@bio.unc.edu*

Direct and indirect selection on size and development in Manduca sexta

Adult size and development time are the outcomes of growth and differentiation throughout the life of an individual organism—its developmental trajectory. As a result, there will be both direct and indirect components of selection on body size and age during development. We used two field studies in experimental gardens to evaluate phenotypic selection on size and age across larval, pupal and adult stages in the tobacco hornworm, *Manduca sexta*. Rapid larval development was positively associated with survival to pupation and adulthood, in part because it allowed escape from larval parasitoids. Egg production was positively correlated with adult mass, but not with development time. Principal components analyses of size and age throughout development showed that adult size and development time were not negatively correlated, contrary to life history expectations. As a result, selection favoring larger adult size (via female reproduction) and selection favoring rapid larval development (via juvenile survival) act quite independently in this system. We discuss the physiological mechanisms that may underlie the independence of adult size and early larval development for holometabolous insects, and the implications for selection on body size and developmental trajectories.

61.1 KIRKTON, S. D.*; HENNESSEY, L. E.; DUFFY, B.; BENNETT, M. M.; LEE, W-K.; GREENLEE, K. J.; Union College, North Dakota State University, Argonne National Laboratories; *kirktons@union.edu*

Intermolt development reduces oxygen delivery capacity and jumping performance in the American locust (Schistocerca americana)

Among animals, insects have the highest mass-specific metabolic rates; yet, during intermolt development the tracheal respiratory system cannot meet the increased oxygen demand of older stage insects. Using locomotory performance indices, whole body respirometry, and X-ray imaging to visualize the respiratory system, we tested the hypothesis that due to the rigid exoskeleton, an increase in body mass during the intermolt period compresses the air-filled tracheal system, thereby, reducing oxygen delivery capacity in late stage insects. Specifically, we measured air sac ventilation frequency, size, and compressibility in both the abdomen and femur of early, middle, and late stage 6th instar *Schistocerca americana* grasshoppers. Our results show that late stage grasshoppers have a reduced air sac ventilation frequency in the femur and decreased convective capacities in the abdomen and femur. We also used X-ray images of the abdomen and femur to calculate the total proportion of tissue dedicated to respiratory structure during the intermolt period. We found that late stage grasshoppers had a lower proportion of their body dedicated to respiratory structures, especially air sacs, which convectively ventilate the tracheal system. These intermolt changes make oxygen delivery more challenging to tissues, especially critical ones such as the jumping muscle. Indeed, late stage grasshoppers showed reduced jump frequencies compared to early stage grasshoppers, as well as decreased mass-specific CO_2 emission rates at 3 kPa PO_2. Our findings provide a mechanism to explain how body mass changes during the intermolt period reduce oxygen delivery capacity and alter an insect’s life history.

31.4 KLINE, L.W.*; KARPINSKI, E.; University of Alberta, Edmonton; *lkline@ualberta.ca*

The flavone, chrysin, relaxes cholecystokini or KCl-induced tension in male guinea pig gallbladder strips through multiple signaling pathways

The flavonoids are a large group of plant-derived pholic compounds with biological effects. Chrysin has relaxant effects on both vascular and intestinal smooth muscle. In this laboratory an in vitro technique was used to determine the effects of chrysin on male guinea pig gallbladder strips, and to determine which second messenger system(s) mediated the chrysin-induced relaxation. Chrysin relaxed cholecystokinin octapeptide (CCK) or KCl-induced tension in a concentration dependent manner. When chrysin was added to the chambers 3 min prior to the KCl, a significant decrease in tension was observed (1.12+/-0.12 vs. 0.64+/-0.08g). To determine if the PKA/cAMP second messenger system mediated the chrysin-induced relaxation of CCK-induced tension, PKA-IM 14-22 amide myristolated (PKA-IM) was used. PKA-IM caused a significant decrease in chrysin-induced relaxation (69.8+/-3.5 vs. 56.4+/-2.8%). Neither the PKG inhibitor, KT5823,the NO synthase inhibitor, L-NMMA, nor the protein tyrosine kinase inhibitor, genistein,had a significant effect on the amount of chrysin-induced relaxation. When the PKC inhibitors, bisindolymaleimide IV and chelerythrine Cl^- were used together, a significant reduction in chrysin-induced relaxation (57.9+/-4.4 vs. 52.2+/-5.1%) was observed. 2-APB, an inhibitor of IP_3 induced Ca^{2+} release, significantly decreased the amount of chrysin-induced relaxation (60.7+/-6.0 vs. 49.1+/-2.5%). The results show that the chrysin-induced relaxation is mediated by the PKA/cAMP and PKC second messenger systems. The blocking of extracellular Ca^{2+} entry and blocking intracellular Ca^{2+} release are also involved in mediating the chrysin effect.

6.11 KMACK, DA*; YEO, SH; PAI, DK; UYENO, TA; WILKINSON, KC; TESTER, JT; NISHIKAWA, KC; Northern Arizona University, University of British Columbia, Valdosta State University; *dak58@nau.edu*

Linear actuator design based on a new hypothesis of muscle contraction

The conventional approach for simulating muscles is to use Hill-type models that include contractile, series elastic, and parallel elastic elements. Under limited conditions, Hill models provide reasonable predictions of muscle force output. However, because they fail to capture the non-linear, history-dependent behavior of active muscle, Hill models perform poorly at predicting muscle force under real-world conditions. Yet, the history-dependent properties of muscle provide intrinsic stability to load perturbations, as well as sustained energy storage. Failure to model these properties has limited the development of devices, such as prostheses, that perform like real muscles. The “winding filament” model solves these problems by incorporating a titin spring that engages mechanically upon activation and winds upon the thin filaments with each cross-bridge cycle. This mechanism was captured in a constitutive “winding ratchet” model. We designed and tested a linear actuator based on the winding ratchet model. The actuator system works by adjusting the center tension between two serial springs with a DC motor. Once the tension stabilizes, a servo latches the ratchet and holds the length between the two springs. A dual-mode force-lever applies forces by adjusting the length of the system, and measures the resulting force output. During isovelocity lengthening and shortening, the actuator replicates history-dependent behavior displayed by muscle in the absence of feedback control. With feedback, these features are enhanced as in real muscles. We plan to develop the actuator system for use in orthotics, prosthetics and robotics, as well as to obtain a better understanding of muscle function.

S3-1.1 KNOTT, K.E.*; MCHUGH, D.; University of JyvÃ¤skylÃ¤, Finland, Colgate University, USA; *emily.knott@jyu.fi*

Poecilogony, polymorphism or polyphenism: a window on larval evolutionary transitions in marine invertebrates

Poecilogony, intraspecific variation in developmental mode, has been described in some marine invertebrates. Poecilogonous species produce different larval forms (e.g. free-swimming planktotrophic larvae as well as brooded lecithotrophic larvae). Poecilogony can be a controversial topic, since it is difficult to identify and characterize with certainty: does poecilogony represent polymorphisms with a genetic basis or is it a case of developmental polyphenism with phenotypes determined by plastic responses to environmental cues? Do common mechanisms underlie the developmental variation we observe in poecilogonous species? Is poecilogony maintained in different taxa via similar mechanisms or selective pressures? This symposium highlights recent research on poecilogonous species using a variety of approaches including comparative phylogenetic, developmental, ecological, genomic and transcriptomic, and population genetic studies. We hope to encourage further studies of poecilogony that integrate methods and perspectives from across sub-disciplines for understanding developmental mode transitions. Poecilogonous species provide a unique opportunity to elucidate the cellular, developmental and genetic mechanisms underlying evolutionary transitions in developmental mode, as well as help clarify the selective pressures and possible ecological circumstances that might be involved. Since such evolutionary transitions have occurred frequently in a wide range of invertebrate taxa, we expect the symposium to interest a wide audience. As an introduction, we describe an integrative approach to the study of poecilogony and its potential role in larval evolutionary transitions.

113.6 KOEHL, M. *; STOCKER, R.; NICOLAU, D.; KING, N.; Univ. of California, Berkeley, MIT; *cnidaria@berkeley.edu*

Swimming and Feeding by Unicellular vs. Colonial Choanoflagellates

Many aquatic protozoans are unicellular, while others form multicellular colonies. We used *Salpingoeca rosetta*, a unicellular choanoflagellate that can be induced to form colonies, to study consequences to feeding of being unicellular vs. mulitcellular. Feeding by unicellular and colonial protozoans is not only ecologically important, but is also of evolutionary interest. Choanoflagellates are closely related to animals, and *S. rosetta* is a model organism in studies of the evolution of multicellularity. By using *S. rosetta* to study feeding performance, we explore a basic aspect of choanoflagellate biology that could have been an important selective factor during the evolution of multicellularity. A choanoflagellate cell swims with a single flagellum and eats bacteria captured on a collar of microvilli encircling the flagellum. Feeding performance depends: 1) encountering patches of prey, and 2) capturing bacteria from the water that flagellar beating moves past the choanflagellate. To study how *S. rosetta* encounter prey patches, we used a microfluidic device to put a stripe of high bacterial density in the water in a chamber where we could video *S. rosetta* swimming behavior. Colonies swim slowly in tight spirals, and thus hold their position in the water. In contrast, single-celled *S. rosetta* swim more rapidly along straighter paths, and can aggregate in the bacterial patch by turning more often once there. High-speed video revealed that the water currents produced by colonies are different from the flow around single cells, and feeding studies showed that colonies capture more prey per time than do single cells, A model of swimming and feeding behavior in which prey patchiness and shear due to ambient flow are varied reveals the types of habitats in which colonies vs. single cells show better feeding performance.

66.8 KOHN, A.B.*; CITARELLA, M.R.; GILLETTE, R.; SWEEDLER, J.V.; MOROZ, L.L.; Whitney Lab for Marine Bioscience University of Florida, St Augustine, FL, Department of Chemistry and the Beckman Institute, University of Illinois at Urbana-Champaign, Urbana-Champaign, Illinois, Department of Chemistry and the Beckman Institute, University of Illinois at Urbana-Champaign, Urbana-Champaign, Illinois, Dept of Neuroscience,University of Florida, Gainesville, FL, Whitney Lab for Marine Bioscience University of Florida, St Augustine, FL; *abkohn@msn.com*

Genome-wide Characterization of Signaling Peptides in Molluscs: Insights into Neuronal Evolution

Neuropeptides and protein hormones are ancient signaling molecules involved in virtually every activity of neural circuits and plasticity. First, using a combination of direct genome-wide transcriptional profiling of individual neurons, the entire CNS and developmental stages, we have identified and characterized the genomic organization of 96 prohormones in *Aplysia* including 56 previously unknown secretory products. Second, using *in situ* hybridization we validated neuron-specific expression of all discovered prohormones and showed cell-specificity in their expression. At least 5-6 prohormones were identified in key neurons of a simpler memory forming circuit. Third, we identified at least 20 neuropeptide-type prohormones differentially expressed during development of *Aplysia*. These data indicates that many peptides controlling early development can be recruited as signal molecules within adult nervous systems including learning and memory processes. Fourth, we employed various mass spectrometry protocols (MALDI TOF & LC MS/MS) to confirm the expressing of novel prohormones in both developmental stages and neuronal samples leading to direct experimental validation for the majority of novel prohormones with an astonishing diversity of >500 secretory products in *Aplysia*. Fifth, using deep transcriptome profiling (>5 million ESTs) from CNSs of 12 gastropod and cephalopod species we identify >70 of *Aplysia* prohormone homologs as evolutionary conserved precursors for multiple classes of signal molecules. The comparative analysis indicates that neuropeptides are amongst the fastest evolving intercellular signal molecules. Combined comparative and proteomic data from molluscs provides the unique opportunities to reconstruct of ancestral neuronal lineages, identify cell homologies across species and reveal trends in evolution within neural circuits.

9.5 KOHNO, S*; STERN, WH; LOWERS, RH; GUILLETTE, LJ; Univ. Florida, Dept. Biology and Med. Univ. South Carolina, Dept. Ob/Gyn, Univ. Florida, Dept. Biology and College Medicine, Kennedy Space Center, Innovative Health Applications; *kohno@musc.edu*

Can environmental contaminants alter sex hormone signaling of splenic function in the American alligator?

The American alligator is a sentinel species for local environmental contaminations because of its habitat, feeding hierarchy and non-migration. Some contaminants have the potential to disrupt the immune and endocrine system in wildlife as well as in humans. Indeed, American alligators in Lake Apopka, contaminated with agricultural chemicals exhibit altered immune and reproductive function. Interactions between sex hormones and immune system function have been demonstrated in mammals, but have not been examined in alligators. The aim of this study is to help clarify potential environmental impacts on the interaction between immune system function and sex steroid hormones. The spleen of juvenile female American alligators from Lake Apopka (AP) were compared with those from a reference site (WO) and from coastal Merritt Island (MI) National Wildlife Refuge. Splenic mass index was smaller at MI compared to WO and AP. Density of the periarterial lymphoid sheath in spleen, indicating immune active level, was higher in AP and MI than WO, although an area of red pulp in spleen, indicating immune function and red blood cells turnover, did not showed differences among the sites. Estrogen receptor 1 (ESR1) and androgen receptor (AR) mRNAs were expressed in alligator spleen. Spleens from AP alligators expressed higher ESR1 mRNA than tissues from WO, whereas no difference was noted in AR mRNA expression. These results suggest direct interactions of estrogen and androgen with the spleen, a central organ of immune function. Although MI alligators exhibited altered characteristics in splenic mass and histology, the causal factors could be different than those observed at AP.

86.2 KOMAN, James S.*; TOMANEK, Lars; Cal Poly San Luis Obispo; *jkoman@calpoly.edu*

Proteomic analysis of hyposalinity stress in the ascidian species Ciona savignyi and C. intestinalis

The ascidian species *Ciona savignyi* and *C. intestinalis* are invasive species but show interspecific differences in their population response to hypo-saline stress associated with heavy winter-run off events that are predicted to become more frequent due to climate change. Despite an almost world-wide distribution, *C. intestinalis* seems to be more susceptible to hypo-saline stress than the geographically more limited *C. savignyi*. Given that the genomes of both species are fully sequenced, we were able to compare their proteomic response to both acute and chronic salinity to characterize the mechanisms that are responsible for setting tolerance limits to hyposaline conditions in these two congeneric species. For the acute hypo-saline stress experiment, we exposed each species to decreasing salinities, 100%, 85% and 70% full-strength seawater, for 6 hours followed by a 4-hour recovery at 100%. In the chronic salinity stress experiment, each species was kept at 100% or 85% with individuals removed for analysis during a 16-day time course. Organisms were dissected to remove the tunic, and 2D SDS-PAGE was performed to separate proteins and characterize changes in protein expression. In the acute experiment, we determined 5% and 19% of the proteins to be differentially expressed in *C. savignyi* and *C. intestinalis*, respectively, due to the treatment effect. For both species in the chronic experiment, we determined over 40% of the proteins to be differentially expressed given the treatment, time, or interaction effect. Analysis of these proteins with MALDI TOF-TOF mass spectrometry has identified numerous proteins implicated in the cellular stress response (HSPs), metabolism (glycolysis, ATP & NADPH production), cytoskeleton (actin filament breakdown), and cell signaling (Ca-binding proteins), among others.

43.1 KONOW, N*; ROBERTS, TJ; Brown University; *nkonow@brown.edu*

Does extended training alter the operating length of leg extensor muscles?

Muscles are susceptible to damage during active lengthening. If a muscle operates at short fascicle lengths, on the ascending limb of its length-tension (LT) curve, the risk of damage may be reduced. It has been argued that adaptive changes in response to training may allow a muscle to shift its operating length to the left (i.e., relatively shorter) on the LT curve. We tested this hypothesis by determining relative operating length of the lateral gastrocnemius (LG) muscle. Two cohorts of wild turkeys (six animals each) were trained to run either uphill only (UH) or downhill only (DH) on a treadmill for 30 minutes per day for 10 weeks. After training, the right LG muscle of each bird was fitted with straingages on the calcified tendon to directly measure muscle force, while sonomicrometry was used to measure muscle fascicle length. During experiments, all birds ran a set trial sequence of 8 incremental slopes, from +20□ to -25□. A tetanic length-tension curve was then measured for each muscle in situ. By superimposing the in-vivo work loops and the LT curve for each muscle we could determine if training-mediated changes in the active operating range had occurred. Our prediction was that during downhill running, the DH trained muscles would operate at relatively shorter lengths compared with UH trained muscles. We found no consistent pattern in the active operating length of DH trained muscles during eccentric loading. Contrary to our expectations, we found that UH trained muscles operated at relatively short fascicle lengths. Our data do not support the hypothesis that safe operating range of a muscle results from adaptive changes acquired with training. This implies that the mechanisms of training-mediated resistance to muscle damage have yet to be fully explored. Supported by NIH (AR055295) to TJR.

119.3 KOVAC, Mirko*; VOGT, Daniel; ITHIER, Danielle; SMITH, Michael, J.; WOOD, Rob, J.; Harvard University, Microrobotics Laboratory, http://micro.seas.harvard.edu; *mirko.kovac@wyss.harvard.edu*

Experimental flight performance evaluation of forewing orientation in butterflies

The Harvard Microrobotics Laboratory is developing a series of biologically inspired flying micro robots at the scale of butterflies. One of the goals in this project is to optimize the wing shape and find optimal designs for gliding flight using a state of the art low speed wind tunnel which offers the unique ability to test butterfly size wings at scale. As a starting point we focus on wing shapes found in four butterfly species that are known for their distinct flight patterns and flight efficiency. For example, we selected migrating Monarchs (*Danaus plexippus*), which are famous for their astonishing capability of traveling large distances using a combination of hybrid flapping and gliding flight. Besides the 'Monarch' butterfly, we evaluate the wing shapes of the 'Orange Aeroplane' (*Pantoporia consimilis*), the 'Glasswing' (*Acraea andromacha*) and the 'Fourbar Swallowtail' (*Protographium Ieosthenes*). Based on museum specimens we extract the wing shapes and vary the forewing orientation angle systematically in order to account for the ability of the butterflies to dynamically change this angle during flight. We then fabricate models of these wings and test them in the wind tunnel at different velocities. The results indicate that the best gliding performance is achieved when the forewings are spread out and the wing span is maximized. In addition, we measure that the gliding performance is increased when flying faster confirming the assumption that a higher Reynolds number leads to a more beneficial aerodynamical regime. We believe that these results are an interesting insight for Biology allowing a comparison of the aerodynamic findings to behavioral observations of live butterflies.

110.5 KROCHMAL, A.R.*; LADUC, T.J.; PLACE, A.J.; Washington College, The University of Texas at Austin, Northwestern Oklahoma State University; *akrochmal2@washcoll.edu*

Proximate And Ultimate Perspectives On One-Trial Learning In Rattlesnakes

Little empirical work has focused on decision-making and learning in snakes. The few studies that have been conducted generally lack biological relevance and a phylogenetic framework, curtailing their scope substantially. We investigated the ability of 13 pitviper species – 7 rattlesnake and 6 non-rattlesnake pitvipers – to escape from a thermally stressor. Though all species were able to escape the thermal stress equally well, rattlesnakes in the study learned to escape in one trial (i.e., escape in 11 subsequent trials was faster than trial 1), whereas non-rattlesnake pitvipers never decreased their escape time over the 12 trials. Herein, we offer both proximate and ultimate mechanisms explaining one-trail learning in rattlesnakes. We used signal detection theory (SDT) to model the possible proximate neural mechanisms underlying the observed differences in learning between rattlesnakes and non-rattlesnake pitvipers. Our SDT model suggests profound differences in the neural processing abilities between the brains of rattlesnake and non-rattlesnake pitvipers, and we predict marked anatomical differences in the medial and lateral cortices of the cerebra of these lineages. At the ultimate level, we propose that the observed learning patterns could have arisen to aid in navigating an extreme and variable thermal environment, an idea supported by behavioral studies and the biophysical profile of the region in which rattlesnakes likely arose. Alternatively, the high predation pressure presumed to have driven the origin of the rattle could have also selected for one-trial learning relative to a suite of behaviors. Our results, and our hypotheses explaining them, underscore the need for future empirical studies of both the function, and mechanisms of learning in rattlesnakes.

S3-1.4 KRUG, P.J.*; GORDON, D.; California State University, Los Angeles; *pkrug@calstatela.edu*

Ecological triggers and evolutionary consequences of alternative larval types in sea slugs

Sea slugs in clade Sacoglossa evolve lecithotrophy at a high rate, and five species express larval dimorphisms. Poecilogony may facilitate shifts in larval type and could promote speciation, but we have little understanding of how variable development affects marine macroevolution. I present data for two sea slugs with contrasting forms of poecilogony: *Alderia willowi*, in which larval type changes seasonally, and *Costasiella ocellifera*, with populations fixed for planktonic or non-planktonic larvae. Native to Californian mudflats, *A. willowi* is unique because larval type can vary among clutches laid by the same mother. Field populations shift from lecithotrophy in summer and fall to planktotrophy in winter. In lab experiments, juvenile rearing environment strongly influenced the type of offspring produced by adults. Slugs raised at high temperature and full salinity (dry, summer conditions) produced lecithotrophic larvae, whereas slugs reared under cool temperatures and low salinity (wet, winter conditions) laid planktotrophic eggs. This is the first demonstration of seasonal polyphenism in larval type, and may be an adaptation to annual closures of Californian estuaries during the dry season. In contrast, the Caribbean *C. ocellifera* is planktotrophic in all but two populations that produced entirely non-planktonic larvae over a six-year study period. Lecithotrophic populations are self-recruiting, and show strong pre- and post-mating reproductive isolation in crosses with slugs from nearby planktotrophic demes. These results indicate that mating barriers quickly form in populations that lack a dispersive stage and receive immigrants from planktotrophic demes, likely to prevent outbreeding depression. This is the first experimental evidence that poecilogony may drive speciation in the sea, and could explain why sister species in diverse taxa often differ in larval type.

S2-1.5 KUDOH, Tetsuhiro; Univ. of Exeter, Exeter, UK; *t.kudoh@exeter.ac.uk*

The hermaphroditic mangrove killifish as a model for embryological studies

The self-fertilizing hermaphroditic mangrove killifish, *Kryptolebias marmoratus*, provides us with a very unique genetic model to study processes in embryonic development. To better utilize this species for embryological studies, we have reexamined details of developmental stages from the early cleavage stage to the blastula, gastrula, somitogenesis and organogenesis stages. To clearly observe internal structures during late stages of development, embryos were treated with PTU effectively generating melanocyte-free transparent embryos without causing morphological abnormalities. To visualize the movements of the yolk syncytial layer (YSL), we injected a fluorescent dye, sytox green, in the interphase between blastomeres and yolk and observed the movements of nuclei in the YSL during gastrulation. On the surface of the yolk, a dense network of blood vessels is formed from the mid-somitogenesis stage onwards, which is a very unique and powerful system to observe detailed cell behavior of endothelial cells forming blood vessels. Aiming to obtain gene probes to examine gene expression patterns in the embryos, we sequenced embryonic cDNAs using Solexa/Illumina next generation sequencer. From the sequence analysis, we obtained full-length cDNA sequence for a variety of early marker genes such as sox3, sox2, sox9, otx2, hoxb1b, p63, brachyury, myoD, pax6 and fli1. I aim to discuss the dynamics of these gene expression patterns during the embryonic development of *K. marmoratus*.

45.3 KUMAR, Sandeep*; GANJI, Purna Chandra Nagaraju ; SONG, Hojun; VON KALM, Laurence; BORST, David W.; University of Central Florida; *skumar@knights.ucf.edu*

siRNA-mediated down-regulation of hexamerins suppresses reproduction and feeding in the lubber grasshopper Romalea microptera

Juvenile hormone binding proteins (Hexamerins) are the major insect storage proteins. They are important for many regulatory processes, including stress management. In the lubber grasshopper *Romalea microptera* there are 3 major hexamerin proteins of molecular weight 90 kd, 270 kd and 500 kd. Simultaneous siRNA knockdown of all three hexamerins leads to decreased reproduction (both male and female animals) and feeding capacity (female animals only). We demonstrate a significant decrease in mean ovarian index, mean oocyte diameter and mean oocyte length in female animals treated with siRNA against all three hexamerins. In treated males, testicular indices and testicular follicular diameters were significantly lower than control animals. siRNA against all hexamerins also significantly decreased the feeding capacity, body weight, and rolling time. Taken together, our observations suggest that the hexamerin proteins are essential for grasshopper development and reproduction. To the best of our knowledge, this is the first report of simultaneous multicistronic gene silencing in invertebrates.

2.1 KUO, CY*; GILLIS, GB; IRSCHICK, DJ; Univ. of Massachusetts Amherst, Mt. Holyoke College; *chiyun@bio.umass.edu*

The role of practice (or lack thereof) on the recovery of jump performance in tailless green anole lizards Anolis carolinensis

Locomotor performance is critical to organismal survival but is often impaired when the body parts involved in locomotion is damaged or lost. We hypothesize that practice can help the animals to improve impairment locomotor performance. Green anole lizards (*Anolis carolinensis*) represents an excellent system for this inquiry. Researchers have found that green anoles suffer from reduced in-air stability after autotomizing their tails. This can pose a serious problem to green anoles given their reliance on jumping in the field. To see whether practice can help restore in-air stability, we examined jump kinematics in three groups of lizards for five consecutive weeks. The first group (practice group) had their tails removed and were allowed to jump once a week. The second group (awareness group) had their tails removed but were only allowed to jump on the first and the last weeks. The third group (control group) had intact tails and were allowed to jump once a week. If practice can help restore in-air stability, a significant difference in in-air stability should exist between practice and awareness groups. On the other hand, if both groups fail to improve their jump performances through time, we might be able to conclude that practice cannot restore in-air stability in green anoles. However, it is also possible that the awareness of tail loss suffices for the lizards to make kinematic adjustments accordingly. If this is true, then we should observe an improvement in jump performances in both practice and awareness groups. Results of this study will elucidate the role of practice in restoring locomotor performance in non-human vertebrates.

112.1 KURTH, J.A.*; THOMPSON, J.T.; KIER, W.M.; University of North Carolina, Chapel Hill, Franklin and Marshall College, Lancaster, PA; *jkurth@live.unc.edu*

Tuning of Mantle Connective Tissue to Non-Uniform Strain in the Squid Doryteuthis pealeii

The mantle of squid includes networks of intramuscular (IM) connective tissue fibers that store and release energy to augment ventilation and jetting. Recent studies have shown that the mantle experiences significantly greater circumferential strain on the inner lumen surface compared to the outer lumen surface as it expands and contracts. Our goal was to determine how one network of IM fibers, the IM-3 fibers, accommodates this strain gradient. The IM-3 fibers run parallel to the circular muscle fibers that power mantle contraction. They appear folded at rest but straighten during mantle hyperinflation to store elastic energy and resist further mantle expansion. We hypothesized that the IM-3 fibers near the inner surface would show more extensive folding than the outer fibers to accommodate the strain gradient and maximize elastic energy storage. We used sonomicrometry to determine the diameter of the mantle during hyperinflation, and maximal and intermediate degrees of contraction. We fixed rings of mantle tissue at each of the three states then embedded and sectioned the tissue using glycol methacrylate plastic. We compared the degree of IM-3 fiber folding between the inner and outer regions with a dimensionless "folding index," by dividing the full length of the folded fibers by the straight-line distance between the fiber ends. In the intermediate and maximally contracted mantle tissues, the IM-3 fibers near the inner surface of the mantle were significantly ($p<0.05$) more crimped than the fibers along the outer surface. In the hyperinflated mantle, folding of the inner and outer IM-3 fibers did not differ ($p>0.05$). Our data show that differences in the degree of folding of the IM-3 collagen fibers accommodate the strain gradient. Supported by NSF IOS-0951067.

110.3 LADAGE, Lara D*; ROTH, Timothy C; CERJANIC, Alexander M; SINERVO, Barry; PRAVOSUDOV, Vladimir V; University of Nevada, Reno, Kenyon College, University of California, Santa Cruz; *lladage@unr.edu*

Spatial memory in the side-blotched lizard, Uta stansburiana

Spatial memory has been shown to be important in many ecologically-relevant behaviors such as territoriality, mate choice, navigation, and the acquisition of food resources. Although true spatial memory has been tested and accepted in mammals and birds, often spatial memory capabilities in squamate reptiles have been, at best, seen as probable and, at worst, non-existent. The handful of previous studies on squamate reptiles has been equivocal- some demonstrated no evidence of spatial memory while others have supported spatial memory capabilities. In our study, we utilized a modified Barnes maze, the typical apparatus used to test spatial memory in rodents, to test spatial memory in the side-blotched lizard, *Uta stansburiana*. Although subjects needed many training trials to reach criterion, during probe trials every subject demonstrated unequivocal evidence of spatial memory capabilities. Thus, our finding refutes previous assertions that the evolution of spatial memory excludes squamate reptiles.

53.5 LAILVAUX, SP*; BARIYA, P; University of New Orleans, University of New ORleans; *slailvaux@gmail.com*

Performance, female choice and sexual conflict in crickets

Whole-organism performance capacities such as bite force have been shown to influence male-male combat outcomes in a variety of animal species. However, support for female mating preferences for high-performance males is mixed at best. In contrast to preferring good performers, females may in fact choose to avoid mating with high-performance males if they are likely to suffer harassment from such males. However, the role of performance in affecting (or enabling) sexual conflict has seldom been considered. We conducted behavioral trials to test whether females prefer or avoid males exhibiting high bite force during mating interactions in house crickets, *Acheta domestica*. In addition, we also tested the hypothesis that high bite forces in females may prevent or curtail harassment by unattractive males.

112.5 LAMAS, L.P.*; MAIN, R.P.; SHEFELBINE, S.; HUTCHINSON, J.R.; The Royal Veterinary College, UK, Purdue University, Indiana, USA, Imperial College London, London, UK, The Royal Veterinary College, London, UK; *llamas@rvc.ac.uk*

In vivo locomotor mechanics of the tarsometatarsus bone in juvenile emus

Emus(Dromaius novaehollandiae) have become increasingly popular models for pelvic limb (PL) mechanics. Strain gauge (SG) measurements of the loading patterns from PL bones offer are essential to test the accuracy of computer modelling approaches such as finite element analysis (FEA). If localized SG results match FEA estimates then this would build confidence in FEA, which can estimate strains throughout an entire bone including regions such as muscle attachment sites and joint surfaces for which strains are extremely difficult to determine experimentally. Previous mechanical studies of emu PL bone strains have demonstrated that both the femur and tibiotarsus (TBT) are predominantly loaded under shear strains induced by torsional loads. Although these loading patterns are maintained during ontogeny, the femora and TBT of emu scale with mixed allometry during growth. Unlike the femur and the TBT, no information is yet available on the loading patterns of the more distal tarsometatarsus (TMT) bone. Is the TMT similarly loaded in torsion like the more proximal femur and TBT? To answer this question, in vivo bone strains from the TMT were measured in juvenile (one 6week old and three 30 week old) emus. Simultaneous 3D kinematics of the limb and ground reaction forces were also obtained from these animals. Our results suggest that the TMT does not follow the loading pattern of the more proximal bones, being loaded predominantly in bending, not torsion. This suggests that the torsional strains measured for the proximal bones originate from either hip joint contact forces or, more likely, from internal muscle and other soft tissue forces, which are dissipated before reaching the TMT.

79.3 LAMMERS, A. R.*; ZURCHER, U.; School of Health Sciences, Cleveland State University, Department of Physics, Cleveland State University; *a.Lammers13@csuohio.edu*

Dynamic stability during quadrupedal arboreal locomotion: Body segment contributions to angular momentum

Traveling on narrow tree branches and twigs presents a challenge to maintaining balance and avoiding falls. To remain stable while running quickly on an arboreal support, animals may rely less on static stability (increased duty factor, modified limb phase, crouched posture, etc.) and more on dynamic stability, which results from movement. We examined angular momentum in the trunk and head, forelimbs, and hindlimbs of Siberian chipmunks (*Tamias sibiricus*) running on a cylindrical trackway about half the diameter of the chipmunks' torso. We marked body segments on the chipmunks' fur using white paint, and videotaped the running animals using two 210 Hz video cameras. By digitizing the two videos, we assembled a set of 13 three-dimensional points representing the head, segments of the torso, the tail, and the right forelimb and hindlimb. Using body segment masses obtained from a cadaveric specimen, and the linear and angular velocities of the three-dimensional coordinates, we calculated linear and angular momentum of the entire body, and of the torso/head segment, tail, right forelimb, and right hindlimb. Preliminary data show that fore-aft linear momentum was far greater than vertical, and mediolateral linear momentum fluctuated around zero. Rolling angular momentum also fluctuated around zero for all body segments; yaw angular momentum also fluctuated around zero, but there were relatively large moments when the forelimb or hindlimb lifted off. Pitch angular momentum was considerable, and the forelimb and hindlimb each contributed about twice the angular momentum of the torso. Because a non-zero pitch angular momentum makes falling of the sides of the branch less likely, we conclude that limb movement plays a major role in maintaining dynamic stability during fast arboreal locomotion.

118.3 LANCE, S.L.*; JONES, K.L.; FLYNN, R.W.; ERICKSON, M.R.; TUBERVILLE, T.D.; SCOTT, D.E.; Savannah River Ecology Laboratory, University of Georgia, University of Colorado School of Medicine; *lance@srel.edu*

Chronic copper exposure in southern toads, Anaxyrus terrestris: lethal, sublethal, and gene expression effects

Chronic exposure to environmental contaminants can cause effects at higher levels of biological organization such as populations and communities. However, due to inherent challenges in assessing these impacts most studies focus on individual survivorship under acute exposure. To assess the long-term effects of contaminant exposure it is critical to examine sub-lethal endpoints, and the potential for organisms to adapt to contaminated environments. We investigated the relevance of sub-lethal endpoints in southern toads, *Anaxyrus terrestris*, exposed to a range of copper concentrations. We examined several endpoints including hatching success, survival to metamorphosis, time to- and size at metamorphosis. Overall copper significantly reduced survival through the egg and larval stages. We examined eggs from multiple clutches and source populations and both factors were also significant sources of variation in survival. Depending upon the source population survival to the free-swimming stage was significantly reduced at concentrations as low as 10ppb and no larvae reached metamorphosis at concentrations above 15ppb. To better understand the effects of copper we used RNASeq to examine gene expression patterns in developing toads. We compared expression in early development of eggs from 24 to 54 hours post copper treatment. At 55 hours nearly 200 genes were differentially expressed between control and treatment individuals. We discuss our findings and relate them to potential impacts on population level processes.

120.1 LANDBERG, T*; WILLINK, B; NOSS, CF; GREENE, RS; VONESH, JR; WARKENTIN, KM; Murray State University, KY, University of Costa Rica, University of Florida, University of Victoria, Virginia Commonwealth University, Boston University; *tobias.landberg@gmail.com*

Development of Climbing Performance and Behavior during Red-eyed Treefrog Metamorphosis– the Effects of Larval Competition

Anuran metamorphosis involves dramatic, rapid changes in morphology, locomotor performance, and behavior and is a critical period for dispersal from larval habitats. For arboreal species, climbing is the most important locomotor mode for dispersal and foraging. While swimming, jumping, and even parachuting, gliding and adhesion have been studied extensively, climbing behaviors have not. We studied the development of climbing performance and behavior through metamorphosis for red-eyed treefrogs (*Agalychnis callidryas*) reared at three larval densities. Higher densities yielded smaller metamorphs. Metamorphosis takes ~6 d, with most tail resorption occurring in the 24 h after forelimb emergence. We observed two climbing gaits with distinct footfall patterns – a slow lateral sequence walk and a faster trot. Latency to climb decreased through metamorphosis. Generally, tail length had a negative effect on climbing performance. Climbing speed increased more through metamorphosis for smaller animals from higher densities than for larger animals from low density. Climbing speeds were similar by the end of metamorphosis, so carryover effects of larval competition decreased through metamorphosis. Proximate locomotor costs of emergence from the water early in metamorphosis are greatest with strong larval competition. Nonetheless, the ultimate fitness costs may be reduced by early stage (long-tailed) metamorphs having a reduced propensity to climb and thus potentially relying more on immobility as a defense.

43.10 LANDLER, Lukas*; VON OHEIMB, Parm V; Virginia Tech, USA, Blacksburg and Natural History Museum of Vienna, Austria, Department of Animal Ecology and Systematics, Germany, GieÃ en; *lukasl@vt.edu*

Y-axis orientation in South American freshwater snails (Chilina spp.)

Y-axis orientation, defined here as movement perpendicular to the shore- or coastline, enables aquatic animals to control migration. In the present study a new arena assay is established to test the orientation response of pulmonate freshwater snails after displacement outside the water. Using this novel experimental design, for the first time, Y-axis orientation was shown in a freshwater snail species, the riverine *Chilina patagonica*. In contrast to *C. patagonica*, no consistent orientation response could be detected in the related lacustrine species *Chilina llanquihuensis*. Several potential cues could be identified as probably being irrelevant for the Y-axis orientation behavior found in this study: chemical, visual, gravity, humidity cues or a sun compass. Magnetic cues, however, may play a role. Since no differences in orientation were detected in different size classes in *C. patagonica*, orientation behavior may not vary substantially throughout its life history. However, the preferred direction of *C. patagonica* seems to be contradictorily, because one would expect an orientation response towards the waterside, when placed outside the water, not away from it. In the case of *C. patagonica*, an adaptation to the physical constraints of its habitat might be of vital importance. We suppose that the different hydrological constraints in river habitats might influence migration and orientation in *C. patagonica*. The highest current velocity exists in the deepest area of the river. Orientation towards the shore is probably more viable than orientation towards the middle of the river as it prevents the gastropods from getting drifted away. Given our findings for *C. patagonica*, further studies might provide new insights into the underlying cues of Y-axis orientation behavior.

40.4 LANGKILDE, T*; FREIDENFELDS, N.A.; ROBBINS, T.R.; Penn State University; *tll30@psu.edu*

Evading invaders: Adaptive significance of a behavioral response

Understanding the mechanisms driving adaptations to survive agonistic interactions, and their function, provides insight into how native species respond to aggressive threats. The introduction of non-native species, which can prey upon and compete with native taxa, provides an opportunity to address this issue. The red imported fire ant, *Solenopsis invicta*, is an invasive species of global importance. Native fence lizards, *Sceloporus undulatus*, from populations invaded by fire ants have altered antipredator behavior. We staged encounters between these species both on and off the ant mound (nest) to determine the effectiveness of lizard antipredator behavior for surviving ants through ontogeny. We used field caught and lab-reared lizards from fire ant invaded and uninvaded sites to assess the impact of lifetime and evolutionary exposure to this invasive threat. Scouting fire ants quickly detected lizards placed 0.5-4 m from a fire ant mound within natural lizard habitat (within 13 sec - 12 min). In addition to functioning to removing attacking ants, lizards' body-twitch and flee behavior prevented fire ant attack. Lizards that behaviorally responded after an initial encounter with a fire ant scout reduced their risk of having additional fire ants recruit to the attack – those that did not respond to ants were quickly attacked which, in nature, would have fatal consequences. Fewer adult lizards responded to fire ants than juveniles, and were recruited to significantly more as a result. Within lifetime selection and/or lifetime exposure to fire ants appears to be driving these behavioral differences.

40.3 LARABEE, F. J.*; SUAREZ, A. V.; Univ. of Illinois, Urbana-Champaign; *larabee@life.illinois.edu*

Evolutionary Co-option of Trap-jaw Ant Mandible Strikes: Defensive Interactions with Antlions

The co-option of existing traits for novel functions is fundamental to many theories of trait evolution, but few studies have examined evolutionary co-option at a behavioral level. Trap-jaw ants in the genus *Odontomachus* have a rapid and powerful mandible snap that can be used to catch fast or dangerous prey. In some species this behavior appears to have been co-opted for defense: in threatening situations ants direct their strikes against the substrate and launch themselves into the air. Until now, no actual predators or competitors have been found in the field against which trap-jaw use their 'escape jumps'. We studied the defensive use of mandible snapping behavior in two trap-jaw species (*Odontomachus brunneus* and *O. relictus*) during their interactions with predatory antlions in the genus *Myrmeleon*, which live in sympatry in the Lake Wales Ridge in central Florida. Using high-speed videography and traditional bioassays, we described how trap-jaw ants can perform escape jumps after falling into antlion pits. Interestingly, while both species use the mandible snap for predation, only *O. brunneus* used the mandible snap to escape from antlion pits (approximately one third of interactions). A comparison of the kinematic properties of mandible strikes suggested that differences in force generation might contribute to the behavioral differences between these species. Taken together, our results indicate that trap-jaw mandible snaps can be used to escape from natural predators, lending support to the idea that this predatory behavior has been evolutionarily co-opted for defense.

16.1 LASALA, J.A.*; WILLIAMS, K.; HARRISON, J.S.; FRICK, M.; ROSTAL, D.C.; Georgia Southern University, , Caretta Research Project, Savannah, GA, Georgia Southern University, Georgia Southern University; *jl02621@georgiasouthern.edu*
Multiple Paternity of Loggerhead sea turtle (Caretta caretta) within the Northern Management Unit
Comprehension of a species mating system is important to conservation efforts and to understanding how populations differ. Patterns of paternal contributions can skew effective population size and alter genetic variability. Specifically, multiple paternity (MP) can influence the maintenance of genetic variation within a population: the more likely a clutch is genetically diverse, the more likely a variety of genes will be passed on. Within Testudines, MP can vary (0-100% of nests) and there is limited evidence as to the cause. Previous studies on the loggerhead turtle (*Caretta caretta*) have shown that within the large management unit of peninsular Florida, MP occurs in approximately 30% of nests. If we examine nests from the smaller and more endangered northern management unit, will the nests show multiple paternal contributions and could there be a difference between the two management units? The primary objectives of this study are to determine if MP exists in Georgia's smaller nesting population and determine if the percentage of nests with multiple fathers differs significantly from previous studies. Secondary objectives are to compare the incidence of MP over multiple years and to determine if MP varies over the course of the nesting season. Mothers and offspring (up to 20) were sampled from more than 90 nests over three entire nesting seasons on Wassaw Island, GA (2008 – 2010). An unforeseen result of our analysis has been our determination of the potential genotypes of the contributing males over all three years. We will discuss the frequency of MP over three years, note whether time of season matters to variation and offer a conservative estimate of the adult males contributing to this population.

114.6 LATTIN, Christine R.*; MEDINA, Carlos; ROMERO, L. Michael; Tufts University; *christine.lattin@tufts.edu*
Effects of chronic stress on brain and peripheral intracellular glucocorticoid receptors in wild House Sparrows
Glucocorticoids such as corticosterone (CORT) are essential in helping wild animals cope with environmental stressors, but sustained high concentrations of these hormones can cause many negative effects. Most studies of chronic stress have focused on hormone titers; some studies have found higher baseline CORT in response to presumed chronic stressors, whereas others have found a decrease. This diversity of results means it is not possible to simply look at plasma CORT and distinguish between healthy and compromised animals, nor to predict exactly what effects chronic stress may have on the animal. To help clarify the effects of chronic stress, we looked "downstream" of hormones at intracellular CORT receptors in the brain and periphery. We captured 45 wild House Sparrows and divided them into two groups: a control group (n=20) to control for the effects of long-term captivity, and a stressed group (n=25) subjected to a 3-week chronic stress protocol (CSP) in the lab. Birds were sacrificed before the start of the CSP, every week during the CSP, and following 1 week of recovery. Mineralocorticoid receptors (MR) and glucocorticoid receptors (GR) were quantified using radioligand binding assays. In whole brain, there was no difference in GR between control and stress birds, or during the recovery period. However, MR was higher in stressed birds during the CSP than in control birds (81.0 ± 7.1 fmol binding/mg protein and 58.9 ± 7.1 fmol binding/mg protein, respectively; $p=0.035$). During the recovery period, MR in stressed birds decreased back to control levels. Preliminary results suggest there was no difference in liver GR or MR between control and stressed birds. These results are consistent with the idea that chronic stress may affect animals in a species- and tissue-specific manner.

S7-1.1 LAUDER, G. V.*; FLAMMANG, B.; ALBEN, S.; Harvard University, Georgia Institute of Technology; *glauder@oeb.harvard.edu*
Robotic models of fish body and caudal fin propulsion
Considerable progress in understanding the dynamics of fish locomotion has been made through studies of live fishes and by analyzing locomotor kinematics, muscle activity, and fluid dynamics. Studies of live fishes are limited, however, in their ability to control for parameters such as fish length, flexural stiffness, and kinematics. Keeping one of these factors constant while altering others in a repeatable manner is typically not possible, and it is difficult to make critical measurements such as locomotor forces and torques on live freely-swimming fishes. In this presentation we will discuss the use of simple robotic models for flexing fish bodies and the effect of changing tail shape on these models for our understanding of aquatic locomotor dynamics. A self-propelling robotic flapping-foil apparatus is used to analyze the effect of changing length, flexural stiffness, and tail shape on swimming speed and locomotor forces and torques. Altering these parameters individually reveals some surprising non-linear effects. We also quantify the wake structure behind swimming foils with volumetric particle image velocimetry, and describe the effect of heterocercal and homocercal tail shapes on wake flow patterns. One key advantage of the considerable degree of control afforded by robotic devices and the use of simplified geometries is that mathematical analyses and computational models are facilitated, as illustrated by the application of an inviscid computational model. Future work with this robotic system includes analyses of unsteady locomotor behaviors such as c-start escape responses.

58.1 LAUDER, G. V.*; OEFFNER, J.; Harvard University; *glauder@oeb.harvard.edu*
Hydrodynamic function of shark skin and two biomimetic models
It has long been suspected that the denticles on shark skin reduce hydrodynamic drag during locomotion, and a number of man-made materials have been produced that purport to use shark skin-like surface roughness to reduce drag during swimming. But no studies to date have tested these claims of drag reduction under dynamic and controlled conditions in which the swimming speed and hydrodynamics of shark skin and skin-like materials can be quantitatively compared with that of controls lacking surface ornamentation or with surfaces in different orientations. We use a flapping foil robotic device which allows accurate determination of the self-propelled swimming speed of both rigid and flexible membrane-like foils made of shark skin and two biomimetic models of shark skin to measure locomotor performance. We studied the self-propelled swimming speed of real shark skin, a silicone riblet material with evenly spaced ridges, and Speedo "shark skin-like" swimsuit fabric attached to both rigid flat plate foils and made into flexible membrane-like foils. We found no consistent increase in swimming speed with Speedo fabric, a 7.2% increase with riblet material, and shark skin membranes (but not rigid shark skin plates) showed a mean 12.3% increase in swimming speed compared to the same skin foils after removing the denticles. Deformation of the shark skin membrane is thus critical to the drag reducing effect of surface denticles. Digital particle image velocimetry of the flow field surrounding moving shark skin foils shows that skin denticles promote enhanced leading edge suction which may have contributed to the observed increase in swimming speed.

64.5 LAUMER, C.E.*; GIRIBET, G.; Harvard Museum of Comparative Zoology; *claumer@oeb.harvard.edu*

A single, stepwise origin of ectolecithality in Platyhelminthes?

Ectolecithality is a process of functionally and (usually) spatially divided oogenesis that effects distinct populations of vitelline cells and nearly-yolkless germ cells. The origin of ectolecithality may have had pervasive impacts on the embryology and diversification of its beneficiaries, but its evolutionary roots remain obscure. Early classifications group all ectolecithal flatworms in a single clade, Neoophora. However, some have proposed multiple origins of the phenomenon and/or reversals to an entolecithal state, and Neoophora has so far seen no molecular support. We address this quandary using perhaps the largest molecular phylogenetic study of deep Platyhelminth relationships to date, with nearly complete 18S and 28S rRNA and two mtDNA fragments from 83 terminals. Taxon sampling was directed to span the diversity of each major group, including several "Problematica", as well as the enigmatic Lecithoepitheliata, hitherto underrepresented in molecular phylogenies. Conventional analytical methods consistently validate the monophyly of nearly all the classical orders, and largely resolve a clade possessing spatially distinct ovaria and vitellaria. In addition, implied-weights parsimony as well as Bayesian analyses under a mixture model both strongly support the monophyly of Neoophora. These data thus corroborate the classical view of lecithoepitheliate germovitellaria as preserving an early step on the road to complete ectolecithality. Certain questions, however, including the identity of the earliest-branching Rhabditophora and the monophyly of Lecithoepitheliata, remain open. We propose that the phylogenetic utility of familiar markers to solve such persistent problems has effectively been exhausted, and that future work must embrace a different paradigm of gene sampling in order to resolve the deepest splits in Platyhelminthes.

82.4 LAVENDER, A. L.*; BARTOL, S. M.; BARTOL, I. K.; Old Dominion University, Norfolk, VA, Virginia Wesleyan College, Norfolk; *alavende@odu.edu*

A two-method approach for investigating the underwater hearing capabilities of loggerhead sea turtles (Caretta caretta)

Sea turtles are one group of protected marine animals potentially impacted by rising levels of anthropogenic sound. According to a limited number of morphological and electrophysiological studies, sea turtles appear to be low frequency specialists. Previous electrophysiological studies have not been correlated with behavioral responses, an important step for hearing assessment, as AEP-audiograms have been found to underestimate the auditory threshold. We collected underwater AEPs and behavioral responses from loggerhead sea turtles (*Caretta caretta*) to low frequency tone bursts (50-1300 Hz) using a J9 underwater speaker. To collect electrophysiological responses to sound, each turtle was positioned below the air-water interface, and a Tucker Davis Technologies (TDT) system was used to collect averaged AEPs during signal presentation. Responses were processed using MATLAB routines to yield time and frequency domain waveforms for threshold determination. Behavioral audiograms were recorded using a two-response, forced-choice approach. Individuals were subjected to a multi-step conditioning procedure to establish associations between experimental apparatus and signal presence/absence. Threshold analyses were based on the percentage of correct responses and response time calculations for each block of trials. Our AEP and behavioral audiograms demonstrate sea turtles respond to low frequency sounds (<1000 Hz) and as hypothesized, the behavioral data indicate a lower threshold for each tested frequency. These data provide two independent measures of hearing frequency range and threshold and promise to serve as an integral component of future assessment plans that address impacts of sound on sea turtles.

S8-1.5 LEDON-RETTIG, C.C.*; PFENNIG, D.W.; CRESPI, E.J.; University of South Florida, Tampa, University of North Carolina, Chapel Hill, Washington State University; *cledonrettig@mail.usf.edu*

Phenotypic plasticity's role in the origins of novel feeding strategies

Although environmentally dependent genetic variation could play a critical role in promoting rapid environmental transitions, few empirical studies have evaluated its presence in ecological and evolutionarily relevant traits. I assessed the role of cryptic genetic variation - variation that has no discernable phenotypic effect under typical conditions, but is exposed and amplified when a population experiences an environmental stressor - in the evolution of a novel feeding strategy among spadefoot toad larvae. Members of the genus *Spea* have evolved a novel suite of traits (behavioral, physiological and morphological) associated with carnivory and cannibalism. Using a comparative approach and a series of experiments, I found that exposing a species with the ancestral feeding strategy to the derived diet amplifies genetic variance in traits that are beneficial for consuming that diet. I also investigated a mechanism for the expression of cryptic genetic variation. Corticosterone (CORT), the major vertebrate stress hormone, is upregulated in response to novel or suboptimal conditions. Further, CORT is known to mediate physiological, developmental and morphological plasticity. By using hormonal manipulations, I determined that diet-induced CORT might be responsible, in part, for the expression of cryptic genetic variation in this ancestral lineage. This suggests that vertebrate hormones not only play a role in mediating developmental transitions and physiological trade-offs at an individual level, but might also mediate the expression of population genetic variation during environmental transitions.

6.5 LEE, S/SM*; BIEWENER, A/A; DE BOEF MIARA, M; ARNOLD, A/S; WAKELING, J/M; Simon Fraser University, Harvard University; *sabrina_lee_4@sfu.ca*

Effect of Motor Unit Recruitment on In Vivo Muscle Function

A mixture of motor unit types can be found in mammalian skeletal muscles, and recruitment of these different motor units may influence whole muscle performance. Key properties that dictate the mechanical output of muscle include the maximum shortening velocity and the activation/deactivation rates that can be important during fast or explosive movements such as galloping and jumping. The purposes of the study were to 1) describe changes in motor unit recruitment patterns due to changes in locomotor dynamics (gait velocity, surface incline, and locomotor activity) and 2) examine if these changes in motor unit recruitment patterns provide mechanical advantages by characterizing the relationships between motor unit activity, fascicle strain rate, and force profiles. We collected electromyography (EMG), tendon force, and sonomicrometry data in the gastrocnemius muscles of 9 goats during jumping and during walking, trotting and galloping on a treadmill (level,incline). Motor unit recruitment patterns were quantified with a wavelet analysis of the EMG signals. Our analysis demonstrates that motor units in the goat hindlimb are preferentially recruited for different locomotor tasks and that recruitment is related to fascicle shortening rate and force rise and relaxation rates. Shortening velocities, and force rise and relaxation rates were significantly different between activities (jump vs. gait,$p<0.001$, and gallop vs. trot and walk,$p<0.001$), and grade (level and incline,$p<0.001$). Also, motor unit recruitment was associated with strain rate ($p<0.001$), force rise and relaxation rates ($p< 0.01$) and myoelectric intensity ($p<0.001$). This study offers new insight into the complex relationships between motor unit recruitment, strain rate, and force generation during different locomotor tasks. (NIH R01AR055648)

29.3 LEE, Eric Myung-Jae*; NGUYEN, Kristy; MEDERIOS, Daniel; MCCAULEY, David; University of Oklahoma, Norman, University of Colorado, Boulder; *ericmlee@ou.edu*
Expression of amphioxus and lamprey SoxE genes in zebrafish reveals ancient neural crest-specific roles in vertebrate evolution
SoxE genes include a group of transcription factors (Sox8, Sox9, and Sox10) that are among key regulators of neural crest cell (NCC) development. The functional redundancy among SoxE paralogs and orthologs suggests that a function of the ancestral SoxE gene was likely in NCC regulation. Here, we investigate the inter-specific functional redundancy of SoxE genes among species that occupy critical phylogenetic positions. Using a heterospecific expression approach, we show that amphioxus and lamprey SoxE genes can induce phenotypic rescue of NCC derivatives when expressed in zebrafish mutant backgrounds. Our results suggest that the amphioxus SoxE gene can drive chondrogenesis, melanogenesis, and neurogenesis when expressed in jellyfish ($Sox9a^{-/-}$) and colourless ($Sox10^{-/-}$) mutants. Lamprey SoxE1 can induce cartilage condensations while SoxE2 and SoxE3, the lamprey ortholog of Sox9, have no effect on chondrogenesis. Surprisingly, expression of SoxE2 results in rescue of melanogenesis and neurogenesis in zebrafish *cls* mutants despite being highly divergent from gnathostome Sox10. Our data suggest that the chondrogenic, neurogenic, and melanogenic roles of gnathostome SoxE genes originated in the ancestral SoxE prior to gene duplication, and that these functions were subsequently retained by Sox8, Sox9, and Sox10 in gnathostomes. Agnathan SoxE genes appear to possess similar functions to zebrafish Sox9a and Sox10 despite a lack of phylogenetic signal through 400 million years of independent evolution. Most notably, lamprey SoxE2 appears to be functionally similar to zebrafish Sox10. Our results have implications for understanding the independent evolution of SoxE genes among jawed and jawless vertebrates, and they demonstrate that phylogenetic signal is not necessarily a reliable predictor of functional homology.

27.4 LEE, Carol Eunmi*; KIERGAARD, Michael; CHARMANTIER, Guy; POSAVI, Marijan; University of Wisconsin, Madison, UW-Madison, UniversitÃ© Montpellier, France; *carollee@wisc.edu*
Evolution of ionic regulation following invasions into freshwater habitats
Marine to freshwater transitions constitute formidable physiological barriers for most animal taxa. However, the estuarine copepod *Eurytemora affinis* has invaded freshwater habitats multiple times independently in the past century. We examined activity and expression of ion transport enzymes V-type H^+ ATPase and Na^+,K^+ ATPase and also hemolymph osmolality for saline and fresh population pairs under common-garden salinities (0, 5, 15 PSU). We found parallel evolutionary shifts across multiple independent invasions. Relative to saline populations, freshwater populations showed evolutionary increases in V-ATPase activity in fresh water (0 PSU) and declines at higher salinity (15 PSU). In contrast, freshwater populations displayed declines in Na,K-ATPase activity across salinities. Results were consistent with expression differences observed in underlying genes. Most notably, ancestral saline populations selected for freshwater tolerance in the lab (12 gen) recapitulated the adaptive shifts in V-ATPase activity observed in natural populations. Hemolymph osmolality increased at low salinity in freshwater populations relative to their saline ancestors. Moreover, the same evolutionary shifts occurred in two independently-derived freshwater populations. Such increases in hemolymph osmolality are consistent with increases in ion uptake found in freshwater populations at low salinity. V-ATPase localization and activity have been hypothesized to be critical for the invasions of fresh water and of land, but evolution of this enzyme during habitat shifts had not been demonstrated. Our findings are consistent with evolution of increased physiological regulation accompanying transitions into stressful environments.

S8-1.2 LEICHTY, A. R.; PFENNIG, D. W.*; JONES, C. R.; PFENNIG, K. S.; University of Pennsylvania, University of North Carolina, Chapel Hill; *dpfennig@unc.edu*
Relaxed selection on rates of molecular evolution: consequence or cause of phenotypic plasticity?
Phenotypic plasticity––the capacity of a single genotype to produce different phenotypes in response to varying environmental conditions—is ubiquitous. Yet, its contribution to evolutionary innovation and diversification remains controversial. Theory suggests that plasticity might foster evolution when genes involved in the production of alternative, environmentally induced phenotypes experience relaxed selection in non-inducing environments and thereby accumulate greater variation. Indeed, genes that are differentially expressed between environmentally induced phenotypes (morph-biased genes) typically accumulate variation more rapidly than genes that are not differentially expressed between phenotypes (unbiased genes). However, rather than arising as a consequence of plasticity, enhanced evolutionary rates of morph-biased genes might be associated with some other variable that is a precondition for plasticity's evolution. To test these ideas, we characterized morph-biased and unbiased genes in two frog species with environmentally induced alternative phenotypes. We also characterized their orthologs in four species lacking such plasticity. Contrary to expectation, morph-biased genes did not evolve any faster in species with plasticity than in species without plasticity. Indeed, in all six species, biased genes evolved faster than unbiased genes. Moreover, morph-biased genes exhibited higher levels of expression variance than unbiased genes in all species. Thus, morph-biased genes are apparently under more relaxed genetic constraint than unbiased genes, which might explain why they were co-opted to become morph-biased genes.

27.5 LENZ, P.H.*; UNAL, E.; HASSETT, R.P.; SMITH, C.M.; BATTA LONA, P.; BUCKLIN, A.; CHRISTIE, A.E.; TOWLE, D.W.; University of Hawaii at Manoa, University of Connecticut, Ohio University, Mount Desert Island Biological Laboratory; *petra@pbrc.hawaii.edu*
Physiological ecology of zooplankton: differential expression in Calanus finmarchicus
Life histories in temperate habitats are highly cyclical, and include changes in physiology in response to seasonal or other environmental cues. With documented changes in global distribution of pelagic organisms, it has become important to understand their physiology and ability to adapt to environmental change. Here, we report on the development and application of molecular tools to investigate the physiological ecology of *Calanus finmarchicus*, a highly abundant North Atlantic calanoid copepod. Publicly available ESTs for *C. finmarchicus* were clustered into contigs and annotated using *Blast2GO* software. From these contigs, 1000 transcripts representing a range of biological processes were selected for inclusion in a species-specific microarray. Comparisons were made between pre-adult individuals collected during early summer (June) and fall (October) from the Gulf of Maine. Comparisons focused on determining physiological differences between morphotypes (lipid-rich vs. lipid-poor), season (June vs. October) and depth (< 100 m vs. > 100 m depth). The largest expression differences were observed between individuals from the shallow vs. deep collection during October. A one-week experimental incubations at high (5000 algal cells ml^{-1}) and low (500 algal cells ml^{-1}) yielded moderate changes in expression (maximum 2-fold differences). These results suggest that expression studies could be a useful tool for studies on the physiological ecology of marine zooplankton. Further studies will be needed to interpret expression results within the context of organism-environment interactions.

S4-2.1 LEVIN, Lisa A.*; BECKER, Bonnie J.; CARSON, Hank S.; COOK, Geoff S.; DIBACCO, Claudio; FODRIE, F. Joel; LOPE-DUARTE, Paola C.; Scripps Institution of Oceanography, Univ. of Washington, Tacoma, Univ. of Hawaii, Hilo, McGill University, Bedford Inst. of Oceanography, UNC Chapel Hill, Rutgers Univ.; *llevin@ucsd.edu*

What Controls Connectivity? A Place-based, Multi-species Approach

The exchange of individuals among habitat patches (connectivity) has broad relevance for the conservation and management of marine metapopulations. Elemental fingerprinting-based research conducted over the past 12 years along the coastline and bays of southern California measured connectivity patterns for one native and two invasive mussels, an oyster, brachyuran crab, and two fishes. The studies spanned different years and seasons but overlapped considerably in space, allowing comparisons of dispersal patterns across species, and the relative importance of location, circulation, and intra-and interannual variability. We explored directional transport, transport distances, sources/sinks, self-recruitment, bay-ocean exchange, and their implications for management. Linked connectivity-demographic analyses conducted for four species allowed us to evaluate the contributions of realized connectivity to metapopulation dynamics. Common trends across species included greater isolation of back-bay populations, front bay-ocean exchange, high retention in northern open coast and bay locations, average along-shore dispersal distances of 20-40 km and seasonal changes in dispersal direction that mirrored along-shore circulation patterns. Connectivity was rarely the most influential driver of metapopulation dynamics, but influenced the importance of other vital rates and was required for persistence. Some locations served consistently as larval sources or nurseries, and reproductive timing guided directional transport. Thus local management with an adaptive component may be effective along this coast. Regional, multi-species assessments of larval exchange could move us closer to ecosystem-based management.

62.3 LEVIN, Eran*; YOM-TOV, Yoram; HEFETZ , Abraham; KRONFELD-SCHOR, Noga; Tel-Aviv University, Department of Zoology; *levinere@post.tau.ac.il*

Pre-hibernation saturated fat rich diet in the subtropical mouse-tailed bat (Rhinopoma microphyllum) with relation to hypothalamic NPY and AgRP expression

Prior to hibernation, mammals accumulate large amounts of fat in their bodies. The saturation of fatty acids (FA) in both white adipose tissue (WAT) and membrane phospholipids of mammals often reflect their diet composition. In temperate mammalian species, hibernation is improved by increasing the levels of poly-unsaturated fatty acids (PUFA) in their body fat by alternating to a PUFA rich diet. In this field study we found that the greater mouse-tailed bat accumulates large amounts of fat at the end of summer by switching to a fat-rich diet (queen carpenter ants, Camponotus felah). PUFA are almost absent in this diet, which instead contains a high fraction of saturated fatty acids and mono-unsaturated fatty acids . We found similar low levels of PUFA in mouse-tailed bats' WAT, but not in their heart total lipids. The expression of two appetite stimulating (orexigenic) hypothalamic neuropeptides, AgRP and NPY, increased in parallel to the shift in diet and fat-gain of the mouse-tailed bats. We hypothesize that the increased expression level of these neuropeptides may be triggered by photoperiod and contribute to the diet shift and weight gain. This is the only known example of specific pre-hibernation diet in bats, and constitutes the most saturated fatty acid composition ever documented in a mammal. We suggest that this composition is an adaptation for hibernation at the relatively high ambient temperature (around 20°C), that we recorded in mouse-tailed bat hibernaculas.

21.2 LEVY, O.*; DAYAN, T.; PORTER, W. P.; KRONFELD-SCHOR, N.; Tel Aviv University, University of Wisconsin, Madison; *levyofi@gmail.com*

Biophysical modeling of foraging behavior: climate change may limit foraging

The effect of climate change on activity patterns of animals and thus on the structure of ecological communities is almost unstudied. We studied field foraging behavior of diurnal rocky desert golden spiny mice (*Acomys russatus*), and developed a two-stage statistical model to describe how biotic and abiotic conditions affect this behavior. In the first stage of foraging the mouse decides whether to forage in a certain microhabitat, and in the second stage, after it has entered a microhabitat, it decides how long to stay in it. A biophysical model, Niche Mapper™ ,suggests that spiny mouse foraging behavior is constrained by energy expenditure (EE) and evaporative water loss (EWL): (1) the chances of foraging decrease as EE increases and (2) during summer ambient temperatures (T_a) increased to a range where mice needed to evaporate water to prevent hyperthermia. Foraging behavior at both stages of foraging declined sharply when T_a was higher than 41°C during summer in the non-shaded, between-boulder (BB), microhabitat, and the predicted EWL rate increased to 0.2 [mg H_2O/s*gram]. Under RegCM future climate scenarios for 2100, maximum T_a in the study area will increase by 5.2°C and 3.6°C in A2 and B2 scenarios respectively; our statistical model shows a reduction in the number of hours suitable for foraging in the BB microhabitat from 10 hours under current conditions to 7 and 9 hours in A2 and B2 scenarios, respectively. Consequently, mice may be forced to concentrate their summer foraging in the more sheltered microhabitats, where vipers pose a predation risk in summer. Moreover, mice can be expected to shift their activity towards morning and evening. This reduction in the spatial and temporal niche may increase intraspecific competition.

14.4 LEWIS, Zachary*; KERNEY, Ryan; DORANTES, Jorge; HANKEN, James; Museum of Comparative Zoology and Dept. of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA, United States, Biology Department, Dalhousie University, Halifax, NS, Canada; *zlewis@oeb.harvard.edu*

Pulmonary Surfactant Proteins are Expressed in Lungless Salamanders

Although lungs have been crucial to the remarkable adaptive radiation of tetrapods, they evolved well before tetrapods emerged onto land. Over the course of evolution, certain amphibians have dispensed with pulmonary respiration altogether, relying instead on cutaneous gas exchange through the skin and the lining of the mouth. Although lung loss was long thought to be restricted to salamanders, recent work has demonstrated lung loss in all three modern orders of amphibians--Anura, Caudata, and Gymnophiona. Yet, it remains unclear why or how lung loss occurs. We have discovered that lungless salamanders (family Plethodontidae) complete early stages of lung morphogenesis and begin to develop lung primordia. Lung rudiments are only transiently present and soon regress, resulting in lung loss. The morphological lung rudiment likely represents retention of the ancestral lunged state. In addition to recapitulation of lung morphogenesis in plethodontid salamanders there is conservation of lung developmental genetic pathways. We report the expression of lung-specific surfactant protein C (SP-C) in plethodontids and examine the expression patterns of surfactant proteins B, C, and D. Expression of surfactant proteins offers compelling evidence that lung developmental genetic pathways are conserved in lungless salamanders, despite absence of functional adult lungs for over 100 million years. This work was supported by a grant from the William F. Milton Fund, Harvard University (JH), by an NSF Graduate Research Fellowship (ZL), and by the American Association of Anatomists (RK).

3.10 LEWIS, JM*; KLEIN, G; WALSH, PJ; CURRIE, S; Georgia Southern University, Statesboro, GA, Mount Allison University, Sackville, NB, University of Ottawa, Ottawa, ON; *jmlewis@georgiasouthern.edu*

Thermal stress induces a change in age class composition but not cell death in the circulating red blood cells of rainbow trout (Oncorhynchus mykiss)

Freshwater fish, such as the rainbow trout, are commonly exposed to temperature fluctuations in their aquatic environment. Exposure to increased temperatures places fish under respiratory stress and increases the susceptibility for protein misfolding and degradation that could eventually lead to cell death. Previous work by our group has shown genes associated with the cellular stress response, apoptosis and hematopoiesis to be up-regulated in the red blood cells (RBCs) of rainbow trout post thermal stress. These results suggest a tightly regulated interaction between cell repair and cell death is occurring post heat stress. Additionally, the triggering of hematopoiesis (specifically synthesis of RBCs) is likely an attempt to increase blood-oxygen carrying capacity in the fish. To further this work, changes in age class composition and markers of apoptosis in circulating RBCs were tracked within individual trout during exposure to and recovery from acute thermal stress. RBCs did now show any indication of apoptosis or necrosis post heat stress, however significant increases numbers of early, juvenile and dividing RBCs in were observed. These results suggest the induction of molecular chaperones provides sufficient protection against thermal stress in the RBC, subsequently preventing the initiation of the cell death cascade. Trout also appear to be shifting the composition of the circulating RBCs towards a younger cohort through release of stored cells from the spleen and increasing the maturation rate of early RBCs.

17.2 LEYS, SP*; YAHEL, G; REIDENBACH, M; TUNNICLIFFE, V; SHAVIT, U; REISWIG, HM; University of Alberta, Ruppin Academic Centre, University of Virginia, University of Victoria, Israel Institute of Technology; *sleys@ualberta.ca*

The sponge pump: the role of current induced flow in the design of the sponge body plan

Sponges are suspension feeders known to actively filter a volume of water equivalent to many times their body volume of water per hour, using flagellated collar-cells (choanocytes). Flow through sponges is thought to be enhanced by ambient current which induces a pressure gradient across the sponge wall. Studies of sponge filtration have estimated the energetic cost of pumping to be < 1 % of its total metabolism implying there is little adaptive value to reducing the cost of pumping by using "passive" flow. We quantified the pumping activity and respiration of the glass sponge Aphrocallistes vastus in situ at a 150 m deep reef and in a flow flume; we also modeled the glass sponge filtration system from measurements of the aquiferous system. Excurrent flow from the sponge osculum measured in situ and in the flume were positively correlated ($r>0.75$) with the ambient current velocity. During short bursts of high ambient current the sponges filtered two-thirds of the total volume of water they processed daily. Our model indicates that the head loss (due to resistance) across the sponge collar filter is 10 times higher than previously estimated across the demosponge collar. The difference is due to the resistance created by a fine protein mesh that lines the collar, which demosponges also have, but which was not included in previous measurements. These pumping rates give a conservative energetic expenditure of ~60 mJ (L pumped)-1, at least 25% of the total in situ respiration. We suggest that due to the high cost of pumping, current induced flow is highly beneficial for tall, thin walled sponges living in high flow environments. Our results call for a new look at the cost of biological pumping and its evolutionary role, especially in sponges.

11.3 LI, L.*; ORTIZ, C.; Massachusetts Institute of Technology, Cambridge; *lingli@mit.edu*

A Multiscale Structural Design of a Natural Transparent Armor: Placuna placenta

A number of species of mollusks possess transparent highly mineralized exoskeletons which combine optical and mechanical functionalities that originate from their intricate and hierarchical structures. In this study, the structure of the highly translucent shell from the mollusk *Placuna placenta* (Linnaeus 1758) was investigated from nanometer to millimetre length scales using a variety of high resolution experimental techniques. Electron microscopy showed that the entire *P. placenta* shell (~0.5 mm) has a single primary foliated layer (further stratified with ~1750 individual layers), which is made up of an organic-inorganic nanocomposite (98.93 wt% calcite and 1.07 wt% organic, as measured by thermogravimetric analysis). Each individual foliated layer is composed of fundamental building blocks which are elongated diamond-shaped plates with a characteristic length (141.8 ± 43.4 μm), width (5.54 ± 1.36 μm) and tip angle (10.45 ± 2.95°). Two salient microstructural features of the surface of the individual layers in the foliated structure were observed: 1) micro-ridges (maximum height: 67.0 ± 37.2 nm; inclination angles: 1.4 ± 0.4 and 2.6 ± 0.5°) and 2) nanoasperities (maximum dimension and height: 54.8 ± 17.9 nm and 4.2 ± 2.5 nm), as measured by tapping mode atomic force microscopy. Both electron backscattered diffraction analysis and selected area electron diffraction show that the calcite c-axis was tilted (24.44±6.81°) towards to the end of the diamond-shaped building block plates and the misorientation between adjacent crystalline grains was 13.52 ± 6.63°. The multiscale structural characteristics and the crystallographic arrangement features of this natural nanocomposite contribute to its unique transparent optical behaviour by lowering the scattering and absorption.

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Sponsorship required for permanent residency in sediment

The importance of biotic associations in the evolution of marine taxa is implicitly understood. However, relative to terrestrial systems, meaningful hypotheses and tests of specific mechanisms are underdeveloped. The marine bivalve superfamily Galeommatoidea represents an ideal system to address this deficit: it is a megadiverse clade and embodies a clear lifestyle dichotomy in that members are either free-living or have obligatory commensal associations with invertebrate hosts. I have performed a meta-analysis to determine if this lifestyle dichotomy is correlated with specific ecologies. Galeommatoidea has significant diversity in the two primary benthic habitats: soft- and hard-bottoms. Known free-living species are restricted to hard-bottom habitats, typically hidden within crevices of rocks/coral heads/encrusting epifauna. In contrast, commensalism is almost exclusively associated with infaunal sediment habitats. Preliminary gene trees show that evolutionary transitions from hard-bottom to sediment occur through the formation of a biotic association with a burrowing infaunal host. The details of the biotic association vary among taxa: it may involve direct attachment to the host, or else clustering around its tube/burrow, but all commensals locate within the oxygenated envelope produced by their host's bioirrigation. Sediment-dwelling bivalves are exposed to intense predation pressure that drops markedly with depth of burial. Commensal galeommatoideans attain depth refuges many times their body lengths, independent of siphonal investment, by virtue of their host's bioirrigation. The formation of commensal associations with infaunal bioirrigators may well be a prerequisite for the colonization of sediments by Galeommatoidea as well as a key factor in their exceptionally high diversity.

58.6 LI, Chen*; GOLDMAN, Daniel I.; Georgia Tech; *chen.li@gatech.edu*

Towards a terramechanics for legged locomotion on granular media

During locomotion on sand, animals and robot models interact with granular substrates to generate thrust and lift. While resistance forces on simple shapes like discs and plates during intrusion along vertical or horizontal trajectories are well studied, no general model yet exists to predict resistance forces for intrusion along complex trajectories during footsteps. Recently a granular resistive force theory (RFT) was used to model forces on an intruder moving in the horizontal plane at a fixed depth, e.g. a sand-swimming lizard. The RFT divides the intruder into small elements each generating forces that are assumed independent. Summation of the element forces predicts net thrust and drag. To begin to create a terramechanics for legged locomotion on granular media, we extend the RFT to intrusion in the sagittal plane. We measure the lift and drag on a small plate (3.8 x 2.5 x 0.6 cm^3) moving in granular media (1 mm diameter poppy seeds, 0.3 mm and 3 mm glass particles) of controlled compaction as a function of depth, angle of attack, and direction of motion. Both lift and drag increase with depth and depend sensitively on angle of attack and direction of motion at given depth. Lift, but not drag, is an order of magnitude larger for intrusion into than out of the media due to symmetry breaking by gravity. For a model c-shaped limb rotating about a fixed axle, integration of plate forces captures the net lift and thrust measured in experiments. The RFT predicts that reversal of the c-shaped limb results in a smaller maximal lift with significant negative lift (suction) during the late phase of rotation, which is confirmed by experiments. In accord with difference in lift, on poppy seeds a small bio-inspired legged robot (15 cm, 80 g) walks 50% faster at any frequency with c-shaped limbs than with reversed c-shaped limbs.

58.5 LIAO, James C.*; TAGUCHI, Masashige; Whitney Lab, Univ. of Florida, Gainesville; *jliao@whitney.ufl.edu*

Exploring the parameter space for Kármán gaiting: kinematics across speed and size

Very little is known about how swimming fish relate to turbulence. We measured the body kinematics of 12.1 ± 0.4 cm (mean ± standard error) rainbow trout (*Oncorhynchus mykiss*) Kármán gaiting in a vortex street behind a 5 cm D-section cylinder (n=6 fish). We increased the flow velocity from 2.5 -11 body lengths per second ($L\ s^{-1}$) and found that tailbeat frequency shows a u-shaped curve. Lateral body amplitudes and body wavelength exhibited a reverse u-shaped curve, plateauing at the highest flows. Head angle remained relatively constant until the highest flow velocities. Maximum body curvature was the only variable that increased in a linear fashion with speed, while its position on the body was the only variable that did not show a pattern across speed. Body wavelength and its propagation down the trunk increases with swimming speed, but wavelength decreases at the highest speed. We next ran the same experiment with fish of different body lengths (8.5-18.1 cm, n= 5 fish). At the highest speeds, smaller fish had a lower tailbeat frequency than larger fish, whereas at slow speeds tailbeat frequency was similar for all fish. Lateral body amplitudes, once normalized to body size, were similar across fish sizes. The exception was for the center of mass, which heaved substantially less for a larger fish. Larger fish had a longer body wavelength than smaller fish. Smaller fish had a larger maximum body curvature, the location of which moved rostrally with increasing swimming velocity, but more slowly than compared to larger fish. Smaller fish also possessed larger maximum head angles. Our results reveal new patterns in Kármán gait kinematics that shed light on how flow speed and body length can facilitate or constrain vortex capture.

92.2 LIBBY, T*; MOORE, TY; CHANG-SIU, E; LI, D; JUSUFI, J; COHEN, D; FULL, RJ; Univ. of California, Berkeley; *tlibby@berkeley.edu*

Tail Assisted Pitch Control in a Lizard, Robot, and Dinosaur

Rapid limb or tail movements produce reaction torques that can induce body rotations. Such motions have been observed in several mammalian taxa, implicated in stabilizing walking and branch balancing, and have enabled aerial righting in lizards. By contrast, the effect of tail loss on lizard running performance is unclear. We contend that application of a control theoretic framework could advance our general understanding of inertial appendage use in locomotion. To investigate the control of body attitude in the sagittal plane by a tail, we video recorded lizards (*Agama agama*) leaping toward a vertical surface by first vaulting onto an obstacle with variable traction to induce a large range of perturbations in body angular momentum. To examine a known controlled tail response, we built a lizard-sized robot with an active tail that used sensory feedback to stabilize pitch as it drove off a ramp. We found that lizards swing their tail upward or downward in a measured manner, as in the robot, to redirect angular momentum from their bodies to their tails, stabilizing body attitude. To compare diverse tails, we used a dynamic model to calculate tail-effectiveness, the amount of tailless body rotation a tail could stabilize per degree tail stroke. We used the model to evaluate the hypothesis that small theropods used their tail as a dynamic stabilizer during rapid or irregular movements, We found that *Velociraptor mongoliensis* may have possessed a more effective tail than the Agamas. Leaping lizards show that inertial control of body attitude can advance our understanding of appendage evolution and provide biological inspiration for the next generation of highly maneuverable search-and-rescue robots.

88.2 LIEBL, A.L*; GARRINGER, A.R.; WILEY, D.D; SIERRA, A.S.; MARTIN, L.B.; Univ. of S. Florida, Tampa, FL; *aliebl@mail.usf.edu*

Variation in the Glucocorticoid Stress Response and Behavior along a Gradient of Invasive House Sparrows (Passer domesticus)

Many invasive species show extensive phenotypic variation among populations of different ages. With the short time in which invasions typically occur, genetic evolution is an unlikely explanation for these differences, particularly in recently introduced populations. Behavioral plasticity, which can be mediated by stress hormones (e.g. glucocorticoids; GCs), is a more likely driver of colonization success in many species. In fact, behaviors such as exploration, innovation, and neophobia have been correlated with invasion success. Few direct tests of behavioral plasticity have been conducted in a species undergoing range expansion, though. Here, we predicted populations at an invasion front would be most exploratory and innovative, and least neophobic. To mediate these changes, we expected a damped GC response to restraint at the invasion front and increased capacity for GC regulation. To test this, we caught house sparrows (*Passer domesticus*) from 8 cities in Kenya, the site of one of the most recent introductions of this species. House sparrows arrived in each city at different times, creating a gradient of established (60 yrs) to recently introduced (>5 yrs) populations. We measured behavioral variation by exposing individuals from each population to six behavioral tests. Additionally, we measured GC regulation by measuring baseline and restraint induced GCs as well as GC receptor density in the hippocampus. Contradictory to our hypothesis, individuals from established populations released more GCs in response to restraint. Receptor density and behavior analysis are still ongoing. The results of this study contribute to studies of invasion behavior as well as coping styles generally.

79.2 LIEDTKE, A.M.*; MOORE, S.; WITTE, T.; SPENCE, A.J.; The Royal Veterinary College, UoL; *aliedtke@rvc.ac.uk*

How do animals with limited distal limb musculature use sensory feedback during locomotion?

Sense organs in the muscles, joints and cutaneous tissue provide vital feedback for the control of locomotion. Digital sensory feedback is known to be important for maintaining limb posture and body support in the face of environmental perturbations. Horses provide a unique model in which we can temporarily remove sensory feedback from the distal limb, without affecting its ability to walk and trot. This can give insight into how the nervous system tunes locomotion and the aetiology of both veterinary and human diseases. We predict that animals with limited distal limb musculature, in this case the thoroughbred horse (*Equus ferus caballus*), will use sensory feed back to control limb touchdown position rather than axial leg actuation to control their locomotion and maintain postural stability. We hypothesise that kinematic parameters associated with limb touchdown position will show greater variation in the absence of sensory feedback. To test this, we measured the kinematics of horses with reduced levels of digital sensation. Optical motion capture was used to collect kinematic data from horses walking and trotting on a treadmill before and after an abaxial sesamoid nerve block was administered to remove digital sensation. Interestingly, preliminary results from three horses show that a lack of sensory input results in *less* variability in duty factor for the initially blocked forelimb (linear mixed model; n=3, P< 0.001) for both a trot and a walk. The findings suggest that sensory feedback continuously monitors and adjusts foot placement.

S5-1.3 LILLYWHITE, HB*; BRISCHOUX, F; SHEEHY III, CM; PFALLER, JB; Univ. of Florida, Gainesville, Univ. of Texas at Arlington; *hblill@ufl.edu*

Dehydration and Freshwater Drinking Requirements of Marine Snakes

Osmoregulation is a key problem for vertebrates that have secondarily invaded marine environments. Here we report new data for dehydration and drinking behaviors of Yellow-bellied sea snakes, *Pelamis platurus*. This species is pelagic, ranges throughout the Indo-Pacific, and is arguably the most marine-adapted of sea snake species. Dehydrated snakes refused to drink seawater (SW), but drank freshwater (FW) to restore water balance. The mean dehydration threshold before drinking was 18.8 ± 1.0 % loss of body mass, roughly twice that of previously studied *Laticauda* spp. of sea snakes, which are partly terrestrial. A fraction of dehydrated *Pelamis* drank brackish water ≤ 50% SW, whereas dehydrated *Laticauda* drink only water ≤ 30% SW. Compared with *Laticauda* spp., *Pelamis* dehydrate more quickly when exposed to air but maintain low rates of water loss in SW. From 0 to 40% of snakes collected from the Guanacaste coast of Costa Rica drank FW when provided with the opportunity immediately following capture during both dry (Dec–May) and wet (June–Nov) season sampling. The percentage of snakes drinking FW correlated with time since heavy rainfall and inversely with body condition index. Hematocrit values varied from 30-56% (mean = 38 ± 0.9 %), further suggesting that snakes are dehydrated at sea. Thus, *Pelamis* dehydrate in their pelagic environment where they must depend on brackish or FW lenses formed by precipitation. This marine species appears to tolerate chronic dehydration and exhibits evolutionary reduction of FW drinking response. Rainfall and salinity may influence the distribution of marine snakes that are variably adapted to life in the salty sea.
Supported by NSF IOS–0926802 to HBL.

42.1 LIN, H*; ROS, I/G; BIEWENER, A/A; Harvard University; *huaiti.lin@gmail.com*

A bird's eye view of path planning: Is there a simple rule for flying in a cluttered environment?

For a bird, flying through cluttered environments is challenging due to the complexity of 3D obstacles and high speed of flight. A variety of navigation strategies have been shown on the scale of migration and homing behaviors. However, relatively little is known about how birds negotiate nearby obstacles when flying in a cluttered environment. To address this question we tracked pigeons (*C. livea*) flying through a vertical pole forest in which the obstacle distribution can be manipulated between trials. Interestingly, pigeons did not adjust their flight path until ~1.5m before the forest. Once in the forest, the average flight speed dropped from ~6m/s to ~3.5m/s and the wing-beat frequency increased from ~7Hz to ~8.8Hz. Head saccades were rare during these flights, indicating that the overall optical flow might be more important than frontal vision in guiding maneuvers. Furthermore pigeons aimed for large openings in the forest only when these paths were visible in the angular sense. This observation suggests that pigeons' depth perception may be insufficient to reconstruct an 'obstacle map'. Instead, pigeons might rely on angular positions of the obstacles and optical flow for close range path planning. Combining the flight trajectories and obstacle pole positions, we recreated the pigeon's visual field during flight. The obstacle poles can be represented as looming vertical bars across the bird's visual field. We constructed a simple navigation model that steers a pigeon toward the largest frontal opening and tested different range estimating strategies (e.g. looming cues) given a specific set of experimental visual inputs. Such a simple navigation model explains a large number of pigeons' flight trajectories through the cluttered environment. The results could provide insight for controlling high-speed unmanned aerial vehicles with simple visual feedback.

108.3 LINDNER, K.K.*; HARING, J.S.; RUBALCAVA, J.; NGUYEN, T.; GREENLEE, K.J.; North Dakota State University, North Dakota State University , Northern Arizona University , University of Maryland; *kimberly.lindner@my.ndsu.edu*

The Role of Matrix Metalloproteinases in Immunity in the Caterpillar, Manduca sexta

Insect immunity can be classified as humoral, such as the production of anti-microbial peptides, or cell-mediated. Cell-mediated immunity includes encapsulation, nodule formation, and phagocytosis. Because matrix metalloproteinase (MMP) mRNA is expressed in *Drosophila* hemocytes, we hypothesized that MMPs play a role in immunity. MMPs are a family of endoproteinases, with many roles across species, including immunological and developmental processes. However, the exact role of MMPs in immunity is still uncertain. To further understand the role of MMPs in cellular immunity, we used flow cytometry to assess phagocytosis by hemocytes, phase contrast microscopy to analyze hemocyte spreading, an anti-microbial assay to determine hemolymph cytotoxicity, and qPCR to determine MMP mRNA expression in the hemocytes and fat body 6 and 24 hours post *E. coli* infection. MMP mRNA expression was significantly up-regulated both 6 and 24 hours post-infection in both hemocytes and fat body, indicating a role of MMPs in both cell-mediated and humoral immunity. In addition, MMP protein expression was detected on hemocytes using immunohistochemistry. However, MMP inhibition did not affect hemolymph cytotoxicity or hemocyte phagocytosis and spreading. These data suggest that MMPs may be more involved in humoral immunity.

20.2 LIU, J*; KARASOV, WH; University of Wisconsin-Madison; Taiwan Endemic Species Research Institute, University of Wisconsin-Madison; *jliu22@wisc.edu*

Energetics and use of torpor during summer in a subtropical bat, the Formosan leaf-nosed bat Hipposideros terasensis

Sex differences in patterns of torpor during the breeding season have been reported in a number of temperate bats. Less attention, however, has been paid to patterns of torpor use between the sexes in warmer subtropical areas. The 60-g subtropical Formosan leaf-nosed bat, *Hipposideros terasensis* (Hipposideridae), has been shown that it enters hibernation in winter and males and reproductive females use separate roosts in summer. The objective of this study was to test the hypothesis that male and reproductive female *H. terasensis* use different patterns of torpor during summer. Result on free-ranging telemetered bats showed that, despite a relatively warm roost temperature, both male and reproductive female *H. terasensis* employed torpor during summer. Reproductive females, however, used torpor less frequently and for shorter duration than males. In the laboratory, we used respirometry to measure metabolic rate of bats. The results showed that *H. terasensis* has a below-average basal metabolic rate (BMR) for bats. There was no significant difference in BMR or body temperature within the thermal neutral zone between males and non-reproductive females and between females in different reproductive conditions. Using our data and a time-energy model, we predicted that a 74.3 g male *H. terasensis* can reduce metabolism 8.6 KJ (approximately 5%, or 0.22 g fat) per day by lowering body temperature during the rest phase. Because we found that body mass of free-ranging male *H. terasensis* substantially increased in summer. We suggest that male *H. terasensis* might reallocate energy saved during daily torpor to accumulate body fat in preparation for high energetically demanding period of mating in August.

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Activity of Mauthner cells and their serial homologues during alternative startles in larval zebrafish

Fishes perform a range of escape responses to threatening stimuli. Many species perform C-starts, characterized by a C-shaped body bend during stage 1, the initial turn away from the point of attack. Some species, such as northern pike and muskellunge, can also perform S-starts, where the stage 1 body bend takes on an S shape. We have previously shown that larval zebrafish also perform both C- and S-starts, the latter more likely triggered by a stimulus from the caudal end. Studies have shown that a set of hindbrain neurons, a pair of Mauthner (M-) cells and their serial homologues MiD2cm and MiD3cm, play roles in generating C-starts; however, the neural circuitry responsible for the S-start is as yet unknown. Ablation experiments point to the M-cell and its homologues as likely candidate neurons for driving the S-start, thus we aimed to investigate the Mauthner array's involvement in this alternative startle behavior. We used electrical tail stimulation to elicit startles and recorded from peripheral motor axons to identify and classify startle types. We performed whole-cell patch recordings from M-cells ipsi- or contralateral to the stimulus during startles and found bilateral firing during S-starts, while only the ipsilateral M-cell fired during C-starts as had been shown in previous studies. We also recorded from the Mauthner homologues and performed spinal cord transection experiments to explore their contributions to startle neural control more broadly. The S-start may provide a valuable comparative startle model to the C-start for understanding the organization of simple neural circuits. The interaction and overlap of C- and S-start neural control systems provides opportunities to understand coordination and control of the startle behavioral repertoire more broadly.

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When settlement doesn't settle it: the pitfalls of still-water larval assays

For many marine sessile invertebrates, the swimming larva is the sole motile phase in the organism's life cycle. Much research has been focused on the larva's ability to select an optimal substratum for settlement, using a variety of physical and chemical cues that are attributed to specific substrata. Various chemical cues have been shown to induce settlement, the attachment of the larva to the substratum, and sometimes metamorphosis, at a higher rate than in controls. However these results may not indicate an adaptive response to the extracts, instead representing an artifactual result of perfusing larvae with high concentrations of a bioactive metabolite that they may never encounter at similar concentrations in nature. We observed that the larvae of the Caribbean Orange Icing Sponge, *Mycale laevis*, settled rapidly in response to the presence of freshly cut pieces of the sponge *Amphimedon compressa* in still-water assays. Because *A. compressa* is chemically defended from fish predation, we tested the hypothesis that the palatable *M. laevis* preferentially settles on *A. compressa* for associational defense. However, when the experiment was repeated with pieces of *A. compressa* that had healed before assays, the larvae of *M. laevis* did not settle. Sponge 'juice' squeezed from *A. compressa* induced faster settlement and metamorphosis of the larvae compared to controls, but at higher concentrations, the settled larvae died within 48 hours of exposure to the 'juice', and never developed to the 'flattened' stage seen in the controls. Rather than inducing normal settlement, secondary metabolites from *A. compressa* trigger metamorphic changes in larvae of *M. laevis* that are probably unrelated to any natural response

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Navigating the Atlantic Ocean with Geomagnetic Markers: An Inherited Magnetic Map in Hatchling Loggerhead Sea Turtles

Young loggerhead sea turtles (Caretta caretta) from eastern Florida undertake a transoceanic migration in which they gradually circle the north Atlantic Ocean before returning to the North American coast. Hatchlings begin the migration with a 'magnetic map' in which regional magnetic fields function as navigational markers and elicit changes in swimming direction at crucial locations along the migratory route. Orientation responses are elicited by at least eight different magnetic fields that exist at widely separated geographic areas. The direction of swimming elicited by each field appears to be suitable for helping turtles remain within the warm waters of the North Atlantic subtropical gyre and advance along the migratory pathway. The results demonstrate that the magnetic map of young loggerhead turtles is remarkably complex and flexible. Turtles can derive both longitudinal and latitudinal information from the Earth's field, and responses appear suitable for helping turtles exploit favorable ocean currents for migratory transport in at least some oceanic areas. The magnetic map also appears to be inherited, inasmuch as regional magnetic fields elicit orientation responses in turtles that have never migrated or even been in the ocean. These findings imply that hatchling turtles from different populations in different parts of the world are likely to have magnetic navigational responses uniquely suited for the migratory routes that each group follows. Thus, from a conservation perspective, turtles from different populations are probably not interchangeable.

9.3 LOPES, P.C.*; ADELMAN, J.S.; CHAN, H.; DEMATHIEU, S.L.; BENTLEY, G.E.; Univ. of California, Berkeley and GABBA, Univ. of Porto, Virgina Tech, Univ. of California, Berkeley, Univ. of California, Berkeley; *pclopes@berkeley.edu*
Potential trade-off between recovery from infection and current reproductive opportunity: social effects on sickness behavior
Sickness behavior refers to a collection of symptoms, including weakness, lethargy and decreased appetite, exhibited by an animal over the course of an infection. While sickness behavior may increase the chances for survival by reallocating metabolic resources to fight infection, it may also decrease chances for other adaptive opportunities, such as mating. Therefore, it may be of adaptive value for animals to modulate their sickness behavior according to their environment. We examined the extent to which birds exhibit sickness behavior based on their social context. In the first experiment, we tested whether male zebra finches (*Taeniopygia guttata*), when maintained either in groups or in isolation, would alter sickness behavior. We injected the birds with a non-pathogenic bacterial component (lipopolysaccharide, LPS). While birds kept in a group showed no overt behavioral signs of infection, isolated birds significantly reduced activity after an LPS injection. Critically, LPS birds in both social settings exhibited similar physiological immune responses. These data suggest masking of sickness behavior in the presence of conspecifics. In the second experiment, we tested specifically whether the presence of a novel female suppressed sickness behavior in male finches. Activity was decreased in isolated birds injected with LPS. When presented with a novel female, both LPS and control males became highly active and courted females to an equal degree. Our results suggest that male zebra finches prioritize the opportunity for current reproductive investment over allowing recovery from infection.

117.2 LOPEZ-MARTINEZ, G*; HAHN, D.A.; University of Florida; *gc.lopez@ufl.edu*
Anoxia boosts post-irradiation longevity and mating success in a lekking fly
Oxidative stress can be triggered by an array of environmental stressors and increases in oxidative stress can mediate sexual selection and impact mating success. One such stressor is gamma irradiation which in insects is used as part of a control tactic known as the sterile insect technique (SIT). Irradiated organisms suffer stiff performance costs, such as reduced flight ability, mating competence/success, and longevity compared to their non-irradiated counterparts. Using the Caribbean fruit fly, Anastrepha suspensa, we hypothesized that a one hour anoxia treatment prior to irradiation, as well as, performing irradiation in an oxygen-free environment, improves post-irradiation performance in part due to an elevation in antioxidants. This enhancement in antioxidant defenses has been shown to lead to a reduction in post-irradiation oxidative stress and damage, and performance improvements in adult emergence and flight ability. We previously found that anoxia leads to an increase in antioxidants accompanied by a reduction in oxidative damage. Here we present evidence that this antioxidant boost also leads to improved mating success at both the time of sexual maturation (10 days) but also four weeks after the irradiation/sterilization event. Males irradiated in anoxia had higher mating success than those irradiated in oxygen at both time points. In addition, the protective role of anoxia increased male longevity by several weeks. Thus our data reinforces the idea that a boost in antioxidant defenses prior to irradiation effectively lowers irradiation damage and improves post-irradiation male sexual performance. Other mild stressors, such as temperature manipulations, may also lead to increases in antioxidants enzyme and future investigations will be geared toward that end.

96.4 LOVE, Oliver/P*; BOURGEON, Sophie; MADLIGER, Christine; SEMENIUK, Christina/AD; WILLIAMS, Tony/D; University of Windsor, Norwegian Institute for Nature Research , University of Calgary, Simon Fraser University; *olove@uwindsor.ca*
Glucocorticoids, workload and fitness: the role of environmental context, plasticity and repeatability
There is growing debate as to whether (and if so how) baseline glucocorticoids (GCs) are linked to variation in organismal fitness (e.g., the "CORT-fitness hypothesis"). Baseline GCs show all the potential hallmarks of an adaptive trait: large intra-specific (individual) variation, an apparent genetic (heritable) component, and trait repeatability when measured under optimal or captive conditions. However, we lack basic information about the adaptive potential of baseline GCs, and paradigms such as the CORT-fitness hypothesis have not been tested within an environmental or individual quality context via experimental manipulations. We will discuss results of an experimental manipulation of environmental context during reproduction in a free-living bird designed to examine two key components of the CORT-fitness paradigm: i) the repeatability of baseline GCs across two within-year reproductive events, and ii) whether single point measures of GCs or plasticity in GCs during reproduction better predict fitness. Using our results, we will emphasize that environmental context can significantly influence the repeatability of baseline GCs and therefore alter the relationship between both static measures and plasticity of GCs and fitness.

27.6 LOVETT, D.L. *; BRADLEY, L.M.; CHAN, B.C.; NAYAK, S.; OSBORN, J.M.; College of New Jersey, Ewing; *lovett@tcnj.edu*
A Four-Pronged Approach to Supporting At-Risk Students: Successes and Re-Evaluations of the PERSIST Scholars Program
The PERSIST (Program to Enhance Retention of Students in Science Trajectories) Scholars Program in Biology and Chemistry at TCNJ provides basic support services to at-risk students in a four-pronged approach: (1) careful recruitment and selection of scholars, (2) a bridge program to provide skills for success, (3) individual faculty and peer mentors, and (4) personal "Super Tutors." We discovered that openness to advice and strength of identification with long-term goals were better predictors of scholar success than were GPA, previous coursework, or quality of high school district. During the first year of the program, we found that workshops on note-taking, study skills, and time management during the first weeks of the semester were ineffective; instead, a bridge program on these topics prior to the start of classes was more effective. The selection interview and the bridge program are used to identify potential areas of concern (academic or personal); these concerns are addressed through careful assignment of mentors and tutors and through sharing of critical information with the faculty mentor. Finally, the use of Super Tutors (students trained to tutor all 2-3 math/science courses being taken by a scholar) have allowed each scholar the flexibility to customize their tutoring needs each week. The scholars, expectedly, valued the flexibility; but unexpectedly, the close personal relationship that developed between the scholar and the Super Tutor was cited as one of the most important factors contributing to the scholar's success and retention. Our discoveries have changed how we mentor our students in general, and we have observed a halo effect among students not in the PERSIST program. Supported by NSF DUE-0807107.

116.3 LUKEN, Alissa N.*; ESPINOZA, Robert E.; California State University, Northridge; *alissa.luken.842@my.csun.edu*
Temperature-Dependent Sprint Performance of Nocturnal and Diurnal Geckos: Does Dollo's Law Apply to Physiological Traits?
One of the most intriguing and rare phenomena in evolutionary biology is the occurrence of evolutionary reversals because of the presumed difficulty of re-evolving "lost" traits (AKA: Dollo's law). Most of the world's 1200+ gecko species are nocturnal and active at body temperatures that are suboptimal for performance. Yet, geckos descended from ancestrally diurnal lizards, which are generally active at temperatures near their thermal optimum. Several gecko lineages have independently reversed to diurnality, possibly to take advantage of activity temperatures closer to their optimum for performance. We tested whether these reversals to diurnality are associated with a return to performance levels of typical diurnal lizards or whether their long history of nocturnality has compromised gecko performance. We hypothesized that diurnality in geckos would be associated with higher sprint performance at warmer temperatures (as for typical diurnal lizards) and a decrease in performance at lower temperatures compared to closely related nocturnal geckos. Following Dollo's law, we predicted that the maximum performance of diurnal geckos would not approach values of typical diurnal lizards. We used a comprehensive phylogeny of geckos to identify the nocturnal sister taxa of secondarily diurnal geckos. 17 gecko species were sprinted at five ecologically relevant temperatures and maximum sprint performance was determined for each temperature. Sprints analyzed to date (three nocturnal:diurnal species pairs), show no difference in temperature-dependent sprint performance between the nocturnal and diurnal species. This may indicate that thermal physiology is evolutionarily conserved in geckos; however, data from additional species are needed to determine whether this pattern is widespread.

111.1 LYNCH, Kathleen S.*; RAMSEY, Mary E; CUMMINGS, Molly E; University of Texas at Austin; *lynchks@mail.utexas.edu*
Understanding the mate choice brain in two related poecillid fish with divergent mating systems
Female mate choice is a social behavior that exhibits considerable intra- and inter-specific variation. Identifying and understanding genes underlying female mate preference provides insight into the evolution of preference behavior. Here, we compare mate preference behavior in two related poeciliid fishes with contrasting behavioral phenotypes and relate these behaviors to gene profiles in the brain. We examine three previously identified mate preference candidate genes: neuroserpin (NS), neuroligin-3 (NLG-3), and N-12 methyl-D-aspartate receptor (NMDA-R). Results reveal that one poeciliid fish, the Northern swordtail (Xiphophorus nigrensis), exhibits robust mate preference as compared to Western mosquitofish (Gambusia affinis), which utilizes a coercive mating system. Female swordtails display no significant difference in association time between male- and female-exposure trials whereas female mosquitofish spend significantly less time associating with males relative to females. Furthermore, the preference strength for large males is significantly lower in female mosquitofish relative to swordtails. Whole brain gene expression patterns reveal that NS and NLG-3 are positively associated with mate preference behavior in female swordtails. In mosquitofish females, the expression of these genes is lowered when females express biases towards males, yet are elevated in association with total motor activity patterns under asocial conditions, suggesting that the presence of males in mosquitofish species may inhibit expression of these genes. Both gene expression and female behavioral responses to males displays opposing patterns between these species, indicating that these genes may potentially act as a substrate for the evolution of mate preference behavior.

115.4 MABRY, Karen *; BLUMSTEIN, Daniel ; VAN VUREN, Dirk; SHELLEY, Erin; New Mexico State University, University of California, Los Angeles, University of California, Davis; *kmabry@nmsu.edu*
The evolutionary relationship between social mating system and sex-biased dispersal in mammals
In vertebrate animals, natal dispersal is often sex-biased (one sex disperses farther, or more frequently, than the other). Birds are often socially monogamous and have female-biased dispersal, while mammals are typically socially polygynous and have male-biased dispersal. A hypothesized evolutionary relationship between social mating system and sex-biased dispersal in vertebrates is widely accepted, but has never been subjected to a phylogenetic analysis. To elucidate the evolutionary relationship between mating system and dispersal in mammals, we applied modern comparative methods to a phylogenetic tree of 52 species for which both social mating system and degree of sex-biased dispersal are known. Our results indicate that the most likely path from the ancestral state of non-monogamy and male-biased dispersal to the derived state of monogamy and female-biased dispersal is a change in social mating system followed by a change in the direction of sex-bias in dispersal. However, our analyses also suggest that the relationship between these two traits is more complex than previously thought.

59.2 MACESIC, L.J.*; GILLIS, G.B.; Mount Holyoke College, South Hadley, MA; *lmacesic@mtholyoke.edu*
Pre-landing muscle tuning in the forearm and shoulder of Bufo marinus
In contrast to a typical frog, which often lands on its belly after a hop, the cane toad (*Bufo marinus*) is exemplary at landing. Toads use their forelimbs to balance the body for extended periods after impact as the hindlimbs are rocked back into contact with the ground. Recent investigations of antagonistic muscles acting at the elbow demonstrated that both the timing and intensity of pre-landing electromyographic (EMG) activity are tuned to hop distance. Longer hops lead to more intense pre-landing EMG activity, and in elbow extensors, the onset of activity occurs at a nearly fixed interval before landing, regardless of the length of the hop. In this study, we report results from antagonistic muscles acting at the wrist and shoulder joints to test whether pre-landing recruitment patterns of muscles acting more proximally and more distally to the elbow also change in response to hop distance. Data from wrist flexors (palmaris longus and flexor carpi ulnaris) show similar patterns of tuning with distance in both pre-landing activation timing and intensity. Likewise, antagonistic wrist extensors (extensor digitorum communis longus and palmaris carpi radialis) also exhibit tuned pre-landing activity patterns. Data from a suite of deltoideus muscles suggest that their role in bracing the forelimbs for landing may be minimal when compared to their role in positioning the forelimbs for landing during the aerial phase of the hop. This study demonstrates the importance of forearm muscles in stabilizing and controlling whole body movements of the toad during landing and provides a model system for understanding motor control strategies for controlled deceleration more generally.

74.1 MACMIILLAN, Heath A.*; WILLIAMS, Caroline M.; STAPLES, James F.; SINCLAIR, Brent J.; University of Western Ontario; *hmacmil2@uwo.ca*

After the cold: the reestablishment of osmotic balance and neuromuscular function during chill-coma recovery in a cricket (Gryllus pennsylvanicus)

When exposed to low temperatures most insects enter a state of chill-coma, where impaired nerve and muscle signal transmission renders movement impossible. This loss of neuromuscular function and the chilling-induced injuries that follow are associated with flux of ions and water from the hemolymph to the gut lumen during low temperature exposure. Although it is used regularly as a means of quantifying cold-tolerance in insects, little is known about the processes underlying chill-coma recovery. Using the fall field cricket (*Gryllus pennsylvanicus*), we characterized the return to osmotic homeostasis following prolonged (24 hour) chill-coma using atomic absorption spectrometry to quantify Na^+, K^+, Mg^{2+} and Ca^{2+} content of muscle, hemolymph and the three gut segments. Crickets recovering from chill-coma rapidly established ion concentrations in the hemolymph sufficient to re-polarize muscle membranes and permit coordinated leg movement, although hemolymph volume and total ion content did not return to normal for a further 2 hours. Using open-flow respirometry, we confirmed that an overshoot in the rate of resting CO_2 release (a measure of metabolic rate) during chill-coma recovery corresponds with the mobilization of ions and water back out of the gut in order to regain initial hemolymph volume. Thus, chill-coma recovery appears to require a reversal of the physiological effects of cold exposure in insects, but re-establishment of homeostasis may take far longer than expected from studying the recovery of movement.

102.3 MADDIN, HC*; RUSSELL, AP; ANDERSON, JS; University of Calgary; *hcmaddin@ucalgary.ca*

Phylogenetic implications of the morphology of the braincase of caecilian amphibians (Gymnophiona)

Currently, phylogenetic analyses of characters drawn from the morphology of caecilians lack resolution, as well as complementarity, with results of phylogenetic analyses that employ molecular data. Stemming from the hypothesis that the braincase has the potential to yield phylogenetic information, the braincases and intimately associated stapedes of twenty-seven species (twenty-three genera) of extant caecilians, and one fossil stem-caecilian (*Eocaecilia micropodia*), were examined using images assembled via micro-computed tomography. Thirty-two new morphological characters pertaining to the braincase and stapes were identified and tested for congruence with previously recognized morphological character states. The results reveal that characters of the braincase and stapes resolve generic-level relationships in a way that is largely congruent with the results of molecular analyses. The results of a combined analysis of molecular and morphological data provide a framework for conducting ancestral character state reconstructions and permit the generation of a hypothesis relating to the plesiomorphic condition of the caecilian braincase, which bears relevance to ongoing discussions about lissamphibian phylogeny. The current analyses also resulted in the identification of 70 new synapomorphies for various clades of taxa, 24 of which appear to be unique for the taxa that possess them. Together these data demonstrate the utility of the application of characters of the braincase and stapes for resolving phylogenetic relationships in this group, and provide a framework for future evolutionary studies.

96.5 MADLIGER, C.L.*; LOVE, O.P.; University of Windsor, Ontario; *madlige@uwindsor.ca*

An Investigation of the CORT-Fitness Hypothesis: the Importance of Age and Environmental Quality

Across taxa, measures of baseline stress hormones (eg. corticosterone) are increasingly being utilized as conservation tools for the assessment of individual and/or population condition. To be an effective biomarker in this regard, baseline corticosterone (CORT) levels must show a predictable relationship with fitness. It has been assumed that high levels of baseline CORT are indicative of individuals with low relative fitness, a phenomenon recently coined the CORT-Fitness Hypothesis. However, empirical evidence for this relationship has been largely inconclusive, showing variation both within populations and within individuals across different life history stages. We investigated the relationship between baseline CORT levels and reproductive success in Tree Swallows (*Tachycineta bicolor*), across two reproductive stages and within the context of habitat quality. We find that individual CORT levels changed from the incubation stage to the nestling provisioning stage, with the direction of change being highly dependent on age. In addition, baseline CORT levels predict fitness only for experienced individuals (those in their second breeding season or later) in high quality habitats and only during the nestling provisioning stage. This is inconsistent with the CORT-Fitness Hypothesis; baseline CORT levels do not show a predictable relationship with reproductive success for all age classes and habitat types. Our results indicate that the relationship between baseline CORT and fitness is context-dependent. Therefore, more information on life history stage, age, and habitat metrics may be necessary to effectively apply stress hormones as relevant physiological indices for conservation.

113.4 MAIA, A.*; LAUDER, G.V.; WILGA, C.D.; University of Rhode Island, Harvard University; *amaia@my.uri.edu*

Hydrodynamic Function of Dorsal Fins in Sharks

Kinematic and electromyographic data from dorsal fins in sharks indicate that these structures are actively controlled during steady swimming. Here, we investigate how the two dorsal fins interact with the surrounding flow in spiny dogfish and bamboo sharks during steady swimming by means of particle image velocimetry (PIV). A horizontal laser sheet intersecting the dorsal fins was filmed from above with a high-speed camera (500 fps). Cross correlation analysis of consecutive images was used to calculate stroke averaged velocity and vorticity variables. Results reveal the presence of vorticity in the wake of all fins. In the wake of the first dorsal fin of spiny dogfish the flow is decelerated with strong lateral velocities in the opposite direction to the movement. The first dorsal fin is thus not contributing thrust but rather is stabilizing the shark. Accelerated flow was observed in the wake of both dorsal fins in bamboo sharks with some lateral losses. In addition in bamboo sharks, the fluid flow in the wake of the second dorsal fin had higher longitudinal velocities compared to the wake of the first dorsal fin. This may result from vortex interaction between the first and second dorsal fins through an additive effect. Fluid flow patterns in bamboo sharks indicate that both dorsal fins are adding m to the swimming shark. These results are consistent with previous studies on fin kinematics and muscle function that show different functions in shark dorsal fins depending on fin and species. Shark dorsal fins are capable of interacting with the flow and producing thrust in a manner similar to that of bony fishes, despite a relatively simpler musculoskeletal arrangement. In addition, this study refutes the long standing idea that dorsal fins in sharks are only used as stabilizers.

22.3 MAIE, Takashi*; SCHOENFUSS, Heiko H.; BLOB, Richard W.; Clemson Univ., St. Cloud State Univ.; *tmaie@clemson.edu*

Comparative functional capacity of adhesion and climbing among sicydiine gobiid fishes and related species

Sicydiine and related goby species are able to adhere to surfaces using a ventral sucker (fused pelvic fins). This sucker is used by juveniles of many amphidromous species as they scale waterfalls during upstream migration after embryonic development and oceanic dispersal. However, adults may still use pelvic suckers to resist flash floods, or to re-scale waterfalls if they are displaced. Adhesive performance of the pelvic sucker is expected to affect climbing ability and, thereby, impact in-stream distribution. We measured adhesive pressure and force across wide size ranges of species from Hawai'i, Dominica, and Japan including climbing and non-climbing species. Adhesion by suction is achieved via two different strategies: (1) small size and isometric (or negatively allometric) scaling of the sucker among sicydiines, vs (2) large size suckers with isometric to positively allometric growth among non-sicydiines. Because suction attachment force is proportional to the area of the sucker, the force of body mass that must be resisted might be expected to outpace adhesive capacity as fish grow. Thus, adult individuals might have decreased climbing capacity relative to juveniles. However, species using the first strategy (sicydiines) show greater adhesion, aiding their climbing capability throughout ontogeny. In contrast, species showing the second strategy are non-climbing or weakly climbing species in which adhesive ability may decrease with larger size. Moreover, among sicydiines examined, suction pressure and force are higher than expected if adhesion were strictly a function of sucker area. Adhesion by sicydiine pelvic suckers may be regulated by variation in pelvic musculoskeletal activity, complicating expectations based on sucker size. NSF IOS-0817794, 0817911.

66.9 MALISKA, M.E.*; PIERCE, T.; HAUSCH, P.; BROWN, C.T.; SWALLA, B.J.; Department of Biology, University of Washington, Department of Biology, Ripon College, Department of Computer Science and Engineering and the Department of Microbiology and Molecular Genetics, Michigan State University; *mem24@uw.edu*

Molgulid ascidians show an early heterochronic shift in the expression of genes critical for metamorphosis in other ascidians

Ascidian species (Tunicata: Ascidiacea) in the Molgulidae are found to have urodele, tailed, chordate larvae with notochord and muscle as well as closely related species with anural, tailless larvae that completely lack larval structures, including the sensory otolith and muscle and notochord in the tail. This loss of a tailed larva is likely to have happened at least four times evolutionarily and is tractable at the molecular level. To examine how this development has affected the expression of genes critical for tail and notochord resorption and metamorphosis in developing embryos, the transcriptomes of closely related tailed and tailless species, *Molgula oculata* and *M. occulta*, were sequenced throughout embryogenesis and counts were accumulated using an RNASEQ approach. Preliminary findings show that gene expression of several genes critical for metamorphosis, are heterochronically shifted in expression for both the tailed and tailless species when compared to other non-molgulid ascidian species. These results suggest that it will be critical to understand the similarities and differences of metamorphosis in the molgulid ascidians before further studies can be addressed into the evolution of taillessness.

103.5 MANDECKI, Joanna L.*; WESTNEAT, Mark W.; University of Chicago, Field Museum of Natural History; *jmandecki@uchicago.edu*

Coordination of oculomotor and locomotor systems in fishes

An animal's success in its environment ultimately depends on its behavior as a coordinated whole. Typically functional systems such as feeding, sensing, respiration, and locomotion are studied in isolation, and while such work is important for our basic understanding of organismal anatomy and function, studies that consider the integration of functional systems are now crucial to our understanding of animal behavior. Here we investigate the temporal synchrony of oculomotor and locomotor movements in labriform fishes, which generate propulsive forces by oscillating the pectoral fins. In a previous study we found that saccadic eye movements are preferentially timed to fin abduction during steady swimming in shiner perch (*Cymatogaster aggregata*). Using a flow tank and high-speed videography we survey the coupling of locomotor and oculomotor behaviors across surfperches (including fry), damselfishes, wrasses, and tubesnouts, which together span a diversity of fin kinematics and ecologies. Results suggest that the presence of coordinated oculomotor-locomotor behavior may be linked to planktivory. Preliminary results also indicate that this coordination system varies when the animal switches from steady swimming to maneuvering behavior. Exploring the coordination of fins, eyes, and feeding behavior will be important for understanding the biomechanics of planktivory. This material is based upon work supported by the National Science Foundation under Grant Nos. DGE-0903637 and DEB-0844745.

79.1 MARA, K.R.*; HSIEH, S.T.; Temple University; *kylemara@temple.edu*

Slip Perturbation Recovery in the Frilled Dragon, a Dynamically Stable Bipedal Runner

In nature animals often encounter unsteady or unpredictable surfaces and must traverse them while maintaining dynamic stability. Yet, most previous locomotor studies have focused on steady state, non-perturbed, locomotion. As a result, the effects of an unexpected perturbation on center of mass (COM) dynamics and subsequent recovery kinematics remain relatively poorly understood. The goal of this study was to describe locomotor kinematics during unperturbed bipedal locomotion, slip perturbation, and ensuing slip recovery in the frilled dragon (*Chlamydosaurus kingii*), a dynamically stable bipedal runner. We used a 3D auto tracking system (Motion Analysis Corp.) to identify body and limb kinematics in frilled dragons as they encountered, and recovered from, an unexpected slip perturbation. Our preliminary data indicate that in response to an unexpected slip perturbation frilled dragons modify their locomotor kinematics to minimize perturbations to the COM and maintain dynamic stability. During the stride in which the slip perturbation occurs, the unperturbed leg exhibits a shorter swing time, thereby decreasing the overall stride duration and increasing stride frequency. Consequently, the stride frequency is increased during the slip perturbation but returns to normal after one recovery stride. Furthermore, duty factor for the foot encountering the slip perturbation is lower (0.34 ± 0.02 SE) than the non-slip foot (0.46 ± 0.02) with both feet returning to expected (non-slip) duty factors (0.38 ± 0.02) within 1 recovery stride. Finally, we found that lower limb kinematics were remarkably similar between slip perturbation trials and steady state non-slip trials. Lower limb kinematics and COM dynamics during slip perturbation and slip recovery will also be discussed.

68.3 MARCROFT, TA*; VAN WASSENBERGH, S; DORNBURG, A; SANTINI, F; SLATER, GJ; MODLIN, J; NGUYEN, MTT; ALFARO, ME; Univ. of California, Los Angeles, Univ. of Antwerp, Belgium, Yale Univ., New Haven, CT, California State Univ., Channel Islands, Camarillo, CA; *tmarcroft@gmail.com*

Trade-offs and evolution of the boxfish carapace

Boxfish carapaces are hypothesized to function in both locomotion and in mechanical defense, but the relationship between carapace morphology and performance is poorly understood. To investigate whether trade-offs between these performance variables have influenced morphological diversity in boxfishes, we used a 3D laser scanner to construct models of 33 boxfish species. Spherical harmonics coefficients (SPHARM) from these models were used to quantify shape and the main axes of shape variation were extracted using a principle components analysis. To test whether shape influences carapace strength, we used a finite element analysis to simulate dorsoventral biting forces on 3D models selected to represent the morphological diversity of extant boxfishes. To assess the effect of shape on hydrodynamic properties, we used computational fluid dynamics to simulate flow around our models under various angles of attack. Previous tests revealed a significant positive correlation between morphology and performance variables, as well as a significant negative relationship between defense and several hydrodynamic properties, suggesting that a trade-off exists between these carapace functions. We have also assembled the largest molecular phylogeny to date containing 27 species based on 8 genes and used this as a framework to test whether this trade-off has influenced patterns of morphological evolution.

105.3 MARION, Z.H.*; HAY, M.E.; University of Tennessee, Knoxville, Georgia Institute of Technology; *zmarion@utk.edu*

Chemical defense of the eastern newt (Notophthalmus viridescens): variation in efficiency against different consumers and in different habitats

Amphibian secondary metabolites are well known chemically, but their ecological functions are poorly understoodeven for well-studied species. For example, the eastern newt (*Notophthalmus viridescens*) is a well known secreter of tetrodotoxin (TTX), with this compound hypothesized to facilitate this salamander's coexistence with a variety of aquatic consumers across the eastern United States. However, this assumption of chemical defense is primarily based on observational data with low replication. Therefore, we tested the hypothesis that *N. viridescens* is chemically defended against several co-occurring fishes, invertebrates, and amphibian generalist predators and that this defense confers high survivorship when newts are transplanted into both fish-containing and fishless habitats. We found that adult eastern newts were unpalatable to predatory fishes (*Micropterus salmoides*, *Lepomis macrochirus*) and a crayfish (*Procambarus clarkii*) but were readily consumed by bullfrogs (*Lithobates catesbeianus*). The eggs and neonate larvae were also unpalatable to fish (*L. macrochirus*). Despite predatory fishes rejecting eastern newts in laboratory assays, field experiments demonstrated that tethered newts suffered high rates of predation in fish-containing ponds. We suggest that this may be due to predation by amphibians (frogs) and reptiles (turtles) that co-occur with fishes rather than from fishes directly. Fishes can suppress invertebrate consumers that prey on bullfrog larvae, leading to higher bullfrog densities in fish containing ponds and thus considerable consumption of newts due to bullfrog tolerance of newt chemical defenses. Amphibian chemical defenses, and consumer responses to them, may be more complex and indirect than previously appreciated.

3.9 MARSHALL, Katie E*; SINCLAIR, Brent J; University of Western Ontario; *kmarsh32@uwo.ca*

Ecologically-relevant stresses hurt differently: the response of Eurosta solidaginis to repeated freeze-thaw cycles.

Repeated freeze-thaw cycles are common in temperate latitudes, and are predicted to change in frequency in future climates. The goldenrod gall fly *Eurosta solidaginis* overwinters through a broad geographical range as a freeze tolerant prepupa in goldenrod stems above the snow and experiences the full range of air temperatures, which causes repeated freeze-thaw events for this species in the field. Locally-collected flies were subjected to one of three experimental conditions: control (maintained at 0C), sustained freezing (a single 120h exposure to -20C), or repeated freezing (ten 12h exposures to -20C). We characterized both immediate as well as long-term effects of repeated freezing in this species to unravel some of the costs and benefits of repeated freezing. We found that responses to repeated freezing were consistently distinct from the sustained freeze exposure (although the total amount of time spent frozen was equal), and included a depressed freezing point, decreased survival, and increase in development time. We also found that neutral lipid pools in this species are characterized by a large accumulation of free fatty acid as well as the presence of a large quantity of an unknown lipid. Repeated freezing increased the quantity of this unknown lipid at the expense of free fatty acid and triacylglyceride. Taken together, these results indicate that the effects of repeated freezing are not predictable from a single freezing event, and that responses to repeated freeze-thaws are likely more relevant to field conditions.

104.4 MARTIN, Timothy/L.; SHIELDS, Vonnie/D.C.*; Towson University; *vshields@towson.edu*

The responses of taste receptor cells of gypsy moth larvae to various phytochemicals

Gypsy moth larvae, *Lymantria dispar* (L.), are highly polyphagous feeders. They possess taste sensory organs, the medial and lateral galeal styloconic sensilla, which play an important role in host-plant selection through the detection of phytochemicals, such as alkaloids. The styloconic sensilla each house four taste receptor cells, including a sugar, salt, deterrent, and inositol cell. Using a single cell electrophysiological tip-recording method, our aim was to characterize the temporal firing patterns and sensitivities of the receptor cells within each sensillum when exposed to a selected phytochemicals. Our results revealed that these cells responded to alkaloids, (i.e., strychnine, aristolochic acid, nicotine, and caffeine), sugars and sugar alcohols, (i.e., sucrose and inositol), and salt (i.e., potassium chloride). The deterrent cell exhibited a robust temporal firing pattern and displayed varying sensitivity to alkaloid and potassium chloride stimulation. We also examined the effects of mixture interactions on the responses of the deterrent-sensitive, inositol-sensitive, and sugar-sensitive cells. This study offers insights into the role of phytochemicals in the taste physiology of this larval insect. This study was supported by NIH grants (1R15DC007609-01 and 3R15DC0076409-0151) to V.D.S.

78.3 MARTIN, R.A.*; PFENNIG, D.W.; Univ. of North Carolina, Chapel Hill; *ryan_martin@ncsu.edu*

Ecological opportunity and competition predict widespread disruptive selection in the wild

Disruptive selection occurs in a population when two or more modal phenotypes have higher fitness than the intermediate phenotypes between them. Such selection has long been viewed as being important in maintaining and increasing variation within natural populations; in favoring the evolution of alternative phenotypes; and initiating speciation. Nevertheless, disruptive selection has traditionally received relatively little attention. As a consequence, few studies have looked for evidence of disruptive selection in natural populations and relatively little is known regarding its underlying causes, its prevalence in natural populations, or the ecological factors that may promote it. We address these issues in natural populations of Mexican spadefoot toad tadpoles (*Spea multiplicata*), which are highly variable in trophic morphology and resource use. First, using an experimental approach, we show that functional tradeoffs among different trophic phenotypes for their preferred resources allow for frequency dependent competition, and that this competition generates disruptive selection. Next, to evaluate the prevalence and predictability of disruptive selection, we surveyed 15 ephemeral ponds containing S. multiplicata. We found that disruptive selection was the predominant mode of quadratic selection acting on resource-use phenotypes in these ponds. Furthermore, disruptive selection was strongest in populations with high conspecific density and intermediate levels of ecological opportunity and phenotypic variation. Generally, these results suggest that disruptive selection can be common in natural populations and predictable in the presence of certain ecological conditions.

S9-1.4 MARTINDALE, Mark, Q.*; DUBUC, Tim; SIMMONS, Dave K.; Univ. Hawaii; *mqmartin@hawaii.edu*

The evolution of a hox code: evidence from a basal metazoan

Hox genes have played an important role in re-galvanizing a modern understanding of the role of development and body plan evolution. Comparative genomics have revealed an unexpected genomic complexity in basal metazoans, and 'tool kits' of homologous genes with deep evolutionary ancestry have been documented. When, and how, these genes become assembled into functional networks regulating body plan formation is a current focus of evolutionary developmental biologists. Among the more contentious issues in cnidarian evolutionary developmental biology is the role of Hox class homeodomain transcription factors on axial patterning. Many workers refuse to acknowledge the existence of Hox genes in cnidarians and fewer that they might be involved in axial patterning. We use mRNA overexpression and morpholino knockdown microinjection experiments in developing embryos in conjunction with qPCR and in situ hybridization of a variety of target genes to determine what, if any, role these gene have on axial patterning during the development of the anthozoan Nematostella vectensis. We studied posterior and anterior Hox genes and show that misexpression not only affects the development of expected domains of the target genes, but that these genes also affect the expression of each other, revealing the existence of a "hox code" initially described in bilaterians. While these observations are interpretable relative to their own expression domains, it is not clear if they provide deep insight in the evolution and expansion of Hox gene function in bilaterians.

S6-2.1 MARTYNIUK, CJ*; CHOWN , B; DOPERALSKI, NJ; FESWICK , A; KROLL, KJ; SPADE, DS; BARBER, DS; DENSLOW, ND; University of New Brunswick, University of Florida, University of Florida; *cmartyn@unb.ca*

PROTEOMICS AS A TOOL TO STUDY NEUROTOXICITY IN FISH

There are a significant number of environmental pollutants that are neurotoxic to aquatic organisms. Many herbicides and pesticides, for example, are designed to be neuroactive and antagonize synaptic neurotransmission in the central nervous system (CNS). Proteomics approaches can offer new insight into the mechanisms underlying neurotoxicity in fish and bioinformatics approaches can be utilized to characterize cell signaling cascades that involve proteins that are disrupted. Dieldrin is an organochlorine pesticide that acts by antagonizing the gamma-amino butyric acid (A) receptor in the CNS. This pesticide has been shown to be associated with increased risk to neurodegenerative diseases such as Parkinson's disease. Using LC MS/MS and the iTRAQ method, we quantified proteins in the hypothalamus of largemouth bass, an important ecological and economical species found throughout southern Florida, that are affected by dieldrin neurotoxicity. Altered proteins included enolase, apolipoprotein E, and microtubule-associated protein tau. These proteins are reported to be associated with neurodegeneration in the vertebrate CNS. The pesticide also physiologically increases GABA in the fish brain and affects genes involved in inflammation, DNA damage, and neurodegradation. These data provide possible mechanistic links between protein turnover and GABA dysfunction.

74.3 MARUNDE, M.R.*; LI, S.; HAND, S.C.; MENZE, M.A.; Dept. Biol. Sci., Eastern Illinois University, Charleston, IL, Dept. Biol. Sci., Louisiana State University, Baton Rouge, LA; *mmenze@eiu.edu*

Late Embryogenesis Abundant Protein Ameliorates Inhibition of Mitochondrial Respiration

Mechanisms that govern anhydrobiosis involve the accumulation of highly hydrophilic macromolecules, such as late embryogenesis abundant (LEA) proteins. Warner et al. (2009) reported group 1 LEA proteins in *Artemia franciscana* embryos, which were localized within the cytoplasm or the mitochondrion. We designed primers based on NCBI sequence ACX81198 to amplify cDNA from *A. franciscana*. Two variants encoding for proteins of 181 (LEA1.1) and 197 (LEA1.3) amino-acid lengths were cloned and expressed in *Drosophila melanogaster* cells (Kc167). Confocal microscopy revealed a construct composed of green fluorescence protein (GFP) and LEA1.3 accumulates in the mitochondria (LEA1.3-GFP), while LEA1.1-GFP was predominantly found in the cytoplasm. No significant difference in routine respiration was observed among Kc167 controls and cell lines that stably expressed LEA1.3, LEA1.3-GFP, or LEA1.1-GFP (n = 9). Routine respiration of intact Kc167 cells at 25 °C was 17.7 ± 1.3 pmol $O_2 \bullet s^{-1} \bullet 10^{-6}$ cells (n = 18, ±SD). Acute exposure to 500 mM NaCl reduces respiration in controls by 46 ± 4% (n = 6, ±SD) and expression of LEA1.3 did not ameliorate this inhibition. In presence of mixed substrates oxygen consumption of permeabilized control cells was 16.8 ± 2.8 pmol $O_2 \bullet s^{-1} \bullet 10^{-6}$ cells, and addition of 2 mM ADP increased oxygen flux by 1.7 ± 0.21-fold (n = 14, ±SD). Titrations of KCl up to 500 mM led to successive drops in oxygen flux. This inhibition was significantly ameliorated in Kc167-LEA1.3 cells. During desiccation intracellular ion concentrations will increase. Our results suggest that LEA1.3 exerts a protective influence on mitochondrial function (NSF-IOS-0920254, CFR-EIU-2010).

24.5 MARVI, H.*; COOK, J. P.; HU, D. L.; Georgia Institute of Technology; *hamid.marvi@gatech.edu*
Rectilinear locomotion of snakes and the design of Scalybot 2
Snakes use several modes of locomotion including slithering, sidewinding, concertina and rectilinear motion which is the least studied and understood. In rectilinear motion, snakes propel themselves by sending traveling waves of muscular contraction in the posterior direction, in a manner similar to earthworms. This mode of locomotion is especially useful for crawling within crevices, such as found along the trunks of trees. In this combined experimental and theoretical study, we filmed *Boa constrictor* snakes performing rectilinear locomotion on both horizontal and inclined surfaces. The body kinematics of the snake is parametrized according to the number, frequency, amplitude and phase of the traveling waves observed. We present a mathematical model of a snake as one-dimensional n-linked crawler, in which sliding friction is the dominant propulsive force. Using the measured kinematics and frictional properties of snakeskin, our model predicts 90% of the speed of the snake's center of mass. Our model demonstrates that rectilinear motion is highly sensitive to frictional anisotropy: a snake with isotropic friction and the observed kinematics can barely move, achieving only 4% of the measured speed. Our findings on the mechanisms of rectilinear motion have guided the design and construction of Scalybot 2, a two-link snake-like robot capable of forward and reverse motion as well as steering. Similar to snakes, our robot can enhance the climbing of slopes by motorized adjustment of the angle of attack of its ventral scales, which in turn controls its frictional anisotropy.

78.6 MATSON, K.D.*; MAUCK, R.A.; LYNN, S.E.; TIELEMAN, B.I.; University of Groningen, Kenyon College, The College of Wooster; *k.d.matson@rug.nl*
Island life and innate immunity: combining comparative and experimental approaches to better understand avian immune system evolution
Continents and isolated islands may present their avian residents with different disease-related selection pressures. Thus, these birds and their immune systems may follow different evolutionary trajectories. We compared continental and insular populations of Eastern bluebirds (*Sialia sialis*) to investigate how island life shapes immune function and, in turn, how immune function relates to growth and development. To do this, we integrated an experimental manipulation into the comparative framework. Instead of using an immune challenge, which is typically intended to induce responses and force tradeoffs among limited resources, we attempted an immune enhancement: chicks were supplemented with lysozyme throughout the nestling period. Lysozyme, an anti-inflammatory and anti-bacterial protein found in eggs and plasma, attacks cell-wall peptidoglycan and lyses bacteria. We hypothesized lysozyme supplementation would increase immune defense without increasing production costs. We predicted this treatment would minimize the adverse effects on growth of the low-grade and systemic inflammation caused by the antigenic milieu. Differences between locations in terms of treatment effects (i.e. a significant treatment by location interaction) would provide evidence for population-specific disease-related selection pressures. We collected and analyzed plasma samples, we recorded body and feather growth measurements, and we quantified chick feeding rates. Our preliminary results suggest that continental and insular bluebird populations differ and that lysozyme supplementation affects chick growth, but we found little evidence of treatment by location interactions.

69.5 MATTERSON, Kenan O*; GLEASON, Daniel F; University of Alabama at Birmingham, Georgia Southern University; *kenanm@uab.edu*
Microscale variation in light intensity and its effects on the growth of juveniles of the temperate coral, Oculina arbuscula>
Light intensity varies over small spatial scales (e.g. substrate angles) in marine communities and could affect photosynthetic efficiency and growth in juvenile corals. For example, on temperate hard bottom reefs of the South Atlantic Bight off Georgia, U.S.A we have found that light intensities on vertical rock surfaces are 74% lower than those that occur on horizontal surfaces. In this study, we conducted laboratory experiments to investigate the effects that these differences in light regimes may have on chlorophyll concentrations, zooxanthellae density and juvenile growth rates in the temperate scleractinian coral, *Oculina arbuscula*. The mean light intensity at approximately 18 meters in depth was quantified from multiple hard-bottomed reefs and replicated at three experimental angles (0, 45, 90). A feeding treatment consisting of *Artemia* nauplii was included to determine if juveniles could compensate for reduced light levels through increased heterotrophy. After 90 days, growth, chlorophyll and algal density were found to vary among treatment angles with significantly lower calcification rates, chlorophyll levels, and symbiont densities in juveniles oriented perpendicularly. The addition of heterotrophic food sources did not enhance growth significantly. Combined, these results suggest that *O. arbuscula* settling at substrate angles >45° may suffer reduced growth and be at a competitive disadvantage during a critical stage in their life-history.

29.2 MATUS, D.Q.*; YANG, M.; CHANG, E.; SHERWOOD, D.R.; Duke University; *david.matus@duke.edu*
Anchor cell invasion across the Nematoda: a highly conserved cell biological process required for establishing the uterine-vulval connection
The rhabditid nematode vulva is a well-studied evolutionary developmental model for understanding the mechanisms of organogenesis. In *Caenorhabditis elegans*, the induction of the epithelial vulval precursor cells (VPCs) requires signaling from a specialized somatic gonadal cell, the anchor cell (AC). Following induction the AC also plays a pivotal role in connecting the developing uterus to the vulva, by invading through the gonadal and vulval epithelial basement membranes (BMs) to initiate direct uterine-vulval contact. After the initial breach in the BMs, the AC is not required to expand the BM gap. Instead, as the VPCs invaginate, the BM breach is widened through BM sliding and is stabilized by the innermost secondary-fated VPC cell, vulD. To examine the degree of evolutionary conservation underlying AC invasion across the Nematoda, we have investigated AC invasion in seventeen species of rhabditid nematodes representing hundreds of millions of years of nematode evolution. Using Nomarski microscopy and laser ablation, we observed little morphological diversity in terms of the timing and positioning of AC invasion in relation to the underlying VPCs. Following invasion the boundary for the expanding hole appears stabilized over vulD in all species surveyed to date. Notably, vulD is unique within these species compared with other VPCs in that it undergoes one fewer division cycles and is post-mitotic at the time of BM sliding and gap positioning. This suggests that BM boundary positioning might require vulD to be post-mitotic. Despite the large degree of evolutionary change observed in vulval development across these species, we suggest that AC invasion and stabilization of the sliding BM are under strong evolutionary pressure to ensure a secure uterine-vulval connection.

85.3 MATZ, Mikhail V.; University of Texas at Austin; *matz@mail.utexas.edu*

Coral bleaching as an adaptive mechanism facilitating transmission of algal symbionts to the next generation of coral host.

High seawater temperatures cause corals to expel their endosymbiotic algae (zooxanthellae), resulting in "coral bleaching" that in severe cases may lead to coral death. The adaptive bleaching hypothesis (ABH) proposed by Buddemeier and Fautin (1993) suggested that corals bleach to make space for more adaptive exogenous zooxanthellae strains. However, numerous studies revealed that adult corals are unable to trade their symbionts for a new strain not originally present within the coral. Here, we explore an alternative possibility: that bleaching facilitates zooxanthellae transmission to the next generation of host. This inverted adaptive bleaching hypothesis (iABH) is based on three observations: (1) corals experience minor bleaching every summer, (2) zooxanthellae expelled during bleaching are viable, and (3) young aposymbiotic corals recruit to reefs at about the same time. Importantly, iABH predicts that evolution of the high bleaching resistance may be maladaptive from the zooxanthellae standpoint. To test the iABH premises, we let aposymbiotic Acropora millepora recruits to receive inflow from heated and unheated jars containing branches of three adult "donor" corals, containing different zooxanthellae clades, C1, C2, and D. The recruits successfully acquired the corresponding donor's zooxanthellae, which is the first evidence of transmission of expelled zooxanthellae to recruits. Contrarily to the original expectation, heat stress diminished the rate of transmission of both C1 and D zooxanthellae. However, clade C2 was appreciably transmitted only from the heat-stressed donor. We hypothesize that clade C2 conforms to the iABH by relying on temperature cues and bleaching physiology to achieve transmission, while clades C1 and D may be transmitted via continuous trickle out of the host.

47.1 MAUCK, R.A.*; HUNTINGTON, C.E.; DOHERTY, JR., P.F.; Kenyon College, Bowdoin College, Colorado State University; *mauckr@kenyon.edu*

Climate, weather, and a long-lived seabird: What can fifty years of data tell us?

We used a 50-year individual-based data set to investigate the effect of weather and climate variation on reproductive success and survival in a breeding colony of long-lived seabirds in the Bay of Fundy. We analyzed hatching success and adult survival as a function of weather and climate across multiple scales, from local weather at the breeding colony to changes in global mean temperature. All models included effects of between-individual variation, as well as within-individual changes in reproduction and survival with age. Local weather indices were based on long-term weather records at the breeding colony. Regional indices included composite weather data and sea surface temperature (SST) records from the Gulf of Maine and Georges Banks. Large-scale climate variation was characterized by the winter North Atlantic oscillation (WNAO) and global mean temperatures. The best models for both reproduction and survival included SST during the breeding season, however, reproduction and survival were inversely affected by sea surface temperatures; reproductive success increased with summer range SST, whereas adult survival decreased under these conditions. Other factors that significantly affected reproduction and survival were global mean temperature and precipitation at the colony. WNAO had some utility in characterizing variation in reproduction and survival, but could not replace the suite of more specific variables as a predictor of environmental effects on reproduction and survival in this population.

58.4 MAZOUCHOVA, Nicole*; GOLDMAN, Daniel; Georgia Institute of Technology; *nmazouch@gatech.edu*

Disturbed ground leads to failure in a sea turtle inspired robot

Animals like sea turtles that must locomote at the water-land interface use flippers for swimming in water and crawling on a sandy beach environment. To reveal locomotor principles of flipper-based interaction with granular media, we study the detailed mechanics behind the success and failure of a hatchling sea turtle-inspired robot (19 cm, 775 g) during quasi-static movement on a granular medium of poppy seeds. The device propels itself with a symmetric gait using two servo-motor driven limbs consisting of flat-plate flippers with passively flexible or rigid wrists. For a wide range of conditions a flexible flipper achieves a greater distance traveled per step than a rigid flipper. For the flexible flipper, at each step the limb penetrates vertically into the medium; once weight balances penetration force, the body lifts. The flipper remains in place, and as the limb retracts the robot is geometrically translated forward. During the step the belly remains lifted off the ground minimizing drag. In contrast, during rigid flipper locomotion, the penetration phase is similar, but the material begins to yield during retraction of the flipper as it slips through the material. Associated with the yielding, the body drops immediately during the step, and drag force increases. The rigid flipper creates a larger region of disturbed material than the flexible flipper. If subsequent steps interact with the previously disturbed ground, forward progress per step is decreased resulting in failure within a few steps. Measurements of intrusion force on a flat plate (3 cm wide) reveal that the penetration resistance (and thus lift) on a second intrusion decreases as the intrusion site approaches the site of first intrusion.

69.4 MAZZILLO MAYS, Maria*; KEMPF, Stephen C.; Auburn University; *mmazzillo@gmail.com*

Mucilage Variation and Ultrastructure Among Symbiodinium Strains

Symbiodinium are unicellular dinoflagellates that reside intracellularly in a variety of invertebrate hosts, including cnidarians. In this symbiosis, the endosymbiotic algae are enclosed in a symbiosome membrane (host and symbiont-derived) and donate photosynthetically fixed carbon to the host in exchange for nutrients. *Symbiodinium* is a diverse genus of 9 clades with multiple strains in each clade. The specificity of the association between symbiont and host varies with some relationships being highly specific and others of a general nature. The symbiont secretes mucilage that lies at the interface with the host and may be involved in recognition and specificity. Cultured *Symbiodinium* from a variety of clades were labeled with 2 antibodies to symbiont mucilage (PC3, developed to a clade B alga cultured from *Aiptasia pallida*; BF10, developed to a clade F alga cultured from *Briareum* sp.). The labeling was visualized with a fluorescent marker and examined with epiflorescence and confocal microscopes. PC3 antigen was found in cultured *Symbiodinium* from clades A and B but not clades C, D, and F. Within clades A and B there was variation in the amount of label present. BF10 antigen was more specific and only found in strains closely related to the strain the antibody was created against. These results indicate that the mucilage secretions do vary amongst *Symbiodinium* strains. Since they are present at the host-symbiont interface, these variations in mucilage composition could house the differences in molecular structure that are involved in specificity. Examining the ultrastructure of the mucilage is also important in understanding how host/symbiont specificity comes about. Identifying how host and symbiont establish these specific associations at the cellular/molecular level will give insight into how these symbioses function.

4.5 MCALISTER, J/S*; MORAN, A/L; Clemson University; *jmcalis@clemson.edu*
Maternal provisioning in echinoids: the role of egg constituents during pre-feeding larval development
Marine invertebrates with feeding larvae utilize maternally-provisioned material (protein, lipid, and carbohydrate) in the egg for morphogenesis and metabolism during early pre-feeding larval development. All eggs are not provisioned equally, however; there is tremendous variation among species, populations, and even individuals in egg size, composition, and energy. This variation suggests that differences in egg size, egg composition, and total egg energy may be associated with differences in the morphogenesis and metabolism of pre-feeding larvae. To determine the role of egg constituents during morphogenesis and early larval development, we investigated changes in biochemical composition, respiration rate, and morphology during pre-feeding larval development of echinoid 'geminate' species pairs from tropical America. Our data show that in geminate pairs, species from the low-productivity waters of the Western Atlantic (WA) that have larger eggs than their Eastern Pacific (EP) geminates also have eggs that are comparatively lipid-rich and protein-poor, suggesting that the large eggs of WA species are not simply scaled-up versions of the smaller EP eggs. We also reared larvae from WA and EP species of *Diadema*, *Echinometra*, and *Eucidaris*, without food, collected samples from successive developmental stages for biochemical analysis, and simultaneously measured O_2 consumption as an index of metabolic energy expenditures. We will use these data to assess the fate of maternally-provisioned egg constituents during larval growth to better understand how larval feeding environment and other selective factors affect the evolution of life histories.

71.8 MCCARTNEY, MA*; YUND, PO; Univ. of North Carolina, Wilmington, University of New England; *mccartneym@uncw.edu*
Transplants of juvenile mussels show that thermal tolerance, alone, is unlikely to set the Atlantic southern range boundary of the northern blue mussel, Mytilus trossulus,
Thermal tolerance limits and thermal optima for growth and reproduction undoubtedly play a large role in establishing marine biogeographic boundaries. However, range limits often occur where water masses carried by ocean currents meet, forming water flow and temperature discontinuities that interact in unknown ways to limit dispersal across range boundaries. The more northern blue mussel *Mytilus trossulus* overlaps with the more southern species, *M. edulis*, throughout the Canadian Maritimes. *Mytilus trossulus* reaches its Atlantic southern range limit at Machias Bay Maine, very near where the swift, southwesterly flowing Eastern Maine Coastal Current (EMCC) departs the coast. Our studies of hydrography and plankton larval samples indicate that, near the range boundary, limited mixing between the EMCC and inshore waters is associated with a decline in bivalve larval abundance, suggesting a role for dispersal limitation. To begin to address thermal limitation, we have performed transplants of tagged juveniles from *M. trossulus*-native source populations in Maine to cages located at increasing distances beyond the range boundary. Results from 3 seasons show a decline in *M. trossulus* survival relative to *M. edulis*, but this pattern does not appear until transplants are moved well southwest of the range boundary. Growth rates of surviving *M. trossulus* individuals, relative to those of its southern congener, are not affected by transplanting. These results suggest a role for temperature, but the scale over which it limits *M. trossulus* cannot fully account for the geographic position of this sharp range limit near the site of EMCC divergence.

101.5 MCCLAIN, Craig R.; National Evolutionary Synthesis Center; *cmcclain@nescent.org*
Increased Energy Promotes Size-Based Niche Availability in Marine Mollusks
Variation in chemical energy, i.e food, availability is posited to lead to variation in body size. However, examinations of the relationship are rare and primarily limited to amniotes and zooplankton. Moreover, the relationship between body size and chemical energy may be impacted by phylogenetic history, clade specific ecology, and heterogeneity of chemical energy in space and time. Considerable work remains to both document patterns in body size over gradients in food availability and understanding the processes potentially generating them. Here, I examine the functional relationship between body size and chemical energy availability over a broad assortment of marine mollusks varying in habitat and mobility. I demonstrate that chemical energy availability is likely driving body size patterns across habitats. I also find that lower food availability decreases size-based niche availability by setting hard constraints on maximum size and potentially on minimum size depending on clade-specific ecology. Conversely, higher food availability promotes greater niche availability and potentially promotes evolutionary innovation with regard to size. I posit based on these findings and previous work that increases in chemical energy are important to the diversification of Metazoans through size-mediated niche processes.

89.5 MCCORD, CHARLENE, L.; Univ. of Chicago; *cmccord@uchicago.edu*
Diversity of cranial morphology and jaw biomechanics in tetraodontiform fishes
The multiply subdivided adductor mandibulae muscles of tetraodontiform fishes provide an excellent model upon which to explore the biomechanical consequences of differential morphology. This work describes and compares the diversification of cranial shape, macro-architecture of the adductor mandibulae muscles, and basic jaw biomechanics of tetraodontiform fishes. A landmark protocol was developed to outline cranial shape and highlight functional elements of the skull for 150 representative fish specimens from six families within the order Tetraodontiformes. Homologous landmarks were located during dissections, photographed, digitized, and then assessed using standard Procrustes geometric morphometric analyses. Morphospace plots of phylogenetically independent contrasts reveal cranial shape-based clustering patterns that mirror family-level phylogenetic groupings. Each family falls out in a significantly different region of morphospace, with fishes from the family Tetraodontidae exhibiting the most divergent morphology overall. The primary axis of shape variation scales to differences in the position of the adductor mandibulae 1 subdivisions, the length of the cranium, and the size of the jaws. In order to elucidate some of the potential biomechanical consequences of the evident geometric diversity of tetraodontiform skulls, mechanical advantage of the jaws was calculated and the mass of each adductor mandibulae subdivision was measured. Intra-familial variation of adductor mandibulae muscle mass and mechanical advantage of the jaws is evident, but is negligible compared to inter-familial disparity. Fishes from the family Tetraodontidae demonstrate the most deviant scaled adductor mandibulae muscle masses and upper jaw mechanical advantage. These results suggest multiple origins of several different morphological and biomechanical strategies through the evolution of the Tetraodontiformes. Project funded by EAPSI Fellowship-1107759, NSF DEB-0844745 and NSF DGE-0903637.

84.4 MCCULLAGH, Gregory*; BISHOP, Cory; WYETH, Russell; St. Francis Xavier Univ.; *gregory.mccullagh@stfx.ca*

Odor-gated rheotaxis and sensory integration by the rhinophores during navigation in the nudibranch, Tritonia diomedea

Neuroethological studies of navigational behaviors have progressed in the mollusc, *Tritonia diomedea*, due to their easily observable behaviors, and accessible nervous system. *T. diomedea* navigates using odor plumes, crawling upstream towards prey and downstream to avoid upstream predators. The mechanism by which *T. diomedea* integrates odor and flow cues to create these behaviors is likely odor-gated rheotaxis, but a bilateral comparison of odors alone has not been ruled out. The rhinophores detect odors during navigation and the oral veil has been shown to detect flow direction in flow alone. However, within odor plumes, the rhinophores or the oral veil may detect flow stimuli. Our goals were to determine 1) whether *T. diomedea* uses a bilateral odor comparison between rhinophores and, 2) whether flow is detected by the rhinophores or the oral veil. Prey and predator odor plumes were generated in a non-recirculating flow tank and we tested navigation performance in animals with either unilateral rhinophore lesions, a bilateral denervation of their oral veil, or unilateral rhinophore lesions and a bilateral denervation of their oral veil. Our results show that in each case, experimental slugs orient similarly to control slugs, suggesting that within odor plumes, *T. diomedea* does not sample odor cues using a bilateral comparison across their rhinophores and the oral veil is not the principal flow detecting organ. This study is consistent with previous research suggesting that *T. diomedea* navigates using odor-gated rheotaxis and thus that the rhinophores may detect bulk flow direction as well as odors. Future studies will evaluate the cellular components of the peripheral nervous system within the rhinophores and further explore the functional relevance of *T. diomedeas'* oral veil during navigation.

38.1 MCCULLOUGH, E.*; WEINGARDEN, P.; EMLEN, D.; TOBALSKE, B.; University of Montana; *mccullough.e@gmail.com*

Elaborate weapons: the costs of producing and carrying horns in a giant rhinoceros beetle

The horns of giant rhinoceros beetles are among the largest sexually-selected traits observed in nature. Male ornaments and weapons are expected to be costly to produce and carry, yet empirical evidence for these costs remain equivocal. Remarkably, the costs of producing and carrying rhinoceros beetle horns are largely unexplored. Given the impressive size and elaborate shape of many beetle horns, we expected them to impose two primary costs: reduced locomotor performance and resource allocation tradeoffs. Surprisingly, the exaggerated horns of *Trypoxylus dichotomus* males do not appear to be particularly costly to carry. Even in the largest males, horns only increase body mass by 2%, and at the angles at which beetles typically fly, the horns represent a trivial increase in body drag. Furthermore, *T. dichotomus* horns do not appear to be particularly costly to produce. Males have larger wings and flight muscles than females, which suggests that they do not face resource allocation tradeoffs. We suspect that males may invest more in flight-related structures to compensate for the small reduction in flight performance imposed by horns. More importantly, our results suggest that even the exaggerated horns of giant rhinoceros beetles may not be as costly as they are expected to be.

4.4 MCDONALD, K.A.; Smithsonian Tropical Research Institute; *characterforming@gmail.com*

Ontogenetic evidence and performance consequences of re-acquisition of planktotrophy in the gastropod family Calyptraeidae

Phylogenetic hypotheses suggest that different lineages of calyptraeid gastropods have regained free-swimming, feeding larvae following loss of the ancestral type of planktotrophic development. This runs counter to expectations based in part on other invertebrate phylogenies that losses of complex larval types are irreversible. The potential to regain ancestral characters depends upon the preservation of the developmental-genetic programme that produces the structures, and also upon the ontogenetic and functional constraints that limit changes to the planktotrophic phenotype. The amount of change in ontogeny and performance that can be tolerated without loss of planktotrophic functions will influence the strength of barriers to re-acquisition of planktotrophy. Here I test the hypothesis that plankotrophic calyptraeids vary in ontogeny of swimming structures and in resulting larval performance. Species differ significantly in growth of prototrochal cilia, velum, and shell mass prior to hatching into the plankton, and in indices of swimming ability at time of hatching. Putative re-evolved planktotrophs show significantly higher mass and rates of mass increase than other planktotrophs, and are predicted to show substantially weaker swimming than all but one of the "primary" planktotrophs. The results support phylogenetic hypotheses of re-evolution of planktotrophy, and indicate possible ecological differences between primary and re-evolved planktotrophic veligers.

2.3 MCELROY, EJ*; ARCHAMBEAU , KL; MCBRAYER, LD; College of Charleston, Georgia Southern University; *mcelroye@cofc.edu*

The correlation between locomotor performance and hindlimb kinematics during burst locomotion in the Florida scrub lizard, Sceloporus woodi

We present data on the three-dimensional hindlimb kinematics during burst locomotion, and the relationship between burst locomotor kinematics and locomotor performance in a small terrestrial lizard (*Sceloporus woodi*). Considerable variation in hindlimb kinematics and performance was observed across the first three strides of burst locomotion. Stride one was defined by larger joint angular excursions at the knee and ankle; by stride three, the knee and ankle showed smaller joint angular excursions. The hip swept through similar arcs across all strides with most of the motion being due to femoral retraction and rotation. Metatarsophalangeal (MTP) kinematics exhibited smaller maximum angles on stride one compared to strides two and three. The significant correlations between angular kinematics and locomotor performance were different across the first three strides. For stride one, MTP kinematics predicted final maximum running speed; this correlation is likely explained by a correlation between stride one MTP kinematics and stride two acceleration performance. For stride three, several aspects of joint kinematics at each joint predicted maximum running speed. These findings suggest that studies of burst locomotion should perform analyses on a stride-by-stride basis and avoid combining data from different strides across the burst locomotor event. The kinematic-performance correlations observed in *S. woodi* were different from other species; suggesting a single unifying model across species may be elusive.

32.6 MCGEE, M.D.*; WAINWRIGHT, P.C.; Univ. of California, Davis; *mcgee.matthew@gmail.com*

Divergence in the functional morphology and feeding kinematics of threespine stickleback

Studies of adaptive radiation rarely examine divergence across functional systems. We examined functional morphological divergence between benthic and limnetic threespine stickleback from British Columbia. We measured eleven morphological variables from four functional feeding systems: Suction Index, the opercular four-bar linkage, and the components of the jaw opening lever and the jaw closing lever. These morphological variables were then used to calculate a functional index variable for each the four systems. Benthics exhibit a higher Suction Index and a higher mechanical advantage of jaw opening than limnetics. Limnetic fish exhibit a higher opercular four-bar kinematic transmission coefficient. This functional divergence was driven largely by two components of Suction Index, epaxial height and epaxial width, and the jaw opening inlever. We then performed a principal component analysis separately on the morphological and functional variables. The major source of both functional and morphological variation in the dataset was benthic-limnetic divergence. Benthics and limnetics show strong separation with little overlap in the morphological PCA and no overlap in the functional PCA. To better understand divergence in this system, we filmed benthic and limnetic fish at 500 Hz feeding on cladoceran prey, a resource consumed by both species in the wild. We digitally tracked eleven landmarks which were then used to derive 18 kinematic variables characterizing motion of the head, body and jaws. Benthics and limnetics exhibit divergence in several kinematic traits, with limnetics exhibiting faster ram speed during the strike. Overall, benthics appear to possess morphological and kinematic traits geared towards generating high suction pressures, while limnetics possess morphology and kinematics better adapted to the capture of evasive prey.

91.6 MCGOWAN, Craig; University of Idaho; *cpmcgowan@uidaho.edu*

Acceleration mechanics in Desert Kangaroo Rats (Dipodomys desertii)

Wallabies are known for their ability to decouple metabolic cost from hopping speed, largely due to elastic energy recovery from long, thin ankle extensor tendons. Smaller species of bipedal hoppers, such as kangaroo rats, have relatively thicker ankle extensor tendons and do not benefit from substantial elastic energy recovery. In a previous study of tammar wallabies, we showed that despite having thin tendons, the ankle joint was primarily responsible for modulating mechanical work during accelerations. However, the majority of the work was likely being transferred from more proximal muscles via biarticular muscles. Further, tammar wallabies changed limb posture such that ankle joint moment (and tendon stress) was independent of acceleration. The goal this study was to determine if kangaroo rats modulate joint level mechanical work for acceleration in a similar way as wallabies, or if relatively thinker ankle extensor tendons enable kangaroo rats to generate higher peak ankle moments or do more mechanical work with their ankle extensor muscles. We measured ground reaction forces and high speed video from eight desert kangaroo rats (*D. desertii*) over a range of hopping accelerations (-7.8 m/s to 10.1 m/s). We used an inverse dynamics analysis to calculate joint moments, power and work. In addition, we used a geometric model to estimate muscle work by the ankle extensor muscles. Consistent with tammar wallabies, our results showed that the ankle joint played the greatest role in modulating mechanical power. However, the geometrical model revealed that the ankle extensor muscles absorbed little mechanical energy in early stance, but generate a large amount of mechanical work in late stance, especially in large accelerations. These results suggest that despite exhibiting similar joint level mechanics during accelerations, the functional role of the ankle extensor muscles differs substantially between tammar wallabies and desert kangaroo rats.

20.3 MCGUIRE, LP*; JONASSON, KA; GUGLIELMO, CG; Univ. Western Ontario, London; *lmcguir5@uwo.ca*

Torpor-assisted migration in bats

Optimal migration theory predicts that migrating animals should seek to minimize some combination of energy, time, or mortality risk. These factors trade-off with each other; animals may spend longer refuelling, increasing energy intake at the expense of time or vice versa. For migratory birds, the trade-off between energy and time lies largely in energy expenditure during periods of stopover. Birds spend twice as much energy during stopover as in migratory flight, largely due to thermoregulatory costs. In a recent study, we found that migrating silver-haired bats (*Lasionycteris noctivagans*) made only 1-2 day stopovers at a site where similar sized birds stayed for one week or longer. We suggested that bats' ability to use daily torpor to minimize energy expenditure may allow the bats to forego extended refuelling stopovers and rather minimize time instead. Here I will present results of a follow-up study combining temperature sensitive radio-telemetry and respirometry at a range of local daytime temperatures. Free-living silver-haired bats regularly used torpor in response to declining ambient temperature. As daytime temperatures approached 27 – 30 ° C or warmer, bats remained normothermic. Below this threshold temperature all bats used torpor, regardless of age or sex. In many cases the bats entered a deep torpor for the entire day, re-warming to depart at sunset. Combining the daily temperature profiles of free-living bats and metabolic measurements from respirometry demonstrates that migrating bats incur very low daily energy costs. Thus bats are able to use a torpor-assisted migration strategy to minimize energetic costs during non-flight periods. Consequently the need for refuelling stopover is virtually eliminated and migrating bats are able to minimize time independent of energy minimization trade-offs.

S7-1.7 MCHENRY, MJ; Univ. of California, Irvine; *mmchenry@uci.edu*

On the speed of lever systems

The geometry of an animal's skeleton affects its ability to move quickly. Many fast-moving species possess joints with a higher displacement advantage (the ratio of output to input displacement) than their slow-moving relatives. It has therefore been suggested that a high displacement advantage endows a species with a superior capacity for rapid motion. However, this idea has rarely been tested. The aim of the present research was to evaluate how the geometry of an animal's skeleton affects their ability to move rapidly. We investigated the influence of geometry alone by mathematical modeling the lever mechanics of three different rapid lever systems: the locust leg, stomatopod raptorial appendage and frog jaw. As established by previous experimental studies, all three systems produce explosive motion with stored elastic energy. We examined how the maximum speed of this motion varies among simulations that were provided with an equal amount of stored elastic energy, but differed in displacement advantage. Assuming conservation of energy, the locust leg was found to kick at the same maximum speed, regardless of differences in the displacement advantage of its knee joint. In contrast, a higher displacement advantage in the stomatopod raptorial appendage acts to reduce maximum speed. This is because the long excursion created by a high displacement advantage causes a loss of kinetic energy through the generation of drag. In the frog jaw, energy is lost within the muscle on the input and of the lever. As a consequence, a large displacement advantage helps to minimize energetic losses and thereby act to enhance high-speed motion. Therefore, the energetics of an elastically-driven lever system mediates the relationship between the displacement advantage and speed of a lever system.

36.9 MCLEOD, L; CACCIATORE, C; LUPICA, N; LUTTON, BV*; Endicott College; *blutton@endicott.edu*

Novel insights into stem cell activity and angiogenesis from an elasmobranch, Leucoraja erinacea

In this study we introduce a unique model system that may provide novel insight into the complex bone marrow niche of mammals. Understanding the mechanisms of interaction between cells and molecules therein is crucial for developing a) strategies to mobilize hematopoietic stem and progenitor cells (HSPC) for cellular transplantation and b) anti-angiogenic factors for cancer therapeutics. The elasmobranch model offers a novel perspective because these species do not possess bone and therefore lack the endosteal component of the mammalian bone marrow niche. Thus, the epigonal and Leydig organs of *Leucoraja erinacea* supply HSPC to the body, and previous studies have demonstrated an increase in angiogenesis and proliferation of epigonal cells during the reproductive period. In this study we have assessed the expression of the chemokine receptor 4 (CXCR4) gene, known to play a major role in angiogenesis and the regulation of HSPC homing/mobilization in mammalian bone marrow via linkage to the chemokine ligand 12 (CXCL12). We have shown that CXCR4 is constitutively expressed in the Leydig organ and is upregulated in the epigonal organ during reproductive activity, supporting the hypothesis that reproductive factors are involved in regulation of angiogenesis and stem cell mobilization. We have also begun to characterize the relationship between HSPC and the vascular niche of *L. erinacea in vivo*, using the BrdU label retention method, which we anticipate will provide important insight into the vascular niche of mammals.

48.5 MEADE, Mark/E*; ROMANO, Frank; SEWELL, Susan; Jacksonville State University; *mmeade@jsu.edu*

Metabolic rates of an aquatic tardigrade, Dactylobiotus nuovo species.

We report here the use of a fiber optic, micro-respirometry system to monitor oxygen consumption rates in aquatic tardigrades. The system is highly sensitive (accuracy ±0.15% at 1% air saturation with a limit of detection of 15 ppb dissolved oxygen) and is not prone to drift as polarographic sensors are. Oxygen consumption of individual adults, eggs, and cysts of *Dactylobiotus nuovo* sp. were measured at 17C, 22C, and 27C. Individual adults acclimated to 17C averaged 238.1 + 7.2 mgO2/kg/hr and increased oxygen consumption rates to 601.33 + 9.8 mgO2/kg/hr when acclimated to 22C. Adults acclimated to 27C had significantly decreased oxygen consumption rates averaging 0.325 + 0.2 mgO2/kg/hr. Individual eggs at 17C averaged 545.1 + 14.1 mgO2/kg/hr and increased oxygen consumption rates to 1478.5 + 23.6 mgO2/kg/hr at 22C. Cysts acclimated at 17C averaged 104.1 + 8.1 mgO2/kg/hr and more than quadrupled oxygen consumption rates to 446.2 + 13.1 mgO2/kg/hr at 22C. Eggs and cysts were not produced from animals held at higher temperatures, thus no data is presented for individuals at 27C. These results indicate that oxygen consumption rates in this Tardigrade species follows previous trends demonstrated by other invertebrate species where environmental temperatures greatly influence oxygen consumption and, hence, overall metabolism. As indicated by significantly reduced oxygen consumption rates at 27C, this temperature may be beyond limits of tolerance for *Dactylobiotus nuovo* sp. Higher oxygen consumption rates in eggs may be reflective of higher energetic demands associated with developmental processes. Lower oxygen consumption rates for cysts indicate a reduction in metabolism as previously hypothesized.

32.1 MEHTA, Rita/S*; POLLARD, Rachel/E; Univ. of California, Santa Cruz, Univ. of California, Davis; *rsmehta1123@gmail.com*

Morays de-couple feeding and respiration via a parabranchial pouch

Moray eels are the only reported example of a teleost where the behaviors of feeding and respiration are decoupled. Moreover, the evolution of a specialized prey capture and transport strategy is associated with a reduction in suction ability. Past anatomical studies have pointed out the derived branchial arch morphology in morays but little work has investigated how these differences relate to respiratory movements. We used gross dissections and videofluoroscopy to study the skull and axial movements of the green moray, *Gymnothorax funebris*, during respiration. We found that the branchial basket is enclosed in a compartment, which we refer to as the parabranchial pouch. The deep wall of the parabranchial pouch is comprised of the gill arches and a highly vascularized membrane, the parabranchial membrane. The medial sides of the gill arches attach to the branchial membrane which separate the arches from the buccopharyngeal cavity. Kinematic analyses resulted in the partitioning of moray respiratory mechanics into the familiar two-phase pump model for teleosts proposed by Hughes and Shelton (1958). However, due to the large differences in moray branchial anatomy in relation to other teleosts, we propose an alternative model for moray eel respiration. In this alternative model, the bucco-pharyngeal and parabranchial pouch are treated as a single unit that deforms in shape pulling in and pushing out fluid much like a bellows.

55.2 MEKDARA, Nalong T.*; CHOUDHURY, Songita; MEKDARA, Prasong J.; BERG, Otto; GOTO, Joy J.; MULLER, Ulrike K. ; Cal. State Univ. of Fresno; *nmekdara@csufresno.edu*

The role of glutamate in insect locomotion: A glutamate agonist causes hyperactivity and loss of climbing ability in adult fruit flies.

L-Glutamate controls insect locomotion both at the level of the peripheral and the central nervous system. We study the effects of excess glutamate on the walking behavior of adult Drosophila melanogaster. Feeding the flies high concentrations of glutamate or N-Betamethyl-amino-L-alanine L-BMAA, a glutamate agonist (concentrations: 0, 12.5, 25, 50 mM) and recording the flies' ability to climb for 10 minutes for three consecutive days. Overstimulation of glutamate receptors at the neuromuscular junctions should result in loss of climbing ability. Overstimulation of the central pattern generator should lead to hyperactivity (walking faster and longer). We used two behavioral assays (climbing up a vertical incline after the tap-down and spontaneous climbing up a gradual incline) to assess motor behavior. The spontaneous-climbing assay was developed by our team to detect subtle differences in climbing ability by assessing use of space in an arena with a lenticular floor. We quantified walking speed, walking bout duration, walking bout frequency, stumble frequency and climbing height. We observed that excess glutamate causes no significant loss of climbing ability and only causes a significant increase in walking speed at the highest dose. L-BMAA causes an increase in walking speed and walking activity even at the lowest dose. L-BMAA causes significant loss of climbing ability at all doses. We observe a clear dosage and progression effect in L-BMAA: higher doses and prolonged exposure cause an increase in the severity of the symptoms.

S1-1.5 MENDES, César S.; BARTOS, Imre; AKAY, Turgay; MARKA, Szabolcs ; MANN, Richard S.*; Columbia University; *rsm10@columbia.edu*

Using frustrated total internal reflection to analyze insect walking

A central question for neuroscientists is the identification of circuits and cellular mechanisms that govern animal behavior, such as walking. *Drosophila* is an attractive model to address these questions due to its relative neuronal simplicity and increasingly sophisticated genetic tools. However, the lack of a reliable and accurate gait analysis method limits the ability to analyze the circuits and mechanisms that regulate coordinated walking. In order to address this challenge, we developed an optical method, based on frustrated total internal reflection (fTIR) coupled with high-speed imaging, that allows us to unambiguously track a fly's footprints and body position as it walks freely on a flat surface. A custom analysis software is used to track and quantify many parameters exhibited by walking flies, such as step timings, footprint positions, and intersegmental and left-right coordination. Using this method we characterized the walking behavior of wild-type animals and initiated loss and gain of function studies to assess the role of sensory neuron feedback in fruit fly walking behavior. For this, we established a combinatorial expression system to specifically manipulate neuronal function in different regions of the adult leg, thus targeting specific components of the sensory system. Our results reveal how interactions between central pattern generators and the sensory system modify walking behavior in fruit flies.

11.4 MENZEL, Lorenzo P.*; STEIN, Barry; BIGGER, Charles H.; Florida International University, Indiana University; *lorenzo.menzel@fiu.edu*

Morphology and histology of the gorgonian coral Swiftia exserta.

The geographic distribution of *Swiftia exserta*, a gorgonian octocoral, is the tropical western Atlantic from Brazil to Florida and the northern Gulf of Mexico in depths from 10 to 200 m. The easy availability, lack of endosymbionts (zooxanthellae), and aquarium tractability has lead to its use in our lab as a convenient animal model for tissue based immune responses (grafting and wound healing responses) and molecular biology. Yet, there is a paucity of structural information available for *Swiftia exserta* despite its being the type species of the genus. This report will show basic histology and ultrastructure of *Swiftia exserta* coenchyme and polyps, with basic cytochemistry.

50.1 METTS, B.S.*; BUHLMANN, K.A.; SCOTT, D.E.; TUBERVILLE, T.D.; HOPKINS, W.A.; Savannah River Ecology Lab, Aiken, SC, Virginia Tech, Blacksburg, VA ; *metts@srel.edu*

Maternal transfer of contaminants and its effect on reproduction and embryonic development in southern toads (Bufo terrestris)

Environmental contamination is thought to be among the greatest contributors to worldwide amphibian declines. Bioaccumulation of contaminants and subsequent transfer to offspring could be an important factor that affects amphibian reproduction and development, but this process has rarely been examined in amphibians. We examined maternal transfer of contaminants in southern toads (*Bufo terrestris*) residing in three locations: 1) a coal ash disposal basin, 2) an adjacent natural wetland contaminated with coal ash that has undergone natural attenuation for over 35 years (ash plume), and 3) a reference site with no previously known contamination. Our study is among the few to document maternal transfer of contaminants and resulting adverse effects in amphibians. We found that females collected from the ash plume wetland and ash basin transferred elevated levels of eight trace elements to their eggs. After correcting for female body size, clutch size of females collected from the ash basin was 14% lower than reference females. Moreover, overall reproductive success was reduced 33-35% in females collected from the ash plume wetland and ash basin compared to reference females. These reductions were correlated with trace element concentrations in females and their eggs. Our findings highlight the negative effects that maternal transfer of contaminants can have on amphibian reproduction and emphasize the importance of future research investigating potential latent effects of maternal transfer and the influence that maternal transfer may have on local amphibian populations.

85.2 MEYER, E*; DAVIES, S; MATZ, MV; University of Texas - Austin; *EliMeyer@mail.utexas.edu*

Gene expression predicts genetically-determined thermal tolerance in corals

Genetic variation in thermal tolerance would be necessary for coral populations to adapt to warming ocean temperatures. However, despite widespread concern over degradation of coral reefs and intensive study of thermal stress responses, genetic variation in this trait has never been shown. We have addressed this experimentally by crossing parental colonies of *Acropora millepora* collected from distinct populations. The set of 30 families produced from this cross displayed a wide range of thermal tolerance during larval stages. Statistical analysis of half-sibling relationships revealed that thermal tolerance is highly heritable in these families (narrow sense heritability = 0.63), indicating a genetic basis for variation in this trait. To identify the functional basis of these differences, we profiled gene expression in a subset of families prior to exposure to thermal stress. We found that constitutive differences in gene expression were strongly correlated with subsequent thermal tolerance, identifying specific gene expression profiles that predict thermal tolerance. qPCR analysis of additional larval families confirmed the predictive power of these expression profiles. Our study has demonstrated for the first time a genetic basis for thermal tolerance in corals, and identified specific genes underlying this variation. These genes provide a plausible mechanistic link between genetic and phenotypic variation, and identify candidate targets of selection that can now be studied in the context of natural populations and episodes of thermal stress.

35.2 MEYER, Erin L*; MATZKE, Nicholas J; WILLIAMS, Simon; Univ. of California, Berkeley; *emeyer@berkeley.edu*
Novel remote sensing technique assesses intertidal habitat and reveals population expansion of West Indian Topshell
Habitat assessments are important for conservation because they establish baselines for spatial distribution and preferred habitat of target species. These data are useful for testing species recovery and for predicting future population expansion. Current methods for mapping intertidal habitat require detailed field data, which are often unavailable and laborious to collect. Thus, developing alternative methods is crucial for exploited species, such as *Cittarium pica*. Fishing pressure on *C. pica* recently increased, resulting in the establishment of management plans in six island territories. In Bermuda, *C. pica* was fished to extinction in the 1800s and was reintroduced in 1982. To monitor recovery in Bermuda, we used a novel remote sensing technique to correlate habitat and species distributions while estimating population size and density. Starting with a digital aerial photograph, we outlined the coastline and manually classified it into three categories: rock, vegetation, or beach. Using these high-resolution data as a training dataset, we created a supervised classification system for identifying intertidal habitats in lower resolution Landsat images. The coastline consists of 74% rock and shore-hardening structures, 10% beach, and 16% vegetation. On the habitat map produced with these techniques, we mapped *C. pica* distribution and population sizes for five field localities in Bermuda. Results demonstrate that *C. pica* population has increased since the 2003 island-wide survey indicating that the species is continuing to recover. We also used these data to predict future expansion of *C. pica* into unoccupied habitat. This is the first habitat assessment for *C. pica*, and the methods developed herein will be applied throughout the Neotropical Western Atlantic.

94.3 MICHEL, K.B.*; VAN WASSENBERGH, S.; AERTS, P.; Univ. of Antwerp, Belgium; *krijn.michel@ua.ac.be*
Comparison of Atlantic mudskippers (Periophthalmus barbarus) feeding in an aquatic and terrestrial environment: a detailed morphological and kinematical study.
In fish-to-tetrapod evolution, the transition from water to land required the adaptation of an aquatic feeding apparatus to a terrestrial environment. In order to understand the role of certain morphological changes observed from the fossil record, a first step is to identify how extant species dealt with such a transition. Here we describe the morphology of the feeding apparatus in the Atlantic mudskipper (*Periophthalmus barbarus*) and how it functions in both a terrestrial and aquatic environment. *P. barbarus* feeds by protrusion of the premaxilla, positioning its oral cavity over the prey, engulfing it, while rapid closure of the lower jaw ensures prey capture. In a terrestrial setting, water is frequently carried in the oral cavity and deposited on the prey as it is imbibed. Kinematics show us that prey capture on land shows a general resemblance to aquatic suction feeding. From high speed digital x-ray videography we learn that the use of water is not required but may facilitate successful prey capture on land. Our results suggest that *Periophthalmus barbarus* uses a modified form of aquatic suction feeding on land to facilitate swallowing and transport of prey inside the buccopharyngeal cavity. A versatile repertoire of volumetric expansion and jaw protrusion allows for terrestrial feeding with a primarily aquatic feeding apparatus.

69.1 MIDDLEBROOKS, M.L.*; PIERCE, S.K.; BELL, S.S.; Univ. of South Florida; *mlmiddle@mail.usf.edu*
Chlorophyll synthesis in the photosynthetic sea slug Elysia clarki
Several species of sacoglossan sea slugs are able to photosynthesize using chloroplasts from the algae they feed upon sequestered inside of their digestive cells. The duration of photosynthesis varies greatly between species, lasting from several hours up to at least 9 months. In most cases, the sequestered plastids eventually stop functioning and slugs must feed again in order for photosynthesis to continue. Some sacoglossan species employ morphological adaptations for shading or behavioral responses to strong light to prolong the duration of their stolen plastids. However, *Elysia chlorotica* synthesizes chlorophyll which aids in preserving the longevity of their sequestered chloroplasts. Here we demonstrate that another sacoglossan, *E. clarki*, is also able to synthesize chlorophyll. However, after 3 months of starvation *E. clarki* the synthesis stops. The timing corresponds with a significant reduction in photosynthetic rates in starved slugs and a loss of plastids, although it is still unclear why *E. clarki* loses the ability to synthesize chlorophyll.

65.1 MILLER, EC*; DREWES, RC; University of California, San Diego, California Academy of Sciences; *ecmiller@ucsd.edu*
A New Species of Hemidactylus Gecko Endemic to the Gulf of Guinea: A Story of Transoceanic Colonization Events
The Gulf of Guinea islands São Tomé and Príncipe are home to a poorly-known endemic herpetofauna. Native and non-native *Hemidactylus* geckos inhabit the islands, including the endemic *Hemidactylus greefi* (Greef's giant gecko). Previous work has found species-level differences in mtDNA between populations found on São Tomé and Príncipe, requiring a closer analysis of morphological and molecular data in order to determine the level of divergence between the two island populations. Fourteen measurements were taken on 12 Príncipe specimens and 14 São Tomé specimens and standardized by snout-vent length, in addition to meristic counts. It was discovered that on São Tomé, individuals were significantly larger across all body measurements, and also had proportionally longer limbs and a more robust head. The two island populations can be visually distinguished by the divided lamellae counts on the third finger, tubercle scale size, and the number of preanal/femoral pores in males. We also sequenced 10 Príncipe and 12 São Tomé specimens for the nuclear intron &alpha-Enolase, which has an intermediate rate of change between those of mtDNA and other nuclear genes previously employed on this species. The two populations are distinguished by a fixed site difference. São Tomé geckos are much more genetically diverse than Príncipe geckos, having eight haplotypes for the gene compared to only two in Príncipe specimens. Not only does our data provide enough evidence to distinguish the two populations as different species, but the lack of genetic diversity in Príncipe geckos suggests a possible founder effect in which the Príncipe population is a result of a single colonization event originating from São Tomé. These results confirm that a description of the new species is needed, as well as the designation of a neotype to represent *H. greefi*.

S7-1.5 MILLER, Laura A; University of North Carolina at Chapel Hill; *lam9@email.unc.edu*

Uncovering the aerodynamics of the smallest insects using numerical and physical models

A vast body of research has described the complexity of flight in insects ranging from the fruit fly, *Drosophila melanogaster*, to the hawk moth, *Manduca sexta*. The smallest flying insects have received far less attention, although previous work has shown that flight kinematics and aerodynamics can be significantly different. In this presentation, three-dimensional direct numerical simulations are used to compute the lift and drag forces generated by flexible wings to reveal the aerodynamics of these tiny fliers. An adaptive version of the immersed boundary method is used to simulate simplified flexible wings in pure translation, rotation, and performing a 'clap and fling' maneuver. Results are validated against dynamically scaled physical models using particle image velocimetry. At the lowest Reynolds numbers relevant to tiny insect flight, the ratio of lift to drag forces decreases. For Reynolds numbers below 10, the relative forces required to rotate the wings and perform 'clap and fling' become substantially greater. Wing flexibility can reduce the drag forces necessary to fling the wings apart while increasing the peak and average lift forces produced during the stroke. These results indicate that flexible clap and fling can improve tiny insect flight efficiency in some situations.

49.4 MILLER, CE*; GRANATOSKY, MC; O'NEILL, MC; BISHOP, KL; SCHMITT, D; Duke, Stony Brook University, Florida International University; *charlotte.miller@duke.edu*

Center of mass mechanics in the squirrel monkey Saimiri sciureus

The significance of whole body center of mass mechanics has been well studied in a range of bipedal and quadrupedal animals, but few data exist for primates. Primate quadrupeds exhibit very different locomotor ecologies and mechanics, including limb compliance and protraction, footfall and force distribution patterns when compared to dogs, horses and other terrestrial cursors commonly used as model animals in locomotion studies. Previous work has shown that in many walking animals inverted pendular movements of the center of mass lead to high levels of exchange (recovery) of potential and kinetic energy (PE and KE). Of the primates studied to date the ringtailed lemur, *Lemur catta*, exhibits recoveries of up to about 70% in walking, much like dogs, while in macaque species values reach up to only about 50%. Here we present the first energy exchange data on a small anthropoid primate, the squirrel monkey, *Saimiri sciureus*. All three components of ground reaction force were collected for full strides from two animals moving quadrupedally on an instrumented runway. These data were used to calculate fluctuations in PE and KE, and percentage recovery and congruency values. In this sample neither recovery nor congruency correlated with speed. The relationship between percent recovery and percent congruity values was moderately strong, but less pronounced than noted in previous studies. Recovery values were consistent with those seen in macaques. These data add to the growing list of animals, including cats, small mammals and turtles, that present with relatively low recovery values, suggesting that this inverted pendulum mechanism may be relatively restricted to use by terrestrial cursors.

71.3 MILLER, RG*; BURROWS, MT; FOX, CJ; INALL, ME; Scottish Association for Marine Science; *raeanne.miller@sams.ac.uk*

Offshore renewable energy structures as stepping stones for biogeographic change: does larval vertical positioning hold the key?

The construction of marine renewable energy devices will alter the availability of shallow water hard habitat around the UK. These structures may act as artificial islands, encouraging changes in species ranges as stepping-stones for dispersal across biogeographic boundaries, altering patterns of population connectivity. For marine organisms with pelagic larvae, the vertical positioning of larvae in stratified coastal flow fields can be an important determinant of transport, dispersal, and connectivity. Between-species and between-stage differences in vertical positioning may drive differential transport of larval assemblages, resulting in distinct patterns of connectivity. Building on laboratory measurements of larval sinking rates and three-dimensional plankton sampling, oceanographic modelling techniques explore the influence of vertical positioning on the dispersal of acorn barnacles along the Scottish west coast. Interspecific variation in naupliar density and drag may be a driver of varying depth distributions of both larval and adult communities. Divergence in the vertical positioning of sub-tidal and inter-tidal larvae may also explain previously observed horizontal variations in larval distributions. For many species, larval hydrodynamics and other physiological properties can be important when assessing the potential connectivity or biogeographic impacts of marine renewable energy device installation as well as for the effective development of marine protected areas, a relevant policy objective.

S8-2.4 MOCZEK, Armin; Indiana University Bloomington; *armin@indiana.edu*

The nature of nurture and the causes of traits: toward a comprehensive theory of developmental evolution

This presentation has three parts. First, I posit that much research in contemporary evolutionary and developmental biology, including efforts focused on developmental plasticity, remains steeped in a traditional framework that views traits and trait differences as being caused by genes and genetic variation, and the environment as providing an external context in which development and evolution unfold. Second, I discuss three attributes of organismal development and evolution, broadly applicable to all organisms and traits that call into question the usefulness of gene- and genome-centric views of development and evolution. I then focus on the third and main aim of this presentation and ask: what conceptual and empirical opportunities exist that would permit research in evodevo in general and developmental plasticity in particular to transcend traditional boundaries and to move toward the development of a more comprehensive and realistic theory of developmental evolution? Here, I focus on three conceptual frameworks, the theory of facilitated variation, the theory of evolution by genetic accommodation, and the theory of niche construction. I conclude that combined they provide a rich, interlocking framework within which to revise existing and develop novel empirical approaches toward a better understanding of the nature of developmental evolution. Examples of such approaches are highlighted, and the consequences of expanding existing frameworks are discussed.

83.3 MOHAJER, YJ*; FINE, ML; GHAHRAMANI, ZN; Virginia Commonwealth Univ.; *mohajeryj@vcu.edu*

High Speed Examination of Pectoral Stridulation Sound Generation in Blue Catfish, Ictalurus furcatus

The blue catfish *Ictalurus furcatus* is an invasive species whose population numbers have exploded in Chesapeake Bay estuaries. Catfishes produce stridulation sounds by rubbing ridges on the dorsal process of the pectoral spine against a rough surface on the cleithrum to produce a series of pulses during abduction. We studied the mechanism of sound generation by synchronizing audio recordings with a high speed camera at 2000 frames per second. Unlike channel catfish that typically keep their pectoral fins retracted (adducted), blue catfish tend to maintain them in a forward position. Therefore sound production requires the fish to adduct the spine before forward stridulatory movement. Adduction movements were about a third as long as abductions (means of 49 and 152 ms respectively). The amplitude of abduction and adduction movements was similar at 25.9 and 26.5 degrees. Stridulatory abductions consisted of a series of 3-17 short rapid movements (median of 13) with an average rotation of 3.1 degree over 1.5 ms. Movement was followed by an interpulse period of 13.2 ms in which the spine was stationary. Sound amplitude was low during movement and increased during the stationary period suggesting time was required to activate vibrations in the pectoral girdle. Sounds are produced by a slip-stick mechanism similar to a bow over a violin string.

19.6 MONGEAU, J.-M.*; MCRAE, B.; JUSUFI, A.; BIRKMEYER, P.; HOOVER, A.M.; FEARING, R.; FULL, R.J.; Univ. of California, Berkeley, Olin College; *jmmongeau@berkeley.edu*

Rapid Inversion: Running Cockroaches, Geckos, and Robots Swing like a Pendulum under Ledges

Escaping from predators often demands that animals rapidly negotiate complex environments. The smallest animals attain relatively fast speeds with high frequency leg cycling, wing flapping or body undulations, but absolute speeds are slow compared to larger animals. Instead, small animals benefit from the advantages of enhanced maneuverability. We report a novel behavior in small, legged runners that may facilitate their escape by disappearance from predators. Cockroaches (*Periplaneta americana*) and geckos (*Hemidactylus platyurus*) ran rapidly at 12-15 body lengths-per-second toward a ledge without braking, dove off the ledge, attached their feet by claws like a grappling hook, and used a pendulum-like motion that can exceed one meter-per-second to swing around to an inverted position under the ledge, disappearing from an overhead view. We discovered evidence for the potential use of rapid inversion in nature. Geckos in the rainforests of Southeast Asia can run over fern leafs, engage their claws, and possibly their adhesive toe hairs, near the tip of the leaf and perform a pendulum-like swing towards the underside. This rapid inversion behaviour is inspiring design advancements of a small hexapedal robot DASH (Dynamic Autonomous Sprawled Hexapod) that begins to demonstrate this capability. We anticipate that the quantification of acrobatic behaviors in small animals will continue to provide biological inspiration resulting in small, highly mobile sentinel and search-and-rescue robots that assist us during natural and human-made disasters.

16.2 MOODY, KN*; KAWANO, SM; MAIE, T; BLOB, RW; SCHOENFUSS, HL; BLUM, MJ; PTACEK, MB; Clemson, St. Cloud State, Tulane; *knmoody@clemson.edu*

Morphological divergence despite gene flow in a Hawaiian waterfall-climbing goby.

Newly recruiting postlarvae of the Hawaiian waterfall-climbing goby, *Sicyopterus stimpsoni*, face differential environmental pressures between islands during migration upstream to predator-free breeding habitats. Kaua'i, ~5 MY in age, has long, broad, gradual sloping streams with waterfalls far inland, resulting in long periods of exposure to a non-climbing fish predator placing a premium on adaptations for predator evasion. Hawai'i, ~1 MY in age, has narrow, fast-flowing, steep-sloping streams with waterfalls close to shore, placing a premium on adaptations for waterfall climbing. Our previous work showed that selection favored contrasting body shapes for climbing (streamlined) and predator evasion (tall), potentially promoting local adaptation in shape between island subpopulations. However, the amphidromous life cycle of *S. stimpsoni*, results in considerable dispersal of oceanic larvae across the archipelago leading to the potential for non-natal recruitment to directly oppose the effects of local natural selection. To examine the interaction between gene flow and local adaptation in shape, we used microsatellite markers and linear morphological measurements to determine the patterns of genotypic and phenotypic differentiation between subpopulations. For adult subpopulations, we found no evidence of between-island or within-island genetic differentiation (F_{ST}~0). Morphological differentiation was significant at both levels of island ($p<0.0001$) and stream-within-island differentiation (both within Hawai'i and Kaua'i $p<0.0001$). Thus, patterns of morphological differentiation were not congruent with patterns of genetic differentiation at either large or small spatial scales, suggesting an important role for local selection in shaping morphological divergence in the face of high levels of gene flow. NSF IOS-0817794, IOS-0817911.

83.5 MOORE, BC*; MATHAVAN, K; GUILLETTE, LJ; Louisiana Tech University, University of Massachusetts, Medical University of South Carolina; *bmoore@latech.edu*

The Functional Complexity of the Male American Alligator Phallus

For over a century there have been scientific descriptions of crocodilian phallus morphologies, however little work has presented detailed cellular-level analyses of these structures. Here we present a histological investigation of the complex functional anatomy of the juvenile male American alligator phallus, including fibrous and vascular erectile structures, a variety of secretory epithelium morphologies, and observed immune cells. Using 3-D reconstruction software, we show the shape and location of vascular erectile tissues within the phallus. Histochemical staining highlights mucin-rich secretory cells in glandular epithelial cells of the phallic shaft and also of the semen-conducting ventral sulcus. Lymphoid aggregates, lymphocytes, and epithelial mucin coats suggest an active immune system in the phallus defending from both the external and intra-cloacal environments. These observations better characterize the complexity of the alligator phallus and predict later adult reproductive functions.

49.6 MOORE, TY*; COOPER, KL; BIEWENER, AA; Harvard Concord Field Station, Harvard Medical School; *tymoore@fas.harvard.edu*

Gait transitions independent of speed in Lesser Egyptian Jerboa

Terrestrial locomotion is well documented and characterized by distinct gait transitions with increasing speed, which can optimize locomotor economy. Past research on bipeds indicates that each foot in a symmetric gait decelerates then accelerates the body to achieve the spring-loaded inverted pendulum running gait. Quadrupeds are capable of favoring deceleration by the forelimbs and acceleration by the hindlimbs within one running stride. The Lesser Egyptian Jerboa (*Jaculus jaculus*) is a desert-adapted bipedal rodent with unique gait characteristics when compared to bipedal and quadrupedal animals. Jerboas perform three distinct bipedal gaits: a symmetrical, in-phase "hop;" an asymmetrical, slightly out-of-phase "skip;" and a fully out-of-phase "run." To characterize the gaits we encouraged 5 male jerboas to run along a straight track equipped with a 2-axis (vertical and fore-aft) force platform, while recording leg kinematics with a high-speed camera. The ground reaction forces on each foot in a skip differed within the same stride: the first foot to touch decelerates then accelerates, whereas the second foot mainly accelerates. Two individuals significantly preferred to lead with one foot ($p<0.05$), but across individuals no significant preference for leading foot was observed (two-sided binomial test, $p=0.2$). Over 140 trials jerboas ran at speeds between 0.4 and 3.0 m/s (mean 1.5 ± 0.6 m/s st.dev.). All gaits were displayed across the speed range, but animals predominantly used the skip (57% of trials). The jerboas only hopped during rapid acceleration and deceleration, whereas skipping was used during acceleration, deceleration, as well as constant speeds. Animals only ran at constant speeds. Jerboa gait transitions are correlated with acceleration rather than speed, suggesting that gait selection is based on maneuverability rather than locomotor economy.

4.2 MORAN, AL*; PHILLIPS, NE; Clemson University, SC, Victoria University of Wellingon, NZ; *moran@clemson.edu*

Gases for the masses: ecological interactions promote rapid embryonic development of a marine gastropod

Oxygen is a limiting resource to embryos developing in protected environments. Among marine invertebrates, embryos of many taxa are enclosed in egg capsules or masses. While these provide physical protection, they also result in hypoxia-driven developmental stasis or even embryonic death when egg masses are too large, embryos are densely packed, or metabolic demand is high. The intertidal pulmonate limpet *Siphonaria australis* lays large, gelatinous egg masses that experience high embryo mortality from UV, desiccation, and temperature stress in nature, suggesting rapid development is advantageous. We first demonstrated that O_2 levels varied from hypoxic to >2x saturation in tide pools containing *Siphonaria* egg masses, and that central O_2 concentrations in masses also varied from zero to hyperoxic. To isolate the role that tide pool photosynthesizers (macroalgae) played in egg mass O_2 dynamics and embryonic development, we kept masses in the lab on a natural light/dark cycle both with and without algae throughout development and monitored external O_2, O_2 in the center of masses, and development. As in tide pools, the presence of algae in lab dishes raised external O_2 to >2x saturation under lighted conditions and lowered O_2 to below saturation in the dark. Egg mass centers contained measurable O_2 only under lighted conditions with algae, and when masses were very young. Masses kept with algae throughout development had significantly less asynchrony in development and had a higher percentage of hatching-stage embryos than masses kept without algae, suggesting that fitness of *S. australis* parents is likely to be higher when masses are laid in pools with abundant O_2 production from macroalgae.

66.7 MOROZ, LL*; KOHN, A; CITARELLA , M; GRIGORENKO, A; KOCOT , K.; HALANYCH, K; ROGAEV, E; Univ of Florida, Univ of Massachusetts Med Sch, Univ of Alabama; *moroz@whitney.ufl.edu*

The Genome of the Ctenophore Pleurobrachia bachei: Molecular Insights into Independent Origins of Nervous Systems

Our understanding of the origins and early evolution of animals is controversial because of limited data from basal Metazoa. The phylum Ctenophora (comb jellies) is one of the earliest animal lineages with well-recognized nervous and “true” mesoderm-derived muscular systems. The sea gooseberry (Pleurobrachia), has one of the most compact genomes within this group. These holoplanktonic predators have sophisticated ciliated locomotion, unique glue-based capture mechanisms and distinct development. Using 454/Roche and Illumina sequencing we achieved ~1,000x coverage of the genome. We then performed RNA-seq profiling from major tissues (~2,000x coverage) to validate the initial genome assembly and annotation: 96% of predicted gene models are supported by transcriptome data. As a result, our phylogenomic analysis is consistent with the most basal phylogenetic position of Ctenophores within the animal tree. This hypothesis is further supported by comparative analysis of selected gene families (including the apparent absence of HOX genes in Pleurobrachia). Second, our experimental data indicate that the nervous system in ctenophores is one of the most distinct in its morphological and molecular organization. Many “classical bilaterian neuron-specific” genes either are not present or, if present, they are not expressed in neurons. Finally, we identified novel markers for ctenophores neurons. Combined, these data suggest that at least some of the ctenophore neural populations were evolved independently from those in other animals.

53.2 MOSELEY, D.L.; University of Massachusetts Amherst; *dmoseley@bio.umass.edu*

Female preferences are influenced by early experience and male vocal performance

Female mating preferences are a crucial component of sexual selection, yet we have poor knowledge of how female preferences develop. Specifically the extent to which experience during development informs mate choice is largely unstudied. Multiple factors may shape mate choice including experiential learning, social copying, and a sexually selected bias for certain male traits such as the performance level of displays. For bird species in which males learn their songs, it is likely that early exposure to song may also influence females' preferences later in life. I address this question in the swamp sparrow (*Melospiza georgiana*), using a new method to elicit preferences from lab-raised birds. Adult, wild-caught females of this species are known to prefer songs of relatively high-performance, i.e. songs that are physically difficult to produce. In 2009, I hand-raised females with tutor songs of normal-performance levels. As further training in their first spring, I presented females with these songs again, but this time coupled with a video of an adult female responding with a copulation solicitation display (CSD). I then used the CSD assay to test female preferences for songs they had experienced during ontogeny against these same songs altered to higher and lower performance levels. Females gave significantly fewer CSDs to low-performance songs than to the trained (normal-performance) songs. Females responded with the most CSDs to trained songs overall, but this value was not significantly different in a pairwise comparison to the high-performance songs, which was intermediate. A greater response to trained songs supports the hypothesis of a strong influence of early experience, but a preference for high-performance songs by some females cannot be ruled out. It appears that both experiential learning and a bias for high-performance guide female preference development.

98.5 MOUNTCASTLE, AM*; COMBES, SA; Harvard University; *mountcastle@fas.harvard.edu*

Resilin and the morphological basis of flexible wing dynamics in flying insects

Flexible insect wings undergo considerable shape changes during flapping flight, and the importance of these emergent deformations to force production and aerodynamic efficiency has been the focus of many recent studies. Relatively few studies, however, have explored the morphological basis of flexible wing dynamics. Resilin, a protein with extremely high elastic efficiency, has been identified in the wings of several insects, often along natural fold lines or in mobile vein joints, driving speculation that it may play an important role in wing deformation. The potential contribution of resilin and other structural features to overall flexural stiffness, emergent wing deformations, and wing resilience has not been thoroughly characterized in any flying insect. Using flourescent microscopy, we mapped the distribution of resilin in the wings of several species, including the bumblebee, *Bombus impatiens*. We have developed a technique to artificially stiffen individual resilin joints and fold lines, allowing us to assess the relative contributions of different wing features to overall flexural stiffness and structural dynamics, with implications for flight performance. These results improve our understanding of insect wing functional morphology, and provide evolutionary insight into general principles of wing design.

14.5 MOUSTAKAS, Jacqueline E*; KALLONEN, Aki; AHTIAINEN L; HäKKINEN, Teemu; HARJUNMAA, Enni; SALAZAR-CIUDAD, Isaac; HäMäLäINEN, Keijo; JERNVALL, Jukka; Institute of Biotechnology, University of Helsinki, Finland, Department of Physics, University of Helsinki, Finland; *jacqueline.moustakas@helsinki.fi*

Changing Tissue Properties and Cell Behavior During Tooth Organogenesis

The mammalian dentition is a model system in which to study the developmental mechanisms of morphological change. Teeth develop through an epithelial-mesenchymal interaction between oral ectoderm and neural crest-derived mesenchyme. Models of the tooth development predict a role for mechanical forces in the growth of the epithelium, and therefore, in the formation of shape. Far less is known about the cellular behaviors and properties of the mesenchyme in this process. First, we examined the growth dynamics of the mesenchyme during the development of mouse molars using computed tomography. We generated three-dimensional reconstructions of the embryonic teeth and found that whereas mesenchymal density declines during morphogenesis, the mesenchyme underneath developing cusps retain high density. Next, to examine the cellular basis of the density dynamics, we used reporter mouse technology to monitor cell division and cell movements in cultured teeth. We found that the cells underneath the developing cusps are more stationary relative to each other than at the base. Together with molecular data on cell adhesion molecules, these results implicate mesenchyme to participate in tooth shape patterning by forming a physically heterogeneous template for the folding epithelium.

47.2 MUñOZ, M.M.*; STIMOLA, M.; LANDESTOY, M.A.; CONOVER, A.; RODRIGUEZ, A.J.; LOSOS, J.B.; Harvard University, Columbia University, University of California, Davis; *mmunoz@oeb.harvard.edu*

Behavioral and physiological mechanisms of thermal adaptation in a diverse clade of Anolis lizards.

Anolis lizards are often studied in the context of adaptive radiation in the Greater Antilles, where they have independently diversified into various habitat types termed ecomorphs. Although members of an ecomorph share similar microhabitat preferences and corresponding adaptive morphologies, species differ according to the thermal range they occupy. Three species in the Hispaniolan radiation of trunk- and ground-dwelling anoles, *Anolis cybotes*, *A. longitibialis*, and *A. shrevei* inhabit different thermal environments. *Anolis shrevei* is found in cool montane environments while *A. longitibialis* is found only in hot lowland forests. *Anolis cybotes*, a purported generalist, is found throughout the island, except at the highest elevations. Here we test three hypotheses about the mechanisms forging different thermal ranges in these closely related species. 1) The thermal preference and thermoregulatory efficiency of each species reflects the temperatures available in their respective environments. 2) Species' thermal tolerances match the thermal range of their environments. 3) Females from colder environments delay laying eggs to increase the rate of embryonic development. Despite their different thermal environments, these three species show similar thermal preferences and body temperatures, and do not differ in thermoregulatory efficiency. Higher elevation populations, and especially *Anolis shrevei*, have greater cold tolerance, but the reverse is not true for heat tolerance in low elevation populations. Egg retention in cold temperatures occurs in all species except in *Anolis longitibialis*. We summarize these behavioral and physiological patterns in light of thermal range experienced, and how thermal adaptation may have influenced diversification in this clade.

34.1 MUNSON, D.A.; Washington College, Chestertown, MD; *dmunson2@washcoll.edu*

The distribution of Acanthamoeba spp. in marine sediments from Great Sound, Bermuda

A previous study (Munson et al., Oceanis, 37, 2007) illustrated the impact of pollution on the incidence of *Acanthamoeba spp.* in North Sea coastal sediments. *Acanthamoeba* is a ubiquitous soil amoeba and its distribution is often associated with sewage pollution and/or nutrient runoff from land. Some species in the genus are opportunistic pathogens of humans. This investigation focused on ameba distribution in sediments from Great Sound, Bermuda. In June of 2011 sediments were collected by scuba from 14 sites in Great Sound and were cultured at room temperature and at 37^0C on non-nutrient agar seeded with *Klebsiella aerogenes*. Room temperature cultures were positive for amebas in 11 of 14 (79%) sediment samples. At elevated temperatures (37^0C) amebic growth occurred in 7 of 14 (50%) sediment samples. In this investigation sampled sites that were positive for ameba showed a relatively even distribution of Group II and Group III *Acanthamoeba spp.* Only one site yielded Group I *Acanthamoeba spp. (A. astronyxis)*. Commonly isolated Group II species were *A. polyphaga, A. castellanii, A. rhysodes*, and to a lesser degree *A. hatchetti.* Several other unidentified isolates that belonged to either Group II or Group III of the genus were also commonly present.

S5-1.1 MURPHY, John; Field Museum of Natural History; *fordonia1@comcast.net*

Marine Invasions by Non-Sea Snakes, With Thoughts on Terrestrial-Aquatic-Marine Transitions

Oceans cover 71% of the earth's surface with about 350,000 km of coastline yet only 2.5% (about 86 species) of the 3364 extant snakes are known to inhabit the oceans, but at least another 54 species are known to use the brackish and marine waters of coastal habitats. The physical environment and possibly marine predators appear to provide challenges for snakes. Yet there is evidence that evolution continues to tinker with snake adaptation to marine environments. A survey of life styles and habitats of 2552 althenophidian snakes in 459 genera revealed about 362 (14%) semi-aquatic and aquatic species; only 70 (2.7%) of these are sea snakes (Hydrophiinae and Laticaudinae). The ancient Acrochordidae contains three extant species, all of which have populations in brackish, marine and freshwater environments. A family that contains terrestrial, semi-aquatic and aquatic snakes, the Homalopsidae has another 14 species that have invaded brackish and marine waters. The specious Dipsadidae of the western hemisphere has an additional seven species with coastal-marine populations; while the cosmopolitan Natricidae has 24 species with populations that inhabit brackish waters; and the semi-aquatic, African Grayiinae has at least one species that uses brackish water. Geographically the most specious brackish water snake assemblages are concentrated in South East Asia and Australasia with distributions that correspond to the most diverse mangrove and salt marsh communities. Species with semi-aquatic lifestyles are compared with more aquatic and terrestrial (fossorial, cryptozoic, and arboreal) species for morphological and life history traits. Emergent morphological and life history characters are identified that may provide clues to the evolution of marine snakes.

107.5 MURPHY, DW*; WEBSTER, DR; YEN, J; Georgia Institute of Technology; *dwmurphy@gatech.edu*

Copepod Escape Jumps: Tomo-PIV Measurements of the Eliciting Hydromechanical Signal and Subsequent Flow Disturbance

We present time-resolved tomographic particle image velocimetry (Tomo-PIV) measurements of freshwater (*Hesperos*) and marine (*Calanus*) copepod escape sequences initiated by an impulsive siphon flow that mimics the aquatic suction feeding of a piscine predator. Copepods perform dramatic escape jumps reaching speeds up to 500 body lengths per second in response to hydromechanical signals that are perceived as threats. Copepods sense the flow disturbance via their long, highly enervated, setae-bearing antennules, and the behavior response is believed to result from the structure of the velocity gradient field. Volumetric velocity measurements around the copepod allow determination of the threshold of both the magnitude and orientation of the hydromechanical disturbance along the antennules to which the animal responds. Further, the flow field resulting from a copepod escape jump, which may carry sensory information to a predator, consists of a wake vortex and a body vortex. These two counter-rotating viscous vortex rings of similar intensity can be modeled as an impulsive stresslet for comparison.

99.3 MURRAY, Erin M.*; SAPORITO, Ralph A.; Missouri State University, John Carroll University; *Erin1989@live.missouristate.edu*

Predation in the strawberry poison frog Oophaga pumilio: Are adults and juveniles equally protected from ctenid spiders?

Many organisms possess defensive mechanisms to protect themselves from predation. Dendrobatid frogs, such as *Oophaga pumilio*, contain alkaloid chemical defenses and advertise their toxicity to predators with warning coloration. However, color signals are not useful for deterring color-blind predators, and little is known about how *O. pumilio* advertise their chemical defenses to these potential predators. The neotropical ant *Paraponera clavata* and ctenid spider *Cupiennius coccineus* are two invertebrate, color-blind predators that avoid adult *O. pumilio* but readily consume non-toxic frogs. Juvenile *O. pumilio* possess the same warning coloration as adult *O. pumilio*, despite being less toxic than adults. This may give juvenile *O. pumilio* protection from color-visioned predators, while leaving them susceptible to predation by color-blind predators. To test this hypothesis, we presented adults and juveniles of both *Craugastor bransfordii*, a non-toxic brown frog, and *O. pumilio* to *C. coccineus* while they were hunting in the field. *Cupiennius coccineus* did not consume any *O. pumilio* adults or juveniles, but consumed 90% of all juvenile and adult *C. bransfordii*. Therefore, species, but not age, was a significant predictor of predation. *Cupiennius coccineus* does not appear to be a natural predator of *O. pumilio*, as both juvenile and adult *O. pumilio* were equally defended from predation. This provides evidence for the use of alkaloids in *O. pumilio* as a strong chemical signal against some invertebrate, color-blind predators.

S8-1.6 MURREN, Courtney J.*; MESSERVY, Jason; STRAND, Allan E.; RUTTER, Matt T.; College of Charleston; *murrenc@cofc.edu*

Plasticity and the integrated phenotype: examination of integration through development and across environments through classic and genomic approaches

Suites of complex characters that work together can be defined as functional modules. Organisms having strong relationships among the traits within a module are hypothesized to have efficient functional performance. Yet integration is not a static feature of an organism, and may vary both across environments and through development. To illustrate the phenotypic variation in integration across environments and through development, we asked: 1) How does integration change through development in three closely related species of *Mimulus*? Our study uncovered a pivotal contribution of development to integration, but the nature of this contribution varied across species. 2) When the genetic system is perturbed (using T-DNA knock out mutants), how do patterns of integration change through development and across environments? Exploration of genomic perturbations are facile in systems where genomic tools are plentiful, including the suite of SALK T-DNA lines that represent "knockouts" of ~67% of *A. thaliana* genes. Yet the vast majority of these knockouts display subtle if any morphological phenotypes. This "absence of phenotype" phenomenon has been observed in other model systems. In yeast, researchers turned their focus to complex characters, such as population growth rate and fitness and across environments. For *A. thaliana*, our preliminary results uncover phenotypes for complex reproductive characters across environments. Comparisons between T-DNA mutants to natural populations and the control line demonstrate that higher integration is observed in natural populations and genomic perturbations reduce integration.

15.5 MYKLES, D.L.; Colorado State University, Fort Collins; *don@lamar.colostate.edu*
Signaling pathways controlling the crustacean molting gland
Molting in decapod crustaceans is controlled by molt-inhibiting hormone (MIH), a neuropeptide that suppresses production of molting hormone (ecdysteroids) by a pair of molting glands (Y-organs or YOs). MIH signaling is organized into a cAMP/Ca2+-dependent "triggering" phase and a NO/cGMP-dependent "summation" phase linked by calmodulin. Molting can be induced by eyestalk ablation (ESA) or by multiple leg autotomy (MLA). During the molt cycle, the YO transitions through four physiological states, which are mediated by endocrine and autocrine/paracrine factors: "basal" state at postmolt and intermolt stages; "activated" state at early premolt; "committed" state at mid premolt; and "repressed" state at late premolt. The basal to activated state transition is triggered by a transient reduction in MIH; the YOs hypertrophy, but remain sensitive to MIH, as premolt is suspended by MIH injection or by limb bud autotomy (LBA). metazoan Target of Rapamycin (mTOR), which controls global translation of mRNA into protein, appears to be involved in YO activation in early premolt. At the activated to committed state transition, the animal becomes committed to molt, as the YO is less sensitive to MIH and premolt is not suspended by LBA. YO commitment involves a putative TGFβ factor, as SB431542, a TGFβ receptor antagonist, lowers hemolymph ecdysteroid titers in mid premolt animals. At the committed to repressed state transition, high 20-hydroxyecdysone levels inhibit YO ecdysteroid secretion and hemolymph titers fall. Molting, or ecdysis, marks the transition from the repressed to the basal state, during which the YO atrophies and regains sensitivity to MIH. A biosystems approach is proposed to define the role and interactions between the MIH, mTOR, and TGFβ signaling pathways at the transcriptional and posttranscriptional levels. Supported by NSF (IOS-0745224).

108.2 NALINI PADMANABHAN, M; KARPAGAM UNIVERSITY, COIMBATORE, INDIA; *nalinimadanagopal@yahoo.com*
In vitro cell-cell co-operation during cellular immune functions in the edible marine crab Scylla serrata
Hemolymph coagulation of *Scylla serrata* was completely prevented by use of a suitable anticoagulant. This enabled for obtaining the hemocytes in native form together with their inherent ability to attach and spread well on glass surface. Three distinct hemocyte morphotypes namely hyaline (H: 43%), semigranular (SG: 35%) and granular (G: 22%) were identified based on the degree of cytoplasmic granulation. These hemocyte morphotypes were successfully separated by a single-step discontinuous density gradient of Percoll. Irrespective of the morphotypes, they contained various immune molecules and displayed the two vital cellular immune responses namely, phagocytosis and encapsulation at varying levels. Plasma enhanced the phagocytic activity of SG and G cells whereas it facilitated and intensified the encapsulation response of all the cell types. Soluble factors derived from the hemocytes also modulated the phagocytic and encapsulation responses, wherein soluble factors derived from SG and G cells exerted opsonophagocytic effect only on G cells. In encapsulation assays, the hemocyte-derived promoting factor specifically acted on H cells, while the inhibiting factor selectively interacted with G cells. Thus the findings of experimental studies performed using pure populations of hemocytes demonstrated the existence of interactive events between specific hemocyte types during cellular immuno-defense reactions. Therefore, it could be envisaged that such co-operative cellular interactions are vital for potentiation as well as regulation of hemocyte-mediated immune functions in crustaceans.

109.3 NAN TIE, D.E.*; KILLPACK, T.L.; KARASOV, W.H.; Univ. Wisconsin, Madison; *nantie@wisc.edu*
Effect of food restriction and realimentation on growth, immune response, and body composition in Zebra finches
Short term food restriction of nestling altricial birds can retard growth and development. Compensatory growth (CG), a period of accelerated growth after restriction, allows nestlings to compensate for a period of reduced growth. There is mixed evidence regarding the occurrence of CG in altricial birds and if CG leads to trade-offs in allocation to tissue development or immune function. We hypothesized that food restricted zebra finch nestlings would display compensatory mass gain, no difference in structural growth, increased tissue water content (an index of functional immaturity), decreased lipid content, and reduced immune function compared to nestlings fed *ad libitum*. Control broods were fed *ad libitum* until 33 days of age. Experimental broods were fed *ad libitum* until 6 days of age, food restricted to 70% *ad libitum* for 3 days, followed by a return to *ad libitum* feeding until 33 days of age. Body mass, structural growth, and food intake were taken daily until 33 days of age. All broods were tested for innate immune response to lipopolysaccharide and adaptive immune response to keyhole limpet hemocyanin (KLH). Average body mass of experimental broods was 25% lower than controls after the 3-day restriction. Body mass did not differ between treatments 2 days after realimentation, demonstrating compensatory mass gain in experimental broods. Structural growth and KLH response showed no significant difference between treatments. Adaptive immune response was 80% lower than adult response, indicating that fledglings at age 33 still have undeveloped humoral immune function and treatment differences may not be detectable. Analyses of innate immune response and body composition will be reported. Support USDA-Hatch.

100.5 NAPIER, K.R.*; XIE, S.; MCWHORTER, T.J.; NICOLSON, S.W.; MARTINEZ DEL RIO, C; FLEMING, P.A.; Murdoch Univ., Western Australia and Univ. of Wyoming, Laramie, Murdoch Univ., Western Australia, Murdoch Univ, Western Australia and Univ. of Adelaide, South Australia, Univ. of Pretoria, South Africa, Univ. of Wyoming, Laramie, Murdoch Univ, Western Australia; *knapier@uwyo.edu*
Can sugar preferences in Australian birds be explained by behaviour or physiology?
Diet preferences may reveal a great deal about the digestive physiology of birds and their relationship with food sources, by reflecting physiological constraints and therefore mechanisms of digestion. We assessed the interaction between diet concentration and sugar-type preferences of four nectarivorous species (red wattlebird, rainbow lorikeet, New Holland honeyeater, singing honeyeater) and two frugivorous species (silvereye, mistletoebird). Each individual bird was offered paired energetically-equivalent diets: a sucrose solution and hexose (1:1 mixture of glucose:fructose) solution over a range of diet concentrations from 0•075 to 2 mol/L Sucrose Equivalents (SE). All species demonstrated a preference for hexose over sucrose on dilute diets and sucrose (or no) preference on concentrated diets, but differed in terms of when this preference switch took place. One physiological constraint that may influence a preference for hexose solutions on dilute diets is the level of intestinal sucrase activity, which we assessed in five of the six study species. Sucrase activity was lowest in birds that displayed a significant hexose preference for a higher range of diet concentrations, suggesting the degree of sucrase activity may determine hexose preference. Sucrose preference at higher concentrations may possibly be explained by taste perception due to differences in solution osmolality, or may reflect a degree of imprinting due to experience with natural nectar compositions.

120.4 NEDVED, B.T.*; ASAHINA, A.Y.; HAFIELD, M.G.; Univ. Hawaii; *nedved@hawaii.edu*

The apical sensory organ is not required for the initiation of metamorphosis in larvae of Hydroides elegans

Larvae of the serpulid polychaete *Hydroides elegans*, like most lophotrochozoans, possess an anteriorly-positioned apical sensory organ (ASO). Larvae of *H. elegans* are induced to metamorphose by bacterial biofilms and, prior to settlement, explore inductive surfaces by repeatedly touching the ASO and surrounding tissue onto biofilms. Due to this behavior it has been assumed that the ASO acts as a chemosensory organ and its stimulation is required for the initiation of metamorphosis. However, there is little evidence to support this hypothesis. In this study, a targeted laser-ablation system was utilized to destroy the ASO in competent larvae of *H. elegans*. After ablation, larvae were split into three treatment groups: (1) larvae challenged with bacterial biofilm; (2) larvae challenged only with filtered seawater (FSW); and (3) larvae kept to assess cellular damage within the ASO. The percentage of metamorphosis was determined for larvae in treatments 1 and 2 after 24 h. For larvae in treatment 3, FMRF-amide antibodies and confocal laser scanning microscopy (CLSM) were used to assess the damage caused by the laser ablations. There are numerous FMRF-amide immunoreactive cells in the ASO and surrounding tissues. The presence or absence of these cells was used to estimate damage caused by the laser. Five or six laser pulses caused extensive damage to the ASO and surrounding cells but did not inhibit metamorphosis. These data suggest that the ASO is not the site for the perception of stimulatory cues and that other chemosensory cells in the episphere of larvae must act as the receptors of metamorphic cues.

111.5 NEMETH, Zoltan*; RAMENOFSKY, Marilyn; University of California, Davis; *znemeth05@gmail.com*

Gonadal androgen and development of vernal migratory condition in Gambel's White-crowned Sparrow

The influence of the gonads on development of vernal migration has been shown to be important as low levels of circulating androgen - testosterone (T) & 5α dihydrotestosterone (DHT) - experienced during the early stages of increasing daylengths are necessary for the development of hyperphagia and premigratory fattening. However, few have addressed effects of wintering levels on the onset of nocturnal migratory restlessness. We eliminated the influence of the gonads by castrating male White-crowned Sparrows before the winter solstice (pre-solstice) and investigated the effects of short-term (16 days) T replacement during winter (post-solstice) on the development of premigratory fattening, muscle hypertrophy, prealternate molt, cloacal protuberance (CP) and nocturnal migratory restlessness in birds held on natural local photoperiod. T replacement increased flight muscle size and fattening directly and post-implant initiated development of nocturnal migratory restlessness. Onset of nocturnal restlessness in these birds coincided with timing of spring departure of the local, free-living White-crowned Sparrow population and preceded the development of migratory activity of control (sham operated) birds by about two weeks. Castrated vehicle controls showed suppressed nocturnal restlessness, lower fat and flight muscle size, as well as reduced CP development. Prealternate molt was slightly delayed in castrated birds relative to sham controls regardless of T replacement treatment. Our study furthers the idea that gonadal androgen is important for development of vernal migration with both immediate and long-term effects on the behavior and physiology of the migration program.

113.2 NGO, V.*; MCHENRY, M.J.; Univ. of California, Irvine; *vngo3@uci.edu*

Swimming at intermediate Reynolds numbers in water boatmen

A wide diversity of aquatic animals swim at intermediate Reynolds numbers, where both inertial or viscous forces may contribute to propulsion. Here we studied the relative importance of these forces during the powerstroke of the lesser water boatmen (*Corixa punctata*) through a novel approach for estimating force coefficients in a freely swimming animal. Due to a large range in body length (1 mm to 10mm), these animals span a 100-fold difference in Reynolds numbers ($200 < Re < 30{,}000$). We used high-speed video of forward swimming to measure the kinematics of the propulsive appendage. We modeled the thrust generated by this motion using a quasi-steady, blade-element approach. For each swimming sequence recorded, this model provided the basis for an optimization algorithm that iteratively determined the thrust coefficient of the swimmer during a powerstroke. Using this method to calculate the coefficients of individuals of different sizes, we determined that the thrust coefficient varies little with Reynolds number. This finding suggests that the thrust generated by the appendage is dominated by inertial fluid forces throughout the large range in Reynolds numbers spanned by these animals during swimming. Therefore, boatmen of very different sizes swim with similar hydrodynamics.

24.4 NICODEMO, Philip*; JAYNE, Bruce C.; Univ. of Cincinnati; *nicodepp@mail.uc.edu*

Longitudinal Variation in the Axial Muscles of Snakes

In snakes, as in other vertebrates, the axial muscles are segmented, but snakes are notable for having individual segments that span several vertebrae. Consequently, muscles that extend anteriorly have a constraint on their length as their origins are located closer to the skull. However, this and other aspects of longitudinal variation in axial muscle morphology are poorly documented for snakes. We compared patterns of segmentation and morphology of the anterior trunk spinalis muscle (SP) in 26 species of phylogenetically and morphologically diverse snakes with midbody lengths of SP segments ranging from 9 to 46 vertebrae. In all species the contractile tissue of a single SP segment usually originates posteriorly from multiple slips attached to several adjacent vertebrae, whereas the anterior site of insertion is a long tendon attached to a single vertebra. Generally, the anterior segment of an adjacent pair of SP muscles both originates, and inserts one vertebra anterior to the adjacent posterior segment, thus identical SP muscle origins and insertions are simply translated along the axial skeleton. Three modifications of this pattern occurred in the anterior trunk. First, the posterior-most site of origin was translated by more than one rather than a single vertebra. Second, adjacent SP segments fused to a single tendon of insertion as indicated by an increased number of muscular slips. Third, in a few highly arboreal colubrids, the anterior tendons of multiple SP segments fused, but they ultimately attached to a single vertebra. The reduction in the length of the SP segments resulted primarily from shortening tendon rather than contractile tissue. Consequently, the ratio of contractile tissue to tendon length of serial homologues varies both longitudinally within individual snakes and between different species.

S8-1.4 NIJHOUT, H. F.; Duke University; *hfn@duke.edu*
Phenotypic Plasticity and Allometry: New Models and Evolutionary Implications
The sizes of body parts of many animals often appear to be related to each other by a power law called the allometric equation. Orderly scaling relationships among body parts depend on their patterns of relative growth, and simple analyses have shown that exponential growth can lead to size relationships that are well-described by the allometric equation. Exponential growth kinetics also allow for a simple biological interpretation of the coefficients of the allometric equation. However, body parts typically do not grow with exponential kinetics and then suddenly stop. Nor do they grow for the same amount of time. The consequences of realistic growth patterns on the form of the allometry equation have been little studied. I have derived new forms of the allometric equation that assume different growth kinetics (linear, exponential and sigmoidal), and that include differences in development time. These equations can be used to analyze the effect of different causes of variation in absolute size. Variation in size can be due to variation in the duration of development, the growth rate, or the initial sizes of parts. It turns out that the form of the allometric equation and the meaning of the coefficients depend on exactly how size variation comes about. The effects of phenotypic plasticity on allometry can now be examined in new and more precise ways because it is possible to partition the effects of environment on overall size variation and on specific parameters of relative growth. Sigmoid growth kinetics lead complex allometries and I will discuss why such allometries evolve to be linear (or nearly so) in nature.

82.1 NOREN, D.P.*; HAUSER, D.D.W.; NOAA Fisheries; *dawn.noren@noaa.gov*
Using behavioral data to identify potential marine protected areas for the endangered Southern Resident killer whale
Southern Resident killer whales (*Orcinus orca*) are listed as Endangered under the U.S. Endangered Species Act (ESA). Both vessel disturbance and reduced prey availability have been identified as risk factors. Previous studies found that vessel presence reduced foraging and resting behaviors in resident killer whales and dolphins, respectively. The designation of marine protected areas where vessels are prohibited is one potential mitigation measure to reduce disturbance. For maximum benefits, protected area designation should be prioritized in regions where these animals engage in critical behaviors, such as foraging and resting. To better understand Southern Resident killer whale habitat use patterns in their ESA-designated core summer critical habitat, GIS analyses were conducted on behavioral data collected during summer months in waters surrounding the San Juan Islands, USA. Travel was observed during 70%, forage during 21%, rest during 7%, and social behavior during 2% of 571 scans. Directionality, spatial arrangement, and configuration of whales varied significantly across the four behavior states ($P<0.0001$). Dive duration, surface duration, ratio of surface duration to previous dive duration, and swimming speed also varied significantly across behavior states ($P<0.001$). Differences in diving and swimming patterns as well as directionality and spatial arrangements indicate that these behaviors likely serve distinct functions for the whales. Most behaviors occurred throughout the study area, though the occurrence of certain behavior states and spatial arrangements tended to vary geographically. In particular, foraging and resting predominantly occurred in localized regions within the core summer critical habitat. These regions could be candidate marine protected areas where killer whales are protected from vessel traffic and other human activities.

61.8 NOREN, S.R.*; WILLIAMS, T.M.; UC Santa Cruz; *norenkramer@yahoo.com*
Ontogeny Influences the Capacity for Bradycardia in Dolphins
Bradycardia is a key component of the dive response that facilitates prolonged breath-holds of marine mammals. Previous research demonstrated that mean steady-state heart rate (HR) during 2-3 min dives was greater for immature dolphins than adults and that these differences were attributable to age rather than body mass or dive duration. Here we expand the range of dive durations to include the preferred shorter duration dives (30 - 225 seconds) of bottlenose dolphin calves to examine ontogenetic control of diving bradycardia. HR was collected from dolphins (age: 1.7 years to adulthood) that were trained to submerge to 4 -5 m depth in a natural saltwater lagoon. We found that within individuals, average HR over the entire dive cycle (breath-submergence-breath) was correlated with dive duration ($P < 0.05$). In contrast, steady-state HR during submergence did not vary with dive duration. Although immature dolphins demonstrated a distinct bradycardia while diving, steady-state HR during submergence and absolute minimum HR during submergence (measured in beats per minute) decreased significantly with age for 1.7 - 5.44 year-olds ($n = 14$), where Steady-state HR = -3.19age + 60.71 ($F_{1,12} = 7.449$, $P = 0.018$) and Absolute minimum HR = -4.46 age + 60.01 ($F_{1,12} = 18.259$, $P = 0.001$). Maximum HR measured during surface intervals between dive bouts did not vary with age ($r = 0.323$, $P = 0.260$). In view of this, the primary ontogenetic change in cardiac control for diving dolphins appears to a progressive development in the intensity of bradycardia over a 4-5 year period until the level of bradycardia approaches adult capacities. Because the movement of blood gases is correlated to HR in marine mammals, these results have important implications for age-related capacities for foraging duration as well as for responding to anthropogenic disturbances.

95.2 NORRIS, DO*; VAJDA, AM; BARBER, LB; SCHOENFUSS, HL; Univ. of Colorado, Boulder, Univ. of Colorado, Denver, United States Geological Survey, Boulder CO, St. Cloud Univ., MN; *david.norris@colorado.edu*
Impacts of neuroactive and estrogenic chemicals in wastewater effluents on behavior and reproduction in freshwater fishes
The reproductive potential and survival of native freshwater fishes may be compromised in stream reaches especially in western states where large volumes of treated wastewater are discharged into relatively small-sized streams. We have investigated the impact of estrogenic and neuroactive compounds from wastewater treatment plants (WWTP) on fish behavior and reproduction. This effluent contains endocrine-active compounds (e.g., nonylphenol, bisphenol A, and synthetic and natural reproductive steroids) as well as selective neurotransmitter reuptake inhibitors (e.g., fluoxetine, sertraline). We have identified female biased sex ratios, gonadal intersex, asynchronous ovarian development, elevated vitellogenin, and other forms of reproductive disruption in feral white suckers (*Catostomus commersoni*) collected downstream of WWTP effluents but not at reference sites. Fluoxetine, sertraline and their metabolites were present in the brains of white suckers. Controlled exposure of adult male fathead minnows (*Pimephales promelas*) to either WWTP effluent, upstream water or mixtures using a mobile flow-through laboratory located at the WWTP confirmed the estrogenicity of the effluent. Analysis of museum specimens of white suckers and fathead minnows collected between 50 and 100 years ago from these field sites reveals no evidence of reproductive disruption. Escape behaviors are impaired in laboratory studies of hatchling fathead minnows exposed to environmentally relevant concentrations of fluoxetine (25, 125, or 250 ng/L).

70.3 NOURABADI, Neda*; NISHIGUCHI, Michele K.; New Mexico State University; *nedan@nmsu.edu*

The role of sensor regulator loci that mediate anaerobic respiration in host symbiotic competence of the Euprymna-Vibrio mutualism

The bioluminescent bacterium *Vibrio fischeri* and its sepiolid squid host *Euprymna tasmanica* has been a valuable model to underpin the mechanisms of recognition and specificity during the onset of symbiosis. Each partner recognizes and responds to one another in a molecular "cross-talk" within the host's nascent light-emitting organ during the association. *Vibrio* bacteria can modulate their behavior through complex systematic interactions of different transcription factors, which can modulate gene transcription and therefore functions specific to the association. One example is the enzymes of the citric acid cycle during oxygen fluctuations. Coding genes are regulated mainly at the transcriptional level by the *arcA/B* two-component regulatory system, as well as *cysB*, which functions in the regulation of cysteine biosynthetic enzymes. Therefore, *arcA/B* and *cysB* are global regulators that control a number of genes involved in various metabolic pathways. We examined the physiological and metabolic consequences of mutation within these key regulatory loci among various strains of *V. fischeri* and measured their response under aerobic/anaerobic conditions. We hypothesized that *arcA/B* and *cysB* are responsible for utilization of carbon sources during anaerobic stress, and mutation of these genes will decouple the control of acidic by-products in the light organ. Thus, the major roles of *arcA/B* and *cysB* loci contribute to the physiological control under anaerobic stress during colonization of *V. fischeri* within the host squid light organ. Determining which molecular signals are responsible for establishing a successful association will help us better understand the subtle cues responsible for specificity in this environmentally transmitted mutualism.

24.3 NOWROOZI, Bryan N*; BRAINERD, Elizabeth L; Brown University; *bryan_nowroozi@brown.edu*

Mechanics and kinematics of the vertebral column in striped bass, Morone saxatilis

Variation in body stiffness impacts propulsive wave propagation and thrust generation during axial undulatory locomotion in fishes. The connective tissues of the vertebral column have been implicated in the regionalization of body stiffness and elastic recoil during locomotion. However, it is unclear which aspects of vertebral morphology are important to body stiffness, and to what extent vertebral stiffness impacts locomotion. The present study investigates the variation in angular stiffness and kinematics of intervertebral joints (IVJs) along the length of the striped bass, *Morone saxatilis*. We performed cyclic dynamic testing on IVJs postmortem at three frequencies (2, 5, and 7 Hz). Testing of IVJs from the cervical (joint 3), abdominal (joint 9), and caudal (joint 20) regions of five fish revealed lower angular stiffness in the caudal and cervical regions relative to the abdominal region. In addition, a substantial neutral zone of bending, where the IVJs bend freely without resistance, begins at 0° and ranges up to 12° in the cervical region, 10° in the abdominal region, and 15° in the caudal region. Hysteresis was fairly high (30-40%) in all regions. Additionally, high-speed fluoroscopy revealed that the maximum angles of IVJ bending attained *in vivo* lie within the neutral zone of bending. Using these kinematic and mechanical data, we estimate the magnitude of energy returned to the system by each cervical, abdominal, and caudal IVJ to be 9.0 x 10-5 J, 3.5 x 10-4 J, and 1.9 x 10-4 J, respectively. Taking into account the 24 IVJs present in a single fish, these elastic recoil estimates sum to just 1.2% of the 17.5 W of muscle power required during burst swimming. Thus, it is unlikely that the vertebral column of the striped bass provides substantial contributions to whole body stiffness and elastic recoil *in vivo*.

50.5 NUNZIATA, Schyler O*; LANCE, Stacey L; SCOTT, David E; University of Georgia, Savannah River Ecology Lab; *schylernunziata@gmail.com*

Genetic and demographic patterns of populations of Ambystoma opacum

Population genetic studies often focus on conserving genetic diversity, which is affected by gene flow and effective population size (Ne). Although the importance of Ne is well accepted in maintaining genetic diversity, there is still a lack of understanding on how to measure Ne and factors impacting it. In this study, we used both demographic and genetic methods to estimate Ne in two populations of marbled salamanders, *Ambystoma opacum*. For genetic analyses we subsampled two isolated wetland populations, Rainbow Bay (RB) and Ginger's Bay (GB), on the Savannah River Site (SC) over a 20-yr period. The numbers of breeding adults (N) and their offspring are known for 30 yrs for RB and 15 yrs for GB. *A. opacum* colonized the RB wetland in 1980 and the population has steadily expanded; the GB population has remained relatively large and stable over this same time period. To calculate Ne with demographic models we used field estimates of longevity, sex ratio, generation time, and breeding success. For genetic estimates we screened samples across 12 microsatellite loci to determine Ne and other classical population genetic parameters (Ho, allelic richness). Genetic methods of determining Ne gave markedly lower estimates than demographic methods, with Ne/N ranging from 0.01-0.11. Both the RB and GB populations incur complete reproductive failure in some years due to early pond drying; failure is more frequent at RB. Zero recruitment years may cause a bias in both demographic and genetic estimates of Ne. In particular, the demographic estimate of Ne does not account for high juvenile mortality, which may partly explain the departure from genetic estimates of Ne. Our results provide important information on what factors should be incorporated into models for estimating Ne.

67.3 OKAMURA, Beth*; HUMPHRIES, Stuart; GRUHL, Alexander; Natural History Museum, London, University of Hull, UK; *b.okamura@nhm.ac.uk*

Buddenbrockia plumatellae: a novel solution to being a worm

The enigmatic Buddenbrockia plumatellae is a worm-like endoparasite of freshwater bryozoans. In 2002 it was demonstrated to belong to the Myxozoa. More recent evidence places the Myxozoa within the Cnidaria, thereby implying an adaptive radiation of endoparasitic cnidarians that have evolved to exploit freshwater, marine and terrestrial hosts. Buddenbrockia is unique in retaining morphological features that have otherwise been lost in the rest of the Myxozoa. In particular, Buddenbrockia possesses a set of 4 muscle blocks that run the length of the worm. The muscle configuration and associated movements of Buddenbrockia are reminiscent of nematodes. However, our confocal studies reveal a unique muscle architecture involving slightly obliquely-orientated muscle fibres within each muscle block and an intervening row of cells rich in circumferentially-orientated actin filaments between the muscle blocks. Videos reveal that the movements effected by this muscle system are not characteristic of nematodes. Here we consider how the muscle architecture of Buddenbrockia provides a foundation for movement that differs from systems utilised in other worm-like/soft bodied animals (conventional hydrostatic skeletons, muscular hydrostats). Buddenbrockia illustrates a novel solution to being a worm by cobbling together elements derived from a limited cnidarian morphological toolkit.

12.2 OLIPHANT, A*; THATJE, S; BROWN, A; MORINI, M; RAVAUX, J; SHILLITO, B; SMITH, F; REED, A; University of Southampton, UniversitÃ© Pierre et Marie Curie;
Andrew.Oliphant@noc.soton.ac.uk
Insights into the physiological adaptations of caridean shrimp to hydrothermal vent living: implications for colonization
Palaemonetes varians, a shallow-living palaemonid shrimp, and *Mirocaris fortunata*, a deep-sea hydrothermal vent bresiliid shrimp, both inhabit environments with highly fluctuating water temperatures. Given the close taxonomic relationship between palaemonid and bresiliid shrimp, physiological comparisons may provide insights into adaptations required for life in the vent environment. In this study, adult *P. varians* were subjected to a temperature/pressure regime from 5 to 30°C and from 0.1 to 30 MPa; oxygen consumption rates and behaviour in response to these conditions were assessed. *P. varians* showed increasing pressure sensitivity with decreasing temperature; however, shrimp were capable of tolerating pressures found outside their normal bathymetric distribution at all temperatures. Respiratory response of adult *P. varians* and *M. fortunata* to acute temperature shock demonstrated that *M. fortunata* had a lower oxygen consumption rate than *P. varians* at all temperatures, indicating lower metabolic costs and greater tolerance of highly fluctuating temperature. During temperature preference experiments, *M. fortunata* (19.2 ± 1.1°C) selected a higher average temperature than *P. varians* (18.3 ± 0.9°C). The similar temperature physiology of *P. varians* and *M. fortunata*, and *P. varians*' pressure tolerance indicate that the common ancestor of both species was probably eurybathyal and eurythermal; physiological attributes which persist in these extant species.

44.3 OLSEN, A.M.*; WESTNEAT, M.W.; University of Chicago, IL, Field Museum of Natural History, Chicago, IL;
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Beyond the Beak: Modeling avian cranial kinesis and the evolution of bird skull shapes
Bird beaks display remarkable morphological, functional and mechanical diversity. While there is considerable literature on the evolutionary morphology of bird beaks and the relationship between beak morphology and ecology, the beak itself (the upper and lower bill) constitutes only two of nine links in the avian jaw apparatus. Cranial kinesis, or movement of the upper bill, depends on kinetic bones behind the upper bill that form four- and five-bar linkage mechanisms, or closed loops of interjointed bones. The upper bill, jugal, quadrate and skull comprise the four-bar linkage while the five-bar linkage includes the upper bill, palatine, pterygoid, quadrate and skull with the palatine or a palatine-pterygoid complex moving as a sliding link. Since the position of one link in a linkage mechanism is dependent on the position of all the other links, biological linkage mechanisms are particularly informative for inferring the mechanical properties of musculoskeletal systems from morphology. We have developed a three-dimensional linkage model of avian cranial kinesis that predicts the kinematics of the beak and its associated linkage bones as well as the distribution of forces throughout the mechanism by static force analysis. We have found that morphological diversity of the avian jaw extends beyond the beak to include the linkage bones underlying the beak. Using our model, we predict that this geometric diversity of the entire cranial linkage mechanism results in mechanical diversity not apparent from considerations of beak morphology alone. Placing these results into a phylogenetic context will provide insights into the evolution of beak function and to what extent cranial bones other than those of the upper and lower bill have influenced beak evolution. Supported by NSF GRFP to AMO and NSF DEB-0844745 to MWW.

100.2 ORR, T.J.*; HAMMOND, K.A.; ORTEGA, J.; Univ. of California, Riverside, PolitÃ©cnico Nacional, D.F., Mexico;
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The effects of reproductive state on dietary shifts in Jamaican fruit bats Artibeus jamaicensis
Bats display an impressive diversity of dietary niches. This variation includes frugivory in many neotropical bats. Fruit however, is nitrogen poor and during reproduction frugivorous bats are expected to be nitrogen-limited. Insects provide a good source of protein and many otherwise frugivorous bats have been observed including insects in their diet faculatively. It has remained unclear if this incorporation is seasonally or physiologically determined. We expected females of *Artibeus jamaicensis*, the Jamaican fruit bat, and the closely related Mexican endemic species *Artibeus hirsutus*, the hairy tailed fruit bat to supplement their frugivorous diets with insects during the nitrogen demanding periods of late stage pregnancy and lactation. We measured naturally occurring stable isotopes of nitrogen (δ15N) to examine the roles of fruit vs. insects in the diets of these two bat species. Because isotopic composition of an animal's tissues reflects its diet we evaluated δ15N of plasma to assess trophic level differences among individuals of variable reproductive states. Our data indicate that males exhibited the narrowest dietary breadth-widths and lactating females the greatest. The highest δ15N values and consequently largest portion of insect usages were noted in pregnant females. As expected, pups were enriched relative to their mothers. Our isotopic data combined with dietary (seed and fecal) samples from under roosts indicate that, while fruits remain an important part of these bats diets, insects may be an extremely valuable source of nitrogen during reproduction. We discuss individual dietary differences observed in Puebla and Morelos, Mexico and the importance of this variation as well as the prevalence of dietary supplementation with insects among frugivorous bats in general.

81.3 OUFIERO, Christopher E.*; HOLZMAN, Roi; WAINWRIGHT, Peter C.; Univ. of California, Davis;
ceoufiero@ucdavis.edu
The diversity of strike kinematics in serranid fishes: support for the ram-suction continuum
Suction feeding, the most common form of prey capture in fish has been well characterized in relation to its biomechanics and morphology; yet, little is known about the underlying constituents for the diversity in this trait. We used principal component analysis to determine the major axes of variation in kinematics, morphology, and mechanics of suction feeding across 30 species of serranid fishes. We also examined correlations among traits to test for expected trade-offs. Prey capture sequences using fish prey were filmed at 1000 Hz. Between 5-10 sequences were filmed for 1-5 individuals per species for a total of 227 sequences. We tracked 11 landmarks throughout each sequence, generating 18 kinematic variables. Body size-corrected species means of traits were used in the PCA. PC1 (30%) distinguished species with a longer strike distance, fast ram speed, high head and lower jaw rotations from species with shorter, slower strikes with less movement; PC2 (24%) was a speed/timing trade-off axis and PC3 (18%) was correlated positively with suction index, lower jaw opening mechanical advantage, residual gape and jaw protrusion. In contrast to common expectations we found no significant correlation between ram speed and maximum jaw protrusion ($r = 0.21$, $p = 0.26$) or lower jaw opening mechanical advantage and jaw opening speed ($r = 0.04$, $p = 0.83$). However, we did find a significant trade-off between suction index with ram speed ($r = -0.38$, $p = 0.04$) and residual strike distance ($r = -0.42$, $p = 0.02$), which was also supported in the PCA. These results support the proposed ram-suction continuum, whereby a negative correlation between ram speed and suction reflects alternative strategies for closing the final distance between the predator and prey.

61.6 OWERKOWICZ, T*; CAMPBELL, C; EME, J; BLANK, JM; HICKS, JW; California State Uni, San Bernardino, Uni California, Irvine, Uni North Texas, Denton, California Polytechnic State Uni, San Luis Obispo; *towerkow@csusb.edu*
Cardiac hypertrophy in response to pressure overload and exercise training in the American alligator
In mammals, cardiac hypertrophy is often categorized as physiologic or pathologic based on the degree of interstitial fibrosis in the ventricular myocardium. Physiologic (muscular) hypertrophy is an expected response to regular exercise, and pathologic (fibrotic) hypertrophy is seen in mammals faced with chronic pressure overload (e.g., aortic banding). We investigated whether these stressors can drive similar cardiac phenotypes in a non-mammalian model with a four-chambered heart, the American alligator. In earlier studies, surgical ablation of the left aorta (LAo), which exits the right ventricle and allows for potential pulmonary bypass (R-L shunt), resulted in chronic pressure overload, with doubled peak systolic pressures in both ventricles. Juvenile alligators, which had undergone LAo ablation as hatchlings, had greater wet ventricular mass (+65%) and higher DNA content (1.5-3 fold) than sham-operated controls. In order to characterize the histologic nature of this impressive hypertrophy, we compared ventricular cross-sections (stained with Masson's trichrome) from alligators with and without the LAo. Animals were either sedentary or exercised to exhaustion (treadmill, flume) every other day. As expected, no significant differences existed in myocardial composition between three exercise groups. Surprisingly, the proportion of myocardial fibrosis was significantly lower in alligators without the R-L shunt, which suggests that their hypertrophy was based on myocyte growth. Whether other vertebrate taxa are capable of similar cardiac plasticity in response to pressure overload remains to be investigated. Funded by NSF IOB 00445680 to JWH.

11.1 OWERKOWICZ, T; YANG, J*; BLANK, JM; EME, J; HICKS, JW; California State Uni, San Bernardino, California Polytechnic State Uni, San Luis Obispo, Uni North Texas, Uni California, Irvine; *towerkow@csusb.edu*
Alligator growth plate thickness as indicator of longitudinal growth rate and circulatory pattern
Avian and non-avian dinosaurs possess long bone growth plates with a convoluted chondro-osseous border. This similarity has been used to argue that the avian-style developmental pattern evolved before the origin of birds. In order to test whether such growth plate microstructure is indeed a synapomorphy of dinosaurs, and whether growth plate thickness can be used as an indicator of skeletal growth rate, we studied the microstructure of the femoral growth plates of juvenile female alligators raised for two years under laboratory conditions. Some of the animals (n=24) had undergone surgery to ablate their left aorta and alter their circulatory pattern from in-parallel to in-series, whereas others (n=36) were sham operated. All animals received injections of fluorochrome dyes (calcein and alizarin), to determine their mineral apposition rates. We quantified the height of the calcified cartilage columns (CCC) of the growth plate, and longitudinal growth rate (LGR) of the femur. We found CCC height correlates with LGR, and is significantly augmented (+35%) in alligators with in-series circulation compared to similarly-sized sham controls with in-parallel circulation. We suggest the highly interdigitated chondro-osseous junction is an ancestral character of archosaurs and its presence in fossils of non-avian dinosaurs does not imply an avian-style physiology. We propose thicker growth plates appeared concurrently with the origin of in-series circulation, and may thus have set the stage for later acquisition of fast growth and endothermic metabolism of birds. Funded by NSF IOB 00445680 to JWH.

S3-2.1 OYARZUN, FX*; GRüNBAUM, D; University of Washington, Seattle; *fernanda.oyarzun@gmail.com*
Two reproductive strategies and their implications for population dynamics: An individual-based model of the poecilogonous spionid Boccardia proboscidea
Poecilogony is the ability of some marine invertebrate species to alternate between multiple developmental modes. The spionid polychaete *Boccardia proboscidea* has three different reproductive modes, including one in which all eggs inside capsules develop as planktotrophic larvae and another in which capsules have approximately 90% nurse eggs and a mixture of planktotrophic and adelphophagic larvae. In this study, we used an individual-based model to explore the implications of these two strategies for population dynamics under different environmental conditions and at different reproductive rates. The model was very sensitive to planktotrophic larval mortality in the pelagic phase, and to catastrophic events in the benthic environment. In addition, reproductive females using the mixed-strategy reproductive mode performed better than individuals that produced only planktotrophic larvae, under low disturbance and reproductive rates. The model was useful in identifying gaps in knowledge, such as mortality rates in the plankton, and in elucidating the implications of current knowledge about this species.

51.6 OZPOLAT, B. D.*; ZATTARA, E. E.; BELY, A. E.; University of Maryland, College Park; *bozpolat@umd.edu*
piwi expression during regeneration in the annelid Pristina leidyi
Identifying the cell types that participate in regeneration and understanding their molecular characteristics is crucial for dissecting the mechanisms of regeneration. Annelid worms have long been used in regeneration research and early studies identified putative stem cells called neoblasts believed to migrate to the wound and participate in regeneration. While there is a substantial early literature on the histology and cytology of migratory cells such as neoblasts, only recently have tools become available to investigate their molecular and behavioral characteristics. *Pristina leidyi*, a freshwater annelid, is able to regenerate both anteriorly and posteriorly and recent time-lapse imaging studies in our lab provide definitive evidence for widespread cell migration towards cut sites. In this study, we investigate the expression of several stem cell markers during regeneration and ask whether there are distinct populations of migratory cells that express these markers differentially. Here we focus on the gene *piwi*, which is required for regeneration and/or germline function in diverse metazoans. We find that *piwi* is dynamically and strongly expressed in the regeneration blastema and primordial gonads, as well as fission zone and posterior growth zone. In addition, *piwi* is expressed in a population of ventral cells that appear to be migrating along the length of the body between the gut and ventral nerve cord. Interestingly, no *piwi* expression is detected in the other migratory cell populations identified by time-lapse imaging. Thus, there are at least two distinct populations of cells that migrate after injury. Future studies are aimed at identifying additional molecular markers for these distinct populations and investigating their function during regeneration.

25.4 PADILLA, D.K.*; SHUMWAY, S.E.; MCCANN, M.J.; HEUPEL, E.; HOLOHAN, B.; WARD, J.E.; Stony Brook University, New York, University of Connecticut, Stony Brook University; *dianna.padilla@sunysb.edu*
How do little suspension feeders make it: larval diet and post metamorphic survivorship, growth and feeding in Crepidula fornicata.
Understanding the adaptability of individuals in the face of environmental change is fundamentally important for assessing the resilience of populations and the robustness of performance. Limits on early life stages can create bottlenecks for later life stages of organisms. Aquatic invertebrates are very small at early life stages, and face hydrodynamic constraints as a function of that small size. All organisms undergo changes in size during ontogeny. Morphological and physiological systems often have size-dependent functions, i.e., all features of organisms cannot be expected to function similarly as individuals change size through ontogeny, which creates challenges for organisms with respect to metabolism and food acquisition among other functions. Suspension-feeding animals, especially molluscs, are ecologically important organisms in most aquatic habitats, provide important ecosystem functions. Their ability to suspension feed effectively, especially at a small size has been questioned due to differences between metabolic demands and energy acquisition. Performance of small individuals, especially those just past metamorphosis, thus may pose an important bottleneck for molluscan suspension feeders. We conducted experiments to test the relative importance of the larval diet on survival at metamorphosis and post metamorphic survivorship and growth in *Crepidula fornicata*, when individuals were allowed to feed only on suspended microalage. In addition, we used videomicroscopy to assess particle capture rates and the mechanism of suspension feeding in newly metamorphosed and juvenile animals.

39.3 PAINTER, M.S.*; DOMMER, D.H.; GNIRKE, M; TRAN, D; MOORE, B; PHILLIPS, J.B.; Virginia Tech; *mipainte@vt.edu*
Characterizing the Light-dependent Magnetic Compass of Drosophila melanogaster
The use of geomagnetic field cues during orientation, navigation, and homing behavior has been demonstrated in a diverse array of organisms, ranging from bacteria to vertebrates, yet the putative receptors and mechanisms underlying this behavior remain elusive. Both theoretical and empirical evidence from birds, amphibians, and insects suggest these behaviors are mediated by a light-dependent magnetic compass (LDMC) involving a magnetically sensitive biochemical reaction that forms long-lived radical pair intermediates. Cryptochrome's have been proposed as likely candidates mediating the LDMC, as they are the only animal photoreceptor known to form radical pair intermediates. Furthermore, the wavelength-dependence of the magnetic compass responses in insects and amphibians are consistent with the absorption spectra of the fully reduced and radical forms of the cryptochrome flavin chromophore; the magnetic field's effect on a photo-equilibrium between these two redox forms has been proposed to underlie the LDMC. Experiments are currently being carried out to obtain a detailed spectral dependence curve for the magnetic compass response of larval *Drosophila melanogaster*. Larval flies will be tested under monochromatic light varying in wavelength from 370nm to 640nm (at 30nm intervals) of equal light intensity. The spectral dependence of the larval LDMC will be compared to the absorption spectra of the two redox states of DmCry, as well of those of other candidate molecules. Characterizing the magnetic compass used by larval flies will fill critical gaps in our understanding of the biophysical mechanism underlying the light-dependent magnetic compass.

36.8 PALMER, A. Richard; University of Alberta; *rich.palmer@ualberta.ca*
Developmental plasticity and the origin of novel forms: Unveiling of cryptic genetic variation via 'use and disuse'
Natural selection eliminates phenotypic variation from populations, generation after generation ... an observation that haunted Darwin. So, how does new phenotypic variation arise, and is it always random with respect to fitness? Repeated behavioral responses to a novel environment — particularly those that are learned — are typically advantageous. If those behaviors yield more extreme or novel morphological variants via developmental plasticity, then previously cryptic genetic variation may be exposed to natural selection. Significantly, because the mean phenotypic effect of 'use and disuse' is also typically favorable, previously cryptic genetic variation can be transformed into phenotypic variation that is both visible to selection and biased in an adaptive direction. Therefore, use-induced developmental plasticity in a real sense "creates" new phenotypic variation that is non-random with respect to fitness, in contrast to the random phenotypic effects of mutation, recombination and 'direct effects' of environment (stress, nutrition). Furthermore, intermediate levels of developmental plasticity may enhance the 'detection' of cryptic genetic variation in organisms the same way that intermediate levels of noise enhances signal detection in signal-detection systems via 'stochastic resonance'. I will present a) a simple, general model illustrating how cryptic genetic variation may be exposed to selection by developmentally plastic responses that alter trait performance in response to 'use and disuse', and b) a more detailed model of, and evidence for, a positive feedback loop between learning (handed behavior) and morphological plasticity (use-induced morphological asymmetry) that may rapidly generate novel, functionally and evolutionarily significant phenotypic variation.

19.5 PARIKH, S.C.*; MARA, K.R.; HSIEH, S.T.; Temple University, Temple Unviersity; *sachincp16@temple.edu*
Does the SLIP Model Apply During Inverted Running in Cockroaches?
Center of mass (COM) dynamics during upright locomotion is described by the spring loaded inverted pendulum (SLIP) model. According to this model, gravity pulls the COM towards the surface, compressing the virtual leg spring. However, many animals, including cockroaches, have the ability to traverse inverted surfaces. When running upside-down, gravity pulls the COM away from the locomotor surface, extending the virtual leg spring. The goal of this study was to assess the applicability of the SLIP model during inverted running in the orange head cockroach (*Eublaberus prosticus*). Cockroaches were run on upright and inverted surfaces while being filmed with a high-speed camera at 250 fps. A 45° mirror provided simultaneous dorsal and lateral views. Points were digitized and transformed from 2D to 3D coordinates using custom digitizing software in MATLAB (DLTdataViewer). We expected inverted running COM kinematics would not reflect SLIP model predictions. Contrary to our expectations, when running upside-down, cockroaches exhibit very similar COM kinematics compared to normal, upright runs. Nevertheless, our results do highlight considerable differences in COM position and footfall patterns. While running invertedly, cockroaches shift their COM posteriorly and further from the surface, at the same time positioning their front and hind limbs further medially and laterally, respectively. In addition, the tripod gait typically observed during upright runs was not as stereotyped during inverted locomotion. Inverted locomotion may therefore require a change in leg movement and placement to maintain, at the very least, altered SLIP kinematics for forward progression.

29.1 PASSAMANECK, Y.J.*; SCHIEMANN, S.; MARTINDALE, M.Q.; HEJNOL, A.; Kewalo Marine Laboratory, Univ. of Hawaii, Sars International Centre for Marine Molecular Biology, Bergen, Norway; *yale@hawaii.edu*

Regulation of larval chaetogenesis in the brachiopod Terebratalia tranversa by Notch/Delta signaling

Chitinous bristles (termed chaetae or setae) occur in the larvae and adults of both articulate and inarticulate brachiopods, and are likely plesiomorphic for the Brachiopoda as a whole. Ultrastructural studies have evidenced that brachiopod chaetae share significant morphological similarities with the chaetae of annelids, presenting the possibility that the structures in the two taxa may be homologous. To gain insight into the molecular mechanisms underlying chaetogenesis in brachiopods, we have investigated the formation of the larval chaetae in the inarticulate brachiopod *Terebratalia transversa*. In *T. transversa* four bundles of chaetae are formed at the margin of the mantle lobe during larval development. By comparative analysis of conserved cell-cell signal pathways, we have determined that the core components of the Notch/Delta signaling pathway are expressed in a pattern consistent with the location of the chaetoblast cells, suggesting a possible role for this pathway in the regulation of chaetogenesis. To test the role of the Notch/Delta signaling, developing larvae were treated with DAPT, a gamma-secretase inhibitor that blocks Notch signal transduction. Larvae exposed to DAPT failed to form chaetae, evidencing a role for Notch/Delta signaling in regulating larval chaetogenesis.

90.1 PATEL, K*; WILLIAMS, K; FRICK, M; ROSTAL, D; GSU, Caretta Project; *patelkv@hendrix.edu*

Variation in Egg Components: A Study of Maternal Investment and Resource Partitioning in the Nesting Loggerhead Sea Turtle.

Understanding maternal contributions and strategies in reproduction can reflect how resources are allocated in response to resource availability and physiological constraints of the mother. Sea turtles have the highest egg yields of any oviparous non-avian reptiles, laying from 50-130 eggs multiple times in a nesting season. Each clutch represents 1-10 % of a female's total body mass. Loggerhead sea turtles have high seasonal fecundity and display little variation in egg size, and instead maximize clutch size. This study was conducted on Wassaw Island National Wildlife Refuge during the 2008-2010 nesting seasons. Comparisons of wet and dry egg mass were made to assess the direct maternal effects. Wet egg mass and albumen mass ($0.01 < p < 0.025$) significantly decreased across the nesting season however, wet yolk did not. Dry component analysis showed that dry yolk ($P = 0.1732$) and albumen ($0.1 < p < 0.5$) did not differ across the nesting season. Results of ash free dry mass analysis showed that there is no difference in the ratio of organic vs. inorganic material in albumen or yolk throughout the nesting season($H = 0.3556$, $df = 2$, $P = 0.8371$ and $H= 1.8667$, $df = 2.$, $P = 0.3932$, respectively). Bomb calorimetry data showed that there was no variation between periods of the nesting season. In addition, results show that dry yolk mass has a stronger correlation to caloric content than wet yolk mass and eggs with bigger yolks had overall more caloric content. This study also shows that females are providing the same amount of albumen and yolk to all clutches but differing amounts of water. Due to the rainfall pattern, the decrease in water allocated to the eggs is compensated by the rise in rainfall during the incubation period. This study supports the conclusion that in C. caretta, hatchling size, not egg size, is being selected for.

27.3 PATHI, B.; KINSEY, S.T.*; HOWDESHELL, M.E.; PRIESTER, C.; MCNEILL, R.S.; LOCKE, B.R. ; Florida State Univ., UNC Wilmington; *kinseys@uncw.edu*

Can spatial variation in mitochondrial degradation predict mitochondrial distribution in skeletal muscle?

Mitochondrial density is governed by the balance between biogenesis and degradation in skeletal muscle. However, there is no paradigm to explain the heterogeneous distribution of mitochondria, which presumably arises from spatial variation in signals that govern biogenesis and degradation. However, mitochondrial biogenesis relies on gene expression in both mitochondria and nuclei, so spatial variation in biogenesis signals is lost as the signal is propagated through the nucleus. In contrast, growing evidence suggests that mitochondria are selectively degraded via targeted mitophagy, which can be induced by low oxygen. We tested the hypotheses that (1) mitochondrial distribution in skeletal muscle is governed by biogenesis that is homogeneous across the fiber and degradation that is spatially variable and dependent on oxygen concentration, and (2) that the heterogeneous distribution of mitochondria yields a higher energetic state and greater aerobic capacity than a uniform distribution. We measured fiber size, capillarity and mitochondrial distribution in red and white fibers of dolphinfish, in white fibers that undergo a large increase in size during hypertrophic growth in black sea bass, and in 4 skeletal muscle fiber types in mouse. We compared these distributions to those predicted by a coupled mathematical model of skeletal muscle that included a reaction-diffusion model of aerobic metabolism and a cellular automata model of mitochondrial biogenesis and degradation. The model effectively predicted the observed distributions, and showed that the heterogeneous distribution of mitochondria led to a higher cellular energy state and greater aerobic capacity.

90.6 PATTERSON, Jesse; Univ. of Calgary; *jesse.patterson@ucalgary.ca*

Ectoparasites as a determinant of host litter size

Life-history theory states that offspring number and offspring size trade-off with each other, as dictated by the energetic environment of the breeder. Mammalian mothers adjust the size of their litters before birth and also during lactation in accordance with their ability to successfully wean offspring. In the present study, I investigated the role of ectoparasites as a possible determinant of litter sizes in a population of free-ranging North American red squirrels (*Tamiasciurus hudsonicus*). I hypothesized that if ectoparasites were experimentally removed from their hosts shortly after mating (approx. 30 days before birth) that mothers would have more energy to invest in their offspring during pregnancy and could invest that energy into producing more offspring. The results of the current study support this hypothesis as it was found that mothers immunized against ectoparasites at mating produced significantly more offspring at birth when compared to non-immunized controls. No litter size effect was found between mothers only immunized at birth and non-immunized controls, suggesting that the presence of parasites and the energetic environment of the mother during gestation may determine the size of the litter she gives birth to. These results indicate that ectoparasites impose strong costs on the reproductive success and life-history strategies of female red squirrels.

4.1 PECHENIK, Jan A*; JARRETT, Jerry; ARELLANO, Shawn; DIEDERICH, Casey; Tufts Univ., Central Connecticut State Univ., New Britain, Woods Hole Oceanographic Institution; *jan.pechenik@tufts.edu*

Exposing larvae to reduced salinity does not impact post-metamorphic growth for the marine gastropod Crepidula onyx

For animals with an ecologically distinct larval stage during development, sublethal stresses experienced before metamorphosis can decrease fitness after metamorphosis. Such "latent effects" are seen in the gastropod *Crepidula onyx* following nutritional stress in the larval stage. In the present study, early larvae were exposed to reduced salinities of 15 psu for 12-48 h, reared to metamorphic competence in full-strength seawater, induced to metamorphose, and then reared for 6 d as juveniles. Even when the stress reduced post-exposure survival and larval growth rates, and increased the duration of pre-competent development, metamorphosed juveniles survived as well and grew as quickly as control animals. Similar results were obtained using larvae of *C. fornicata*. The key issue: Why do some stresses produce latent effects while others do not?

25.3 PEPPER, Rachel E.*; ROPER, Marcus ; RYU, Sangjin; MATSUDAIRA, Paul; MATSUMOTO, Nobuyoshi; NAGAI, Moeto; STONE, Howard A.; University of California, Berkeley; *rachel.pepper@berkeley.edu*

Microscopic filter feeders near boundaries: feeding restrictions and strategies due to eddies

Microscopic sessile filter feeders are an important part of aquatic ecosystems and form a vital link in the transfer of carbon in marine food webs. These filter feeders live attached to boundaries, consume bacteria and small detritus, and are in turn eaten by larger organisms. Such filter feeders survive by creating a feeding current that draws fluid towards them, and from which they filter their food of interest. We show using calculations, simulations, and experiments that eddies form near these feeders as a result of fluid forcing near a boundary. The extent of these eddies, and their effect on the nutrient uptake of the organism depend on the angle of fluid forcing relative to the boundary. We show through calculations that feeding at an angle greatly increases the feeding efficiency of model filter feeders with perfect nutrient capture efficiency in the absence of diffusion. We also show experimental data that cultured filter feeders feed at an angle to the substrate. We discuss the effects of nutrient diffusion and inefficient nutrient capture on our model, as well as a possible mechanism for filter feeders to change their orientation.

S10-2.1 PEREZ-LOSADA, M*; HOEG, JT; ACHITUV, Y; CRANDALL, KA; CIBIO, University of Porto, Portugal, University of Copenhagen, Denmark, Bar Ilan University, Israel, Brigham Young University, USA; *mlosada323@gmail.com*

Deep phylogeny and character evolution in the Thecostraca barnacles

The Thecostraca is a highly advanced class of Crustacea. All have pelagic larvae and permanently sessile adults, but the individual taxa differ significantly in comprising both suspensions feeders and various types of parasites. A combined molecular analysis of major Thecostraca groups has allowed us for the first time to study the evolution of morphological structures and life styles in the group as a whole and in the Cirripedia Thoracica in particular. Our analyses focus on key features such as the cypris larva, suspension feeding, parasitism, shell plate armament, body shape and sexual systems. Our phylogenies indicate that the Cirripedia are monophyletic with the Ascothoracida and Facetotecta clades as successive outgroups. Using this phylogenetic framework and Bayesian methods of character reconstruction we observed that: 1) amoeboid metamorphic stages found both in the endoparasitic Rhizocephala and the presumed endoparasitic Facetotecta are convergent; 2) suspension feeding is probably plesiomorphic for all cirripeds; 3) within the Thoracica, 5-plated and naked forms evolved from multiplated ancestors, thus contradicting traditional interpretations based on fossil and ontogeny evidence; 4) asymmetric barnacles are not monophyletic since the deep sea neoverrucids do not cluster with the verrucids, which are part of the Sessilia clade together with the Balanomorpha; 5) dioecy (separate sexes) is ancestral in the Cirripedia and hermaphroditism evolved in the stem line leading to the Thoracica, although subsequent evolution of reproductive systems within the latter is complex and will require further study.

117.4 PERFITO, Nicole*; HORNICK, Kristin; NGUYEN, Sophie; DARLING, Hannah; BENTLEY, George; UC Berkeley; *nperfito@berkeley.edu*

Gene expression underlying the "decision" to initiate egg-laying: Social effects on vitellogenesis

The 'decision' by female birds to begin egg-laying is a pivotal physiological time point in reproductive timing. Once rapid final maturation of follicles begins, including the incorporation of yolk, the female is committed physiologically to a major energetic investment. While decades'-worth of ecological data correlate lay dates in the field with environmental variables (e.g. temperature), and experimental work demonstrates advancement or delay of lay dates, we understand very little about the physiological mechanisms regulating this major life-history transition. We exposed female European starlings (*Sturnus vulgaris*) to natural changes in photoperiod with differing social cues and measured gene expression in the hypothalamus, anterior pituitary gland, liver and developing ovarian follicles. A group of females was housed in outdoor aviaries with access to mates, nest boxes and ad libitum food and water. A second group was housed in identical conditions but without physical access to mates. Under 12 hour days, both groups began initial follicle development and had slightly elevated liver vitellogenin (VTG) expression. Two weeks later (12.6L), females housed with males began final follicle maturation, had begun oviposition and had elevated VTG expression. On the same day, females in an adjacent aviary without access to males showed no progression past initial follicle development, and had low VTG expression. Subsequently, males were introduced to female-only aviaries. After eight days, newly paired females had begun final maturation and had elevated VTG expression. These data are the first to demonstrate a social effect on VTG expression, and will help to tease apart effects of photoperiod and social interactions on multiple components of the HPG axis.

41.2 PERLMAN, B.M.*; ASHLEY-ROSS, M.A.; GIBB, A.C.; EARLEY, R.L.; Wake Forest University, Northern Arizona University, University of Alabama; *perlbm0@wfu.edu*

Flipping out: jumping performance of mangrove rivulus (Kryptolebias marmoratus) from different geographic locations

Mangrove rivulus (*Kryptolebias marmoratus*) inhabit brackish water habitats of often poor water quality, and perhaps as a result are found in crab burrows, hollowed out logs, or among wet leaf litter in mangrove swamps. *K. marmoratus* is capable of directed terrestrial movement via a tail-flip behavior that moves the fish several body lengths in a single jump. As the precise mechanisms underlying their terrestrial locomotion have not been described, our goal was to quantify the movements these fish make when on land. Fish representing isogenic lineages from multiple populations across their geographic range were tested, including Florida and Belize. Individual fish were placed in a wading pool covered in damp bench liner paper, and allowed to voluntarily jump for two minutes, followed immediately by a 30 second chasing trial to elicit maximal jump performance. A camera (60 fps) was placed above the wading pool to record all trials. Body movements and the following variables were quantified: number of jumps, jump trajectory, average and maximum jump distance. In a typical jump, the fish faces the stimulus, resting on its ventral side, and rotates the posterior half of its body 90°, splaying its caudal fin flat against the substrate. During the tail-flip, the fish curls its head over its tail, and pushes the tail against the substrate to spring into the air. Upon jump completion, the fish may reorient its body to face the stimulus via a squiggle, and execute another jump. Number and average and maximum jump distance decreased with increasing body length and mass. Populations varied in jump performance, suggesting habitat and morphological differences drive the observed kinematics.

10.2 PETERSON, J.D.*; STEFFEN, J.; POHLMAN, W.; MCDONALD, M.; APPEL, A.; COBINE, P.; ROLLINS-SMITH, L.; MENDONCA, M.T.; Auburn University; Troy University, Montgomery, Penn State, Erie, Auburn University, Auburn University, Vanderbilt University; *peterj1@auburn.edu*

Is chytridiomycosis a stress induced syndrome?

Chytridiomycosis, a disease caused by *Batrachochytrium dendrobatidis* (Bd), has contributed to amphibian population declines the world over, but its pathogenesis is still unclear. Infection disrupts cutaneous sodium channels, which leads to hyponatremia and cardiac failure. However, infection also has unexplained effects on appetite, skin shedding, and white blood cell (WBC) numbers. Corticosterone (CORT) may be the biochemical connection between these disparate effects, because it regulates ion homeostasis and can also influence appetite, skin shedding, and WBCs. During a lab outbreak as well as a controlled infection of Bd in *Litoria caerulea*, we compared frogs that were symptomatic for chytridiomycosis to asymptomatic as well as control frogs and determined that symptomatic frogs contained elevated baseline CORT, decreased plasma sodium and potassium, and WBC profiles that paralleled those observed following CORT treatment in other studies. Symptomatic frogs also had decreased body condition and elevated metabolic rates compared to asymptomatic frogs, as predicted by the metabolic effects of CORT in other vertebrates. Prior to becoming symptomatic, we also observed effects on appetite, body mass, and the presence of shed skin associated with these frogs. Collectively, these results suggest that elevated baseline CORT is associated with chytridiomycosis. Therefore, some of the ill effects observed during chytridiomycosis, such as alterations in WBC numbers and elevated metabolic rate, may be a secondary effect of elevated baseline CORT, not Bd.

48.4 PETIT, M*; VEZINA, F; UniversitÃ© du QuÃ©bec Ã Rimouski; *Magali.Petit@uqar.qc.ca*

Do body composition drives winter variations of metabolic performance in black-capped chickadees (Poecile atricapillus)?

Throughout the year, resident birds species living at northern latitudes exhibit changes in metabolic performance in response to seasonal variation in climatic conditions. Indeed, basal metabolic rate (BMR, reflecting minimal maintenance energy costs) and maximal thermogenic capacity (Msum, a measure of cold tolerance) are typically higher in winter relative to other seasons. BMR variations are commonly seen as reflecting the energy consumption of internal organs remaining active at rest whereas Msum, because it is the product of shivering activity, is thought to depend on muscle size. However, few studies investigated intraseasonal variations in metabolic performance and the role of organ size flexibility in this variation is unknown. Using black-capped chickadees as our model species, we measured daily variations in BMR and Msum within winter (November 2010 to March 2011). We also collected 20 birds of known metabolic performance in the beginning of winter (November), peak of cold (February) and at the end of winter (March) to study intraseasonal variations in organ size and its effect on metabolic parameters. Preliminary results show an increase in metabolic performance peaking in February and remaining high throughout the rest of winter, with a high level of variability likely reflecting daily changes in weather. These findings will be discussed in light of the observed variations in body composition.

26.4 PEYER, Suzanne M*; MCFALL-NGAI, Margaret J.; University of Wisconsin, Madison; *smpeyer@wisc.edu*

Eye-Associated Genes in the Eye and Light Organ of the Squid Euprymna scolopes

Research on visual systems has revealed conservation of eye-associated genes across animal phyla, including those involved in eye specification [*pax6* (paired box gene 6), *eya* (eyes absent), *six* (sine oculis), *dac* (dachshund)]. The squid, *Euprymna scolopes*, has evolved at least two independent sets of tissues that interact with light, a complex eye and a 'light organ' that houses the luminous bacterial symbiont *Vibrio fischeri*. Recent studies indicated biochemical similarities between the two organs, such as the presence of visual transduction proteins. Such findings prompted the question: are the two organs under the same developmental specification? We obtained light-organ sequences of each eye-specification gene (RACE-PCR) and determined whether each is expressed in the eye, the light organ, or both (RT-PCR). We localized eye-specification and visual transduction gene transcripts with *in situ* hybridization, throughout development, comparing the patterns of expression in the two organs. At least one isoform of each eye-specification gene was expressed in both organs of embryonic and early postembryonic squid. The eye-specification and visual transduction gene transcripts localized to tissues associated with the visual system ~1/4 into embryogenesis (Naef stage 20). These transcripts localized to the light organ later in development, ~3/4 into embryogenesis (Naef stage 29). We are now examining the effect of symbiosis and endogenous light on gene expression in the light organ, comparing wild-type luminous strains of *V. fischeri* to those defective in light production. Such results promise to provide evidence that eye-specification genes are critical for development of light-interacting tissues, independent of their embryonic origin.

S1-1.1 PEYRIéRAS, Nadine; Institut de Neurobiologie Alfred Fessard, CNRS; *peyriÃ©ras@inaf.cnrs-gif.fr*

A comparative analysis of gastrulation in Deuterostomians using digital embryos

Embryonic development leading from the egg cell to the whole organism can be fully described by the spatio temporal deployment of the cell lineage tree annotated with quantitative parameters for cell membrane and nucleus shape. This data can be automatically extracted from *in toto* 3D+time imaging of the developing organism and allows answering most of the questions of classical embryology such as cell fate, presumptive organs clonal history, cell proliferation rates, contribution of cell division and its characteristic features to shaping tissues and organs. These questions can be answered by using the digital specimen corresponding to the validated phenomenological reconstruction of 3D+time image data sets. Exploring cohorts of individuals with different genetic and environmental conditions allows integrating the cellular and molecular levels of organization. This approach is expected to serve as a basis for the reconstruction of multi-scale dynamics to decipher emergent and immergent features at different levels of organization. This paradigm is explored for investigating gastrulation processes in Deuterostomian species including the teleostean *Danio rerio*, the ascidian *Phallusia mammillata*, the amphioxus *Branchiostoma lanceolatum* and the sea urchin *Paracentrotus lividus*.

S5-2.2 PFALLER, Joseph B.*; FRICK, Michael G.; BRISCHOUX, Francois E. O.; SHEEHY III, Coleman M.; LILLYWHITE, Harvey B.; Univ. of Florida, Gainesville, FL, Univ. of Texas at Arlington, Arlington, TX; *jpfaller@ufl.edu*

Ecology of Epibiosis: What Can We Learn From Marine Reptiles

Epibiosis occurs when one or more typically facultative colonizers (epibionts) live on or attached to a single host (basibiont), resulting in a spatially close association between the species involved. The maintenance of such associations involves a complex suite of ecological trade-offs. The study of epibiosis in marine snakes has a rich history of ancillary reports starting with Darwin (1851, 1854), yet very few accounts quantify the frequency of these interactions. Moreover, there has been limited discussion of the ecological factors that affect these interactions and the possible role that marine snakes play as epibiont hosts. Herein, we report eight previously undocumented epibionts associated with *Pelamis platurus* inhabiting the waters off the northwest Pacific coast of Costa Rica. These novel associations include the first records of motile epibionts from any marine snake and suggest that the propensity of *P. platurus* for foraging along surface aggregations of flotsam and neustron (i.e. 'slicks') facilitate the colonization of pelagic epibionts. The primary goals of this study were to better understand these novel associations by quantifying the frequency and intensity of their occurrence, and assessing the effect of snake size on these interactions. The secondary goals of this study were to provide a review of marine snake epibiosis and discuss what marine reptiles can teach us about the ecology of epibiosis. Supported by NSF IOS–0926802 to HBL.

94.2 PFEIFFENBERGER, J.A.*; TURINGAN, R.G.; Florida Institute of Technology; *jpfeiffenber2009@my.fit.edu*

The effects of prey type on the scaling of prey capture kinematics in invasive lionfish, Pterois spp.

This recent decade has been marked by the rapid spread of the invasive lionfish, *Pterois volitans/miles* complex (henceforth referred as *Pterois* spp.) throughout the Caribbean region and the southeastern United States. This alarming event has underscored the urgent need to understand the biology and ecology of this invasive fish, specifically its ability to utilize different prey resources. Lionfish are generalist feeders; however, juvenile fish consume proportionally more crustaceans than adult fish. In an attempt to contribute to our understanding of the feeding biology of the invasive lionfish, this study was designed to (1) explore the ontogeny of prey-capture kinematics and (2) determine the effects of prey type on the scaling of prey-capture kinematics in the Florida population of *Pterois* spp. Each of the 17 lionfish, ranging in standard length from 39mm to 151mm, was fed two prey types (teleost, *Gambusia* spp. and crustacean, *Paleomentes* spp.) while being filmed multiple times using high-speed videography. All fish aggressively fed on both prey types. Excursion-kinematic variables, such as peak gape scaled isometrically with body size and timing-kinematic variables, such as time to peak gape, scaled allometrically with body size. These scaling relationships were consistent between prey types. It is hypothesized that the invasive lionfish utilizes stereotypical prey-capture kinematics and behavior to feed on a variety of prey organisms. It is conceivable that the ability of *Pterois* spp. to feed on any locally available prey type using a conserved feeding repertoire facilitates its ability to establish viable populations in newly invaded habitats and to continue extending its range of invaded distribution substantially.

77.6 PILGRIM, Melissa A.*; FARRELL, Terence M.; University of South Carolina Upstate, Stetson University; *mpilgrim@uscupstate.edu*

Use of Stable Isotope Approaches to Study Spatial Variation in Diet: Rattlesnakes as a case study.

We tested the validity of the stable isotope approach for determining differences in pigmy rattlesnake (*Sistrurus miliarius*) diet composition among three Florida populations. We collected scale clips from 186 rattlesnakes captured in the study populations (65 Hog Island individuals, 62 Jones Island individuals, and 59 Uplands individuals). We determined the stable carbon and nitrogen isotope ratios for each scale clip ($\delta^{13}C$ values ranged from -18.1 to -23.9 and $\delta^{15}N$ values ranged from 4.3 to 8.4). Hog Island average $\delta^{13}C$ values (-20.8 ± 0.13) were significantly enriched relative to Jones Island and Uplands average $\delta^{13}C$ values (-22.3 ± 0.13 and -22.1 ± 0.12, respectively). Average $\delta^{15}N$ values of each population were significantly different from one another (Hog Island = 6.2 ± 0.08; Jones Island = 6.9 ± 0.07; Uplands = 5.8 ± 0.10). To evaluate what portion of the observed variation in scale tissue isotope values was related to differences in food sources, we built an isotopic profile of potential prey items for each population. We collected 992 prey items, representing 10 amphibian, 8 reptile and 7 mammal species. Prey $\delta^{13}C$ values ranged from -31.1 to -14.5‰ and prey $\delta^{15}N$ values ranged from 0.3 to 7.0‰. When trying to link observed variation in snake isotope values to differences in diet composition, our interpretations were complicated by spatial variation in prey abundance and within-species spatial variation in prey isotopic composition. Our work emphasizes that use of stable isotopes as trophic indicators in natural systems is most accurate when sources of variation in the isotopic baseline (i.e., food sources) of the system are quantified.

117.5 PINSON, SE*; GAM, AE; NAVARA, KJ; University of Georgia, Athens; *sarabeth.pinson@gmail.com*

Effects of acute, physiological elevations of corticosterone on offspring sex ratios in two avian species

Birds have demonstrated a remarkable ability to bias offspring sex. Studies suggest that female birds may use hormones to mediate skews in offspring sex ratios. Corticosterone, the primary stress hormone in birds, is of particular interest as a potential mediator of offspring sex because it regulates responses to environmental and social stimuli that trigger sex ratio biases and it is elevated during and participates in ovulation in birds. In previous studies, elevation of corticosterone concentrations for long periods of time stimulated female-biased sex ratios while acute elevations in the pharmacological range stimulated male-biased sex ratios. Here, we aimed to test the effects of short-term physiological elevations of corticosterone during chromosome segregation on offspring sex ratios. Based on the results of other studies involving acute corticosterone treatment, we hypothesized that females with acute, physiological elevations of corticosterone would produce more male offspring. We tested our hypotheses in two avian species -- zebra finches and laying hens. First, we administered a handling stress to zebra finches five hours prior to chromosome segregation and quantified sexes of the resulting embryos. Because laying hens often show dampened responses to handling, we instead elevated corticosterone in the physiological range using injections of corticosterone prior to chromosome segregation. Contrary to our hypothesis, neither zebra finches nor laying hens produced sex ratios that differed significantly from controls or hypothetical 50:50 ratios. Results of this study suggest that elevation of corticosterone concentrations within the physiological range for just a few hours prior to ovulation is not sufficient to bias sex ratios in birds.

36.1 PIRES DA SILVA, Andre; Univ. of Texas at Arlington, Arlington; *apires@uta.edu*

Sex determination in a nematode that produces males, females and hermaphrodites

The evolution of mating systems has fascinated biologists since the time of Darwin, specifically the causes and consequences of a species transition from one mating system (e.g. dioecy) to another (e.g. hermaphroditism). Theory predicts that these transitions likely involve one or more intermediates. To understand how animals transition from one mating system to another, we are studying the mechanisms by which the nematode *Rhabditis* sp. SB347 generates male, female and hermaphrodite progeny. We found that the male /non-male decision is chromosomally determined, whereas the hermaphrodite/female decision seems to be non-genetic. A pheromone secreted by siblings, or the lack of cholesterol, can convert a female-fated animal to develop into a hermaphrodite. The study of the molecular mechanisms underlying sex determination in this and other closely species might shed some light in how mating systems evolve.

3.11 PLANT, K.P.; POWELL, M.S.; RODNICK, K.J.*; HARDY, R.W.; University of Idaho, Hagerman, Idaho State University, Pocatello; *kplant@uidaho.edu*

Rainbow trout Oncorhynchus mykiss erythrocytes respond to thermal stress in vitro

Fish erythrocytes can be long-lived and carry out gene expression and protein synthesis during their lifetime. In fish, erythrocytes likely compensate in predictable ways, by either up-regulation or down-regulation of specific genes in response to physiological stressors. In this study, blood was sampled from rainbow trout maintained at 14-15°C, transferred to dialysis cassettes and incubated in modified Cortland’s saline and citrate phosphate dextrose adenine (CPDA). After acclimation to the Cortlands-CPDA buffer at 14°C the cassettes were transferred to Cortlands-CPDA at 27°C for 2 h and subsequently transferred back to 14°C for 48 h. Control blood remained at 14°C for 48 h. Blood was sampled for RNA extraction prior to heat shock and 1, 4, 24 and 48 h post heat shock. Blood smears were carried out prior to heat shock and 24 and 48 hours post heat shock to verify cell condition. Real time PCR was used to measure mRNA expression of a selection of heat shock, apoptosis, REDOX and mitochondrial genes along with glucose transporters. Results indicated heat shocked erythrocytes had significantly elevated levels of heat shock protein (hsp) 70 mRNA at 1 - 4 h post treatment, unlike control erythrocytes. Hsp70 levels peaked at 1 - 4 h post heat shock and decreased over time demonstrating a significant response to the treatment. Likewise GLUT1 transporter expression increased more rapidly in heat shocked cells in comparison to erythrocytes that remained at the control temperature. Histological examination of erythrocytes did not show physical changes in erythrocytes between treatment and controls.

120.2 PLOUGH, L.V*; HEDGECOCK, D.; University of Southern California; *lplough@usc.edu*

High genotype-dependent mortality at metamorphosis in the Pacific oyster

Settlement and metamorphosis is a critical period in the life cycle of marine invertebrates, during which larvae undergo substantial morphological, sensory, and genetic changes regulated by distinct developmental processes. High mortality during this transition has been well documented for a variety of marine invertebrates and is generally interpreted as occurring post-settlement and environmentally derived; little is known, however, about how mortality may occur during the process of metamorphosis itself, and what role genotype and endogenous genetic variation play in this mortality. Previous work has shown that the Pacific oyster, Crassostrea gigas, carries a high load of deleterious recessive mutations inferred from massive distortions of zygotic, marker segregation-ratios in inbred families, which cause substantial genotype dependent mortality. Here I present data from multiple studies examining the stage-specific expression of these deleterious loci and the resultant genotype dependent mortality during the life-cycle, particularly at metamorphosis, using QTL mapping methods to identify regions of the genome under viability selection. We find first, that ½ of the loci causing genotype dependent mortality act during metamorphosis. Further dissection of mortality during metamorphosis through careful sampling of settlers and larvae revealed a mutation causing selection during metamorphosis, possibly affecting the morpho-genetic pathway, while another mutation caused a delay in metamorphosis or prevented metamorphosis from beginning, suggestive of a defect in the competence pathway. Overall, selection during the larval-juvenile transition appears to be confined to the induction of metamorphosis and metamorphosis itself, which highlights the importance of understanding the developmental pathways associated with this critical transition.

24.2 PORTER, M.E.*; DIAZ, C; LONG, J.H. Jr; Vassar College; *meporter@vassar.edu*
Regional Variation in the Dynamic Mechanical Properties of Shark Vertebral Columns
In swimming fishes, body curvature varies among species, individuals, and even within an individual depending on anatomical position and swimming speed. The magnitude and pattern of body curvature of the axial midline is thought to be a function of the stiffness of the body and the vertebral column.. Our goal was to examine body stiffness, and other dynamic mechanical properties, of the vertebral column along the length of the body in two conspecific, but phylogenetically distant, shark species, *Squalus acanthias* and *Mustelus canis*. We used a customized rig on dynamic testing machine (MTS Tytron 250) to translate single axis movement into bending. We tested segments of ten centra over a range of frequencies and curvatures, similar to those experienced by these species when swimming, in an environmental chamber. We measured the apparent composite modulus, E (in Pa), which is an estimate of structural stiffness or the resistance, at a material level, to imposed motions. E was calculated using the applied bending curvature and the bending moments that result. There are clear differences, in both species, between the E of the vertebral column in precaudal and caudal regions: the caudal region is much stiffer. These data suggest that the caudal region, compared to the precaudal region, stores and releases more elastic spring energy during swimming. We hypothesize that since this pattern occurs in two phylogenetically-distant species, these regional differences in vertebral column function may be a general solution for thrust production in sharks. This work was supported by NSF IOS-0922605.

12.1 POTEAT, MD*; BUCHWALTER, DB; North Carolina State University, Raleigh; *mdpoteat@ncsu.edu*
Divalent metal trafficking in aquatic insects: A comparative approach
In streams and rivers, aquatic insects typically comprise 80-95% of the invertebrate species pool and are ecologically integral. With ~7,000 aquatic insect species described to date in North America, this diversity is daunting from an experimentalist's perspective but provides a unique opportunity to explore the degree to which fundamental physiological processes vary with phylogeny. In North America alone, the family Hydropsychidae (Order: Trichoptera) currently contains 157 recognized species and the family Ephemerellidae (Order: Ephemeroptera) contains 75 species. We are in the process of comparing metal fluxes (109-Cd, 65-Zn and 45-Ca) and related physiology in selected species from these 2 families. Experiments with *Hydropsyche sparna* provide several lines of evidence that Cd and Zn utilize a high capacity Ca transport system, but with much greater affinity than Ca to that system. All three metals respond similarly to Ca channel blockers nifedipine and verapamil (no effect) and the Ca-ATPase inhibitor ruthenium red (dramatic suppression of influx). Across species, uptake rate constants for Cd varied 3-fold among 3 hydropsychids and 29-fold among 8 ephemerellids. Uptake rate constants of Cd and Zn strongly co-varied among all 11 species ($r=0.948$, $p<0.0001$), providing additional evidence for a shared transport systems for each metal. Efflux rate constants also strongly co-varied across 10 species ($r=0.946$, $p<0.0001$). As more species are added to this dataset, we will develop a sense for how much physiological variability in metal transport occurs within each of these diverse families and the extent to which this variability can be attributed to phylogeny. Ultimately we ask if phylogenetic position can possibly predict physiological performance in these widely used ecological indicators.

21.6 POTTER, Kristen A.*; WOODS, H. Arthur; University of Montana, Missoula; *kristen.potter@mso.umt.edu*
How do insect eggs avoid sunburns?
Ultraviolet radiation (UVR) from the sun damages DNA and causes acute health problems in living organisms. In response, organisms have evolved a suite of defenses against the sun's harmful effects, including UV-screening compounds, UV-absorbing substances, efficient DNA-repair mechanisms, and behavioral strategies to avoid UVR. For most eggs (e.g., insect eggs, which have thinner shells than bird eggs), however, defending against UVR is particularly challenging: embryos are immobile and have poorly developed physiological systems. At the same time, their DNA divides rapidly during development, resulting in a high probability of DNA replication errors. In previous studies of the hawkmoth *Manduca sexta*, we noticed that females occasionally lay eggs on top of leaves (rather than underneath). These eggs turn dark yellow, instead of their typical green color. In a field experiment using UV filters, we showed that yellowing stemmed from UV exposure rather than other factors associated with the tops of leaves. We will discuss a series of laboratory experiments, currently underway, that are designed to distinguish whether (i) eggs are producing a sunscreen; or (ii) eggs are accumulating damage. The sunscreen hypothesis predicts that eggs with pre-exposure to natural levels of UVA and UVB will perform better during and after large UV doses delivered late in development. Egg performance is measured as hatching success, developmental time, and first-instar rates of growth.

30.5 POWERS, D.R.*; FRIESEN, C.R.; MASON, R.T.; MICHAELSON, J.B.; George Fox University, Newberg, OR, Oregon State University, Corvallis, OR; *dpowers@georgefox.edu*
The Energetic Cost of Courtship in Male vs. Female Red-Sided Garter Snakes (Thamnophis sirtalis parietalis)
Courtship can require substantial energy investment particularly when extended courtship activity and male-male competition play a key role in determining fitness. Measuring the cost of courtship can be challenging because often it is difficult to segregate other activities. The scramble-mating system of red-sided garter snakes (*Thamnophis sirtalis parietalis*) offers a model system for studying courtship costs because the snakes fast and restricted movement during the courtship period. In this study we measured metabolic rate during courtship in male and female red-sided garter snakes. We also assessed morphological, metabolic, and behavioral characteristics of successful and unsuccessful males in an effort to identify traits important to fitness. Males attained a max courting metabolic rate (CMR) of 58 J/min (18X resting metabolic rate; RMR). Receptive females received more vigorous courting from males and 2X the energy investment compared to unreceptive females suggesting discrimination. Males that successfully copulated with females exhibited more intense courtship than unsuccessful males but this difference was not tied to metabolic performance. Female CMR did not differ from RMR and was as much as 15X lower than male CMR. Respiratory patterns in females also did not change during courtship suggesting that females minimize energy expenditure. Overall males appear to make a large but likely calculated energy investment in courtship as this is where their fitness will be determined. The minimal metabolic response of females makes it unlikely that they use active male exclusion to exercise "choice" perhaps relying more on alternative post-copulatory mechanisms.

72.3 PRADHAN, DS*; SOLOMON-LANE, TK; WILLIS, MC; GROBER, MS; Georgia State Univ., Atlanta; *dpradhan1@student.gsu.edu*

Neural androgens regulate paternal care in a polygamous sex changing fish

In many vertebrates, changes in circulating androgens regulate critical aspects of the breeding season. In species with considerable temporal overlap in territory defense, mating, and parental care, mechanisms of androgen action and effect are unclear. *Lythrypnus dalli*, a hermaphroditic fish, exhibits a haremic social structure where the male provides all parental care, including fanning and rubbing eggs until hatching, and aggressive defense of the nest/eggs from females and other predators. While there are no sex differences in systemic, brain, or gonadal 11-Ketotestosterone (KT), brain levels are several-fold higher than gonad, and parenting males have high systemic KT compared to non-parenting males. To test the hypothesis that brain KT regulates male parenting behavior, we intracerebroventricularly (icv) injected parenting males with either carbenoxolone (CBX), a KT synthesis inhibitor that does not cross the blood brain barrier, or vehicle. After icv injections, males were allowed to recover until they regained equilibrium and reunited with their harem for 1 h. CBX-treated males took longer to enter and defend their nest and had lower rates of parental care compared to controls. Females from groups with CBX treated males were also successful at entering the nest and consuming eggs. There were no overall differences in agonistic social behavior between the two groups. We will determine to what extent icv CBX manipulations affected KT levels in brain and other tissues of the experimental subjects. This is the first study to demonstrate that KT is necessary to regulate parental behavior in males. The use of an enzyme inhibitor (CBX) demonstrates that KT can be regulated non-genomically and thus rapidly.

36.6 PRAKASH, Manu; Stanford University; *manup@stanford.edu*

Hydraulic stress induced bubble nucleation and growth during pupal metamorphosis

Here I describe the role of physical fluid stress during pupal metamorphosis in flies. During early stages of pupation of larvae into adult flies, a physical gas bubble nucleates at a precise spatial and temporal location, as part of the normal development program in Diptera. Although its existence has been known for the last 50 years, the origin and control of this "gas nucleation" event has remained completely mysterious. Where does the driving negative pressure for bubble nucleation come from? How is the location of the bubble nucleation site encoded in the pupae? How do molecular processes control such a physical event? What is the role of this bubble during fly development? By developing imaging techniques including X-ray microscopy and bio-physical measurements for live insect pupal structures, here I elucidate the physical mechanism for the appearance and disappearance of this bubble. Via growth rate measurements of this bubble in a developing pupae subjected to variable fluid stress environments for three different species (Drosophila melangastor, Musca domestic, Sarcophaga bercaea), I directly measure the evaporative stress and the resulting negative pressure in the pupal cavity. The sharp increase in this negative pressure specifically encodes the exact timing of the nucleation event. Furthermore, controlled buckling of the main tracheal conduits breaks symmetry and thus govern the physical location of the nucleation site. Gaining physical insights into this hydraulic mechanism also allows us to finally predict the mechanics and inherent design of pupal shell architecture in various species.

43.3 PRAKASH, Manu*; DONALD, Kim; Stanford University ; *manup@stanford.edu*

Flying in two dimensions

Surface of a pond provides an ecological niche which is exploited by a large number of species capable of locomotion on a fluid interface. Here we describe the discovery of constrained flight in two dimensions as a novel mode of locomotion used by water lilly beetles. Because water lilly beetles are also capable of three-dimensional free flight, this novel 2D locomotion behavior provides us a with a unique model organism to explore both the transition between two and three dimensional flight and the associated energetics, in the same organism. Here we present a comparative analysis of this transition in terms of wing stroke angles associated with two and three dimensional flight. Special attention is paid to the dynamics and energetics of flight in two-dimensions, focusing on the interaction of the wing strokes with the fluid interface and the capillary and wave drag associated with two-dimensional propulsion. We will finally discuss some of the implications of this discovery to evolutionary origin of flight.

31.2 PRICE, E.R.*; RUFF, L.; GUERRA, A.; KARASOV, W.H.; University of Wisconsin - Madison; *eprice2@wisc.edu*

Mice increase reliance on paracellular intestinal absorption in response to increased energy demand

Intestinal absorption of nutrients has traditionally been thought of as a primarily active (transcellular) process, with the passive (paracellular) pathway playing only a minor role. However, recent studies of birds and bats demonstrate high passive absorption of nutrients, indicating that some species make use of this mode of absorption extensively. We hypothesized that a species with low paracellular absorption (mice) could increase absorption transiently in response to increased energy demand. Specifically, we predicted that mice exposed to cold would increase intestinal size to meet the increased thermogenic energy demand, but in the short term these mice would increase paracellular absorption as a stopgap measure before gut size can be increased. We transferred mice from 21 to 5 °C and assessed paracellular absorption of radiolabeled L-arabinose at 3 timepoints: prior to cold exposure; after 1 day of cold exposure; and after 2 weeks in the cold. Mean gut size increased over the 2 week exposure, and this was accompanied by an increase in food consumption. Absorption of an L-arabinose dose nearly doubled from 16.7% (prior to exposure) to 30.1% after 1 day in the cold, and dropped to 18.7% after 2 weeks exposure. These results suggest that mice can adjust tight junction “leakiness” to meet short-term absorptive capacity needs. Supported by NSF Award 1025886.

93.3 PRIESTER, C*; CORNELISSEN, A; KINSEY, S; DILLAMAN, R; University of North Carolina Wilmington; *cpl3791@uncw.edu*
Nuclear distribution in skeletal muscle of selected members of Chondrichthyes
Mammalian muscle is characterized by fibers (cells) typically <100 µm in diameter and containing multiple nuclei located just under the sarcolemma. As animals grow, new fibers with the same nuclear organization are added (hyperplasic growth). Fibers can also increase in size (hypertrophic growth), reaching very large sizes in some animals. This occurs in white muscle of crustaceans where fibers may increase in diameter from <50 to >400 µm. In response to increases in diffusion distances during hypertrophic growth there are shifts in the distributions of mitochondria and nuclei. Mitochondria are evenly distributed across the fiber in small fibers, but are predominately peripheral (subsarcolemmal or SS) in large fibers; whereas nuclei are predominately SS in small fibers but are more centrally located (intermyofibrillar or IM) in large fibers. We have seen a similar pattern in the teleost *Centropristis striata*. Here we expanded this investigation to include representatives from a primitive class of fishes, the Chondrichthyes. Red and white fibers were identified and mitochondrial distribution was determined by SDH staining. Ratfish white fibers had mostly SS but also IM nuclei in all fish sizes examined. However, representative sharks and rays had red fibers resembling mammalian fibers, but their white fibers, even small ones, had predominantly IM nuclei, suggesting their red and white fibers anchor nuclei using different proteins. Furthermore, the location of nuclei in all species examined to date appears to be associated with microtubules (MT's) that form bundles found throughout the cytoplasm. The MT's are predominantly oriented parallel to the myofibrils and with perpendicular branches. They also often form "baskets" around both IM and SS nuclei, suggesting an anchoring role.

98.1 PROVINI, Pauline*; ABOURACHID, Anick; MusÃ©um National d'Histoire Naturelle, Paris; *provini@mnhn.fr*
Relative role of hindlimbs and forelimbs during take-off and landing in different species of birds
Although take-off and landing are crucial components of avian flight, few studies have focused on these two phases and consequently the functional role of the hind limbs during take-off and landing remains unclear. We investigated the role of the legs in generating propulsion during take-off and their ability to dampen impact forces during landing, in several species of birds. The animals were filmed during short distance free-flights between two perches, situated at different heights. The lower perch was filmed by multiple synchronized high speed video cameras and the reaction forces involved during take-off and landing on the perch were measured. The first and second derivatives of the centre of mass trajectory have provided velocity and acceleration profiles, respectively. We observed that hind limbs are prominent in generating propulsion during take-off and dampen impact forces during landing. These results will help us understand the mechanical demands imposed by take-off and landing on non-level perches and will lead to a better understanding of the role of the hind limbs in bird locomotion.

23.6 PRUITT, JN*; OUFIERO, CE; AVILES, L; RIECHERT, SE; University of Pittsburgh, University of California, Davis, University of British Columbia, University of Tennessee, Knoxville; *Agelenopsis@gmail.com*
It takes all kinds :Iterative evolution of increased trait variance proves advantageous for spider societies
The evolution of sociality is often regarded as a key transition, in part, because group-living is thought to change the adaptive landscape in which ancillary traits evolve. Here we investigate the behavioral correlates of sociality across a clade of polyphenic social spiders in genus Anelosimus. We then experimentally evaluated these trait shifts by staging associations among individuals possessing the hypothesized ancestral character state in four exemplar species. We found that social species tended to be less aggressive towards prey and predators and exhibited lower activity-levels relative to their subsocial ancestors. Additionally, social species exhibit greater trait variation relative to subsocial species. In staged group prey-capture events, groups of non-aggressive individuals outperformed groups of aggressive individuals. Furthermore, groups composed of a mixture of non-aggressive and aggressive individuals outperformed either monotypic group, suggesting the increased trait variance within spider societies is, in fact, functionally adaptive.

70.4 PUNKE, Erin B.*; NISHIGUCHI, Michele K.; New Mexico State University; *ebastian@nmsu.edu*
Spatial and temporal patterns among symbiotic Vibrio fischeri: Environment matters!
The association between *Vibrio fischeri* (γ-proteobacteria: Vibrionaceae) and the sepiolid squid, *Euprymna tasmanica* (Mollusca: Cephalopoda), is an ideal model for understanding how abiotic factors can drive this environmentally transmitted symbiosis. *V. fischeri* are cosmopolitan marine bacteria and are known to environmentally infect the light organ of their squid host during the onset of the symbiosis. Bacterial diversity is high both geographically and temporally, where persistent dominant strains exist throughout both space and time. Free-living vibrios are strongly influenced by environmental conditions, suggesting that constant abiotic fluctuations in areas of thriving *Euprymna–Vibrio* associations may be a driving factor in both the formation and continuation of this mutualism. Utilizing geographically distinct *V. fischeri* strains, we experimentally evolved these bacteria to a wide range of temperatures, and examined growth and competitive dominance compared to native wild-type strains. Results show a gain in fitness in the evolved strains, giving further support to temperature adaptation being a dominant factor behind bacterial phenotypic plasticity. Furthermore, we examined whether temperature was an underlying factor controlling patterns of diversity among *V. fischeri* on a temporal scale. Further understanding of survival limits and temperature thresholds of symbiotic bacteria will provide insight into adaptation of an environmentally transmitted mutualism subjected to daily and seasonal environmental fluctuations.

71.1 PUTMAN, N.F.*; VERLEY, P.; SHAY, T.J.; LOHMANN, K.J.; North Carolina State University, IRD - Sete, France, UNC Chapel Hill, UNC Chapel Hill; *nathan.putman@gmail.com*

Transoceanic migratory dispersal in young sea turtles: the role of currents and geomagnetic navigation

Upon hatching, young sea turtles immediately migrate offshore and into ocean gyre systems that promote long-distance transport. Because young turtles are often characterized as weak swimmers, or as inactive, their distribution in the open-sea is thought to be dependent on prevailing currents. In contrast to this view, lab-based experiments demonstrate that newly hatched loggerhead turtles from Florida, USA orient their swimming direction in response to regional magnetic fields that exist in the North Atlantic Subtropical Gyre. These findings imply that young turtles engage in directed swimming in the open-sea. However, whether this behavior influences the dispersal trajectories and ocean basin-scale distribution of young turtles is unknown. To address this question, numerical experiments were performed using particle-tracking software that coupled empirical observations of magnetic orientation by turtles to an ocean circulation model. Results revealed that even moderate amounts of swimming in response to magnetic fields resulted in substantial differences in dispersal trajectories compared to scenarios of passive drift. Turtles that engaged in magnetic navigation behavior were more likely to encounter productive foraging areas, remain within warm-water currents favorable for growth and survival, avoid areas on the perimeter of the gyre where predation risk and thermal conditions pose threats, and successfully return to the gyre if carried into coastal areas. These findings imply that marine animals traditionally viewed as ineffective swimmers may be able to exert unexpectedly strong effects on their dispersal trajectories and open-sea distributions by relying on a simple navigation strategy and minimal swimming.

89.3 PYENSON, N.D.*; GOLDBOGEN, J.A.; VOGL, A.W.; SZATHMARY, G.; DRAKE, R.; SHADWICK, R.E.; Smithsonian Institution, Cascadia Research Collective, University of British Columbia, FPinnovations, Cleveland Clinic, University of British Columbia; *pyensonn@si.edu*

A putative sensory organ in the mandibular symphysis of rorqual whales (Balaenopteridae)

Marine vertebrates have evolved multiple solutions to the challenges of feeding in an aquatic medium. Large baleen whales belonging to the group Balaenopteridae, or rorquals, engulf and filter large volumes of prey-laden water at high speed by lunge-feeding. This feeding strategy is facilitated by several bony and soft tissue specializations, including unfused mandibles that loosely articulate with the skull and delimit the size of the oral cavity. Here we report the presence of an unusual organ located within the fibrous mandibular symphysis of rorqual whales. We investigated the properties and composition of this organ using gross macroscopic dissection, fine histological examinations, and digital imaging with x-ray CT and MRI techniques on several species of rorquals, including both fetal and adult specimens. These approaches revealed that the organ, located in the open mandibular symphysis, receives branches from neurovascular bundles that emerge from relictual alveolar foramina. Based on the preponderance of evidence, we argue that this structure is a sensory organ that responds to localized changes in jaw configuration during lunge-feeding. Furthermore, its anatomical location in the mandibular symphysis resolves a problematic linkage of specialized tissues (e.g., ventral groove blubber, Y-shaped cartilage) associated with the rapid and dramatic expansion of the oral cavity during a lunge. Beyond its biomechanical significance, this sensory organ also represents an evolutionary novelty, based on its absence in all other lineages of extant baleen whales, despite the antiquity of unfused mandibles in mysticetes since the Oligocene.

58.3 QIAN, F*; ZHANG, T; LI, C; SHEN, J; HOOVER, A.M.; BIRKMEYER, P; PULLIN, A; FEARING, R.S.; GOLDMAN, D.I.; MASARATI, P.; Georgia Institute of Technology, F. W. Olin College of Engineering, University of California, Berkeley, Politecnico di Milano; *qianfeifei_china@gatech.edu*

Legged locomotion of a bio-inspired lightweight robot on granular media

Many desert-dwelling animals exhibit high locomotor performance on granular media (GM) like sand. Previous studies of a 2 kg legged robot (SandBot) revealed that as limb frequency increased, walking speed increased until a critical frequency above which the robot moved ineffectively. Recently a small, lightweight (10 cm, 25 g) hexapedal robot, dynaRoACH, has begun to approach biological locomotor performance on GM over a wider frequency range. It uses an alternating tripod gait to move at speeds of 50 cm/s at frequencies of 12 Hz. To reveal how dynaRoACH maintains high performance, we use high speed imaging to capture kinematics as the robot moves on a GM of closely packed 3 mm glass particles. We also develop a numerical multi-body model of dynaRoACH coupled to an experimentally validated multi-particle simulation of the GM. Average forward speed in simulation matches experiment and increases non-linearly with stride frequency. The nonlinearity is associated with a change in mode of propulsion. At low frequency dynaRoACH moves like SandBot, using a quasi-static rotary walking mode. During stance, the c-shaped legs rotate about their centers atop solidified grains which kinematically propels the body forward. No aerial phases are observed, and the simulation reveals that vertical ground reaction force (GRF) plateaus during mid-stance. For higher frequencies, dynaRoACH moves dynamically, such that stance duty factor falls below 0.5 and aerial phases occur. Peak vertical GRF occurs at mid stance and increases superlinearly with frequency indicating the importance of inertial forces associated with the acceleration of grains.

28.1 RAGLAND, Gregory J.*; HAHN, Daniel A.; University of Notre Dame, University of Florida; *gragland@nd.edu*

Comparative functional genomics of diapause: common physiological pathways and their connections with stress responses.

Many arthropods enter diapause, a state of developmental and metabolic suppression, to avoid exposure to harsh or resource-poor environments. Though diapause seems to be evolutionarily labile and has evolved independently many times, *ad hoc*, gene-by-gene inspection of expression data suggests that there are physiological commonalities. Moreover, these apparent commonalities in diapause include the expression of genes also implicated in various metabolic, stress, and aging responses, consistent with the ecological role of diapause in energy conservation and environmental buffering. Here I use comparative genomic tools with transcript profiling data from several species to test: 1) whether a core set of physiological pathways or co-regulated gene sets unite diapause responses across insects, and 2) whether there is functional overlap between diapause-associated gene expression and expression patterns associated with several stress/aging responses characterized in *Drosophila melanogaster*. I discuss the common physiological features of diapause in the context of convergent and divergent selection pressures on environmental tolerance and synchronization of seasonal life histories.

S10-1.2 RAND, DM; FLIGHT, PA*; Brown University; *David_Rand@brown.edu*
Population genomics of the acorn barnacle: tests of balancing selection at Mpi and diversifying selection across the genome
The acorn barnacle, *Semibalanus balanoides*, has been a model system in marine ecology for decades owing to its distinctive zonation in the intertidal, high dispersal and recruitment dynamics. These features make it an excellent model for studies of selection in the wild given its sessile habit and the range of microenvironments that span the intertidal. The glycolytic allozyme locus Mpi has figured prominently in the population genetics of the acorn barnacle as a gene responding to balancing selection in alternative environments. Here we report the DNA sequence of Mpi and identify the amino acid charge change site that is the putative target of selection. Sequence variation around this site is consistent with historical balancing selection as indicated by an excess of intermediate frequency polymorphisms. To provide a more rigorous null model for patterns of variation in the barnacle genome, whole genome sequence data were collected using the Illumina platform applied to pooled samples of 20 individuals from each of three sites (Rhode Island USA, Maine USA and Southwold UK). The allele frequencies at over 300,000 high quality SNPs were quantified in these three populations and coalescent simulations were used to estimate the site frequency spectrum of variation across the genome. These data allow us to verify that the excess high frequency polymorphism at Mpi is a significant departure from the genomic average. Moreover, comparison of the three populations revealed many loci that show elevated population differentiation (Fst) providing interesting new candidates for the action of diversifying selection between these geographic localities. The utility of this pooled population genomic sequencing in non-model organisms will be discussed in light of approaches to identify the targets of natural selection in the wild.

43.6 RASTOGI, A.; RANI, S.; KUMAR, V.*; University of Lucknow, University of Delhi; *drvkumar11@yahoo.com*
Phase Inversion in Neural Activity of the Sensory Systems but not the Putative Biological Clock Parallels Behavioral Shift during Migration in a Night-Migratory Songbird
The present study investigated neural activity in relation to photoperiodic induction of migration in the Palaearctic-Indian, migratory blackheaded buntings, *Emberiza melanocephala*, using c-fos as neuronal activation marker, and vasoactive intestine peptide (VIP) and neuropeptide Y (NPY) as functional correlates. Activity of individual birds exposed to inductive long days was continuously monitored, and data on body mass and testis size were recorded at intervals. The daily activity pattern defined the non-migratory phase (no nocturnal activity) and migratory phase (intense nocturnal activity, Zugunruhe - a behavioral phenotype that characterizes migration in caged birds). The c-fos, VIP and NPY immunoreactivity (lir) was measured during the day and night in the suprachiasmatic nuclei (SCN) and mediobasal hypothalamus (MBH) regions, which are putative daily and seasonal clock sites, respectively, and in the olfactory and visual subsystems, which contain sensory circuits linked with migration. The MBH, but not the SCN, showed a significant temporal difference in the fos, VIP and NPY immunoreactive cells. This indicated that MBH, and not the SCN, contained photoperiodic clock and VIP and NPY are probably part of neuroendocrine mechanism involved in regulation of avian seasonality. Importantly, there was also phase inversion in the neural activity of the olfactory and visual sensory systems in parallel with the behavioral (activity) shift that occurred during the migratory phase. This suggested the migration linked changes in the activity of olfactory and visual sensory systems that were involved in the migratory orientation and navigation.

13.3 REDMOND, SB*; BOTTS, EA; HILL, KL; EVANS, PK; VAGLIA, JL; DePauw University; *sarahredmond@depauw.edu*
Hoxa13 gene expression is associated with tail growth across embryonic, larval, and adult development in the non-model salamander Eurycea cirrigera
Regulatory *Hox* gene expression is important throughout organismal development to establish and maintain position along the anterior-posterior body axis. Posterior *Hox* genes, particularly *Hoxa9* and *Hoxa13* have been implicated in the development and regeneration of limbs in *Ambystoma mexicanum* and *Xenopus laevis*. Like *A. mexicanum* and *X. laevis*, *Eurycea cirrigera* elongate their bodies throughout their lifespan and can regenerate limb and tail tissue. Unlike the common regenerative models, *E. cirrigera* tail growth arises, in part, from addition of new vertebrae, suggesting that signaling of cellular position along the body axis must accommodate addition of new structures rather than shifting of existing structures. To understand the role of *Hox* gene expression in this signaling process, we used quantitative RT-PCR to measure expression of *Hoxa13* throughout *E. cirrigera* embryonic development and in the tail tips of larvae and adults. *Hoxa13* expression was higher in embryonic stages associated with body and tail elongation compared to those stages associated with limb development. Larval *E. cirrigera* collected early in the summer expressed less *Hoxa13* than those collected in mid or late summer, suggesting that expression may be associated with high resource availability, and therefore more rapid growth. The range of *Hoxa13* expression was similar across all life stages. These data suggest that the *Hox* gene family plays an important role in tail extension throughout *E. cirrigera* development, and that *Hoxa13* may be useful as a marker of tail growth in this species.

S6-1.2 REES, B.B.; Univ. New Orleans; *brees@uno.edu*
The potential of piscine proteomics: examples from studies with Fundulus
Advanced proteomic technologies are being applied to studying patterns of protein expression and protein networks in cells and tissues of a variety of organisms. In this talk, I will review our studies on the small teleost fishes, *Fundulus heteroclitus* and *Fundulus grandis*. These species inhabit estuaries along the North American coasts of the Atlantic Ocean and Gulf of Mexico, and both species tolerate a wide range of variation in their physiochemical environments (e.g., temperature, salinity, and oxygen). Accordingly, the genus *Fundulus* has been promoted as a model system for the study of environmental biology. We have used two-dimensional gel electrophoresis and mass spectrometry (2DE-MS) to study population variation in cardiac protein expression and inter-tissue differences in protein profiles in *F. heteroclitus* and *F. grandis*. In the former study, significant within- and among-population variation in protein expression was observed, with the among-population variation being consistent with selection along a north-south temperature gradient. In the latter study, we describe partial maps of skeletal muscle, liver, gill, brain, and heart proteomes, with the goal of providing a resource for future studies of tissue-specific changes in protein expression during exposure of these and other fishes to environmental stressors. These studies demonstrate the utility of these approaches in describing the *Fundulus* proteome; however, I will also address specific caveats and potential pitfalls in the application of proteomics to non-traditional model systems. Funding provided by the National Science Foundation.

25.2 REIDENBACH, M.A.*; WHITMAN, E.R.; Univ. of Virginia; *reidenbach@virginia.edu*

Benthic flow environments impacting larval recruitment on Crassostrea virginica oyster reefs

Restoration efforts to re-establish healthy *Crassostrea virginica* oyster populations along the Virginia, USA coast are focused on creating benthic habitat suitable for larval recruitment, survival and growth. To determine how benthic flow processes impact rates of larval recruitment, velocity and turbulence data was collected over multiple intertidal benthic surfaces including a mud bed, a healthy *C. virginica* oyster reef, and two restoration sites comprised of either *C. virginica* oyster shell or the relatively larger *Busycom canliculatum* whelk shell. Estimates of the drag coefficient, CD, used as a measure of hydrodynamic roughness, over a healthy reef were found to be 50% greater than those at restoration sites and four times greater than the mud bed. Enhanced fluid shear increased both Reynolds stresses and turbulent mixing above the reef, but within the interstitial areas between individual oysters, mean velocities and turbulent motions were reduced. Larval settling plates of varying triangular-shaped benthic roughness were used to mimic the natural topographic variability found along oyster reefs. The greatest larval recruitment occurred along interstitial regions between roughness elements, where shear stresses and drag forces, which act to dislodge settled larva, were found to be up to 10 times smaller than along exposed surfaces. Greater recruitment was also found on the more hydrodynamically rough *B. canliculatum* whelk shell as compared to the *C. virginica* shell restoration site. Results suggests that restoration efforts should consider creating 3D benthic topography similar to healthy oyster reefs when designing restoration habitat in order to provide hydrodynamic conditions and surfaces that promote larval recruitment, prevent burial by sediment, and provide refuge from predation.

63.3 RENSEL, M.A.*; SALWICZEK, L.; HSIAO, C.F.; XIA, S.; REMAGE-HEALEY, L.; SCHLINGER, B.; Univ. of California, Los Angeles; *mrensel@gmail.com*

In vivo Microdialysis Reveals Dynamics of Estradiol Production in the Avian Hippocampus

Steroids act on the brain after their synthesis and secretion by peripheral organs or by their synthesis in the brain itself. Estrogens, synthesized in the brain due to neural expression of the enzyme aromatase, play a crucial role in the activation of neural circuits controlling reproductive and non-reproductive behaviors as well as in sensory processing. Songbirds are particularly useful models to study neuroestrogens because they express high levels of aromatase in the brain. Recent studies using newly developed in vivo microdialysis procedures show that estradiol levels fluctuate rapidly in a higher-order auditory region (NCM) of the zebra finch brain in response to auditory input, functionally enhancing neural responses to conspecific song. Here we describe studies using in vivo microdialysis to examine estradiol levels in the zebra finch hippocampus (HP), a brain region important for the formation and maintenance of spatial memory. In songbirds, the HP contains a distinct population of aromatase-producing neurons and, in zebra finches, estrogens improve spatial memory capability. We found that estradiol was indeed reliably detectable in the HP of awake, behaving zebra finches. Furthermore, peripheral injections of estradiol transiently increased HP levels of estradiol whereas retrodialysis into the HP of an aromatase inhibitor markedly decreased estradiol levels. HP levels of estradiol were unchanged by stimuli that elevate levels in the nearby NCM, suggesting that estrogens do not diffuse readily across brain regions. We are currently assessing HP estradiol levels as birds perform spatial memory tasks. In vivo microdialysis provides a powerful tool for the investigation of steroid-brain interactions in the awake and freely-behaving animal.

101.4 REVELL, Liam J.; Univ. of Massachusetts Boston; *liam.revell@umb.edu*

Analyzing continuous character evolution on a phylogeny

Recent years have seen the development of likelihood-based phylogenetic methods that allow researchers to test the hypothesis that a discrete character trait (for example, habitat type or trophic level) influences the rate of evolution for a continuous character (for example, limb length or body size). Standard practice in these analyses is to first generate a sample of hypothesized historical rate regimes using a procedure called stochastic character mapping and then fit the model to each hypothesized regime and average the results. Here, I examine this practice and consider the possibility that this analysis pipeline can sometimes lead to biased estimates of the evolutionary rates through time.

33.5 REYNAGA, Crystal/M*; COLLAR, David/C; WARD, Andrea/B; MEHTA, Rita/S; Univ. of California, Santa Cruz, Adelphi Univ.; *cmreynag@ucsc.edu*

A revised metric to quantify body shape diversity in vertebrates

Vertebrates exhibit tremendous variation in body shape, though quantifying this diversity has been challenging. In the past, researchers have characterized shape diversity with multivariate statistics and various simplified metrics of body shape such as, elongation ratio (ER), fineness ratio (FR), and axial elongation index (AEI). While ER and FR are useful for describing overall shape, they provide little insight into the anatomical bases of shape variation. AEI describes the morphology of the underlying axial skeleton but may have only a weak correlation with overall body shape. In this study, we present a new metric of body shape, the Vertebrate Shape Index (VSI), which describes shape using morphological features common to all vertebrate taxa: head length, the 2nd longest body axis (width or depth), vertebral number and the shape of individual vertebrate. We illustrate the usefulness of VSI on a data set of 140 species representing several major vertebrate groups (Actinopterygii, Amphibia, Reptilia, Aves, and Mammalia). We also show how different animal preparations can be used to obtain the variables that comprise VSI by gathering data from radiographs, articulated skeletons, and cleared and stained specimens. Our study quantitatively describes body shape variation for a diverse sample of vertebrate taxa and highlights the relative importance of head length, second major axis (body depth/width), and vertebral characteristics as independent contributors to overall body shape diversity in vertebrates.

6.9 RICHARDS, Christopher T*; SAWICKI, Gregory; Harvard University, North Carolina State University; *richards@fas.harvard.edu*

Power amplification in water: modeling muscle-tendon dynamics during swimming

Models have demonstrated that the power required for some animals to jump exceeds the theoretical limits of muscle power. Such work predicted that a muscle may store elastic energy in the tendon before it is released rapidly, producing 'power amplification' as tendon recoil assists the muscle to accelerate the load. Can this mechanism work for hydrodynamic loads? Using a hill-type mathematical model of an in-series muscle-tendon (m-t) unit generating torque about a lever to rotate a fin submerged in water, we simulated muscle contractions against limb masses ranging from 0.3 to 3 to 30 g, fin areas from 0.005 to 0.05 to 0.5 to 5 to 50 cm2, tendon stiffness (k) values from 1250 to 1667 to 2500 to 5000 N/m and effective mechanical advantage (ema = inlever/outlever) of 0.025 to 0.05 to 0.1. Certain conditions produced power amplification where the m-t produced power ~18% greater than the limit for muscle alone. Surprisingly, k did not strongly influence m-t power output. For the heaviest limb, peak m-t power increased dramatically with ema, but was not influenced strongly by increases in fin area. For the lowest limb mass, m-t power output was highly sensitive to both ema and area, with maximum m-t power produced with fin area = 0.05 or 0.5 or 5 cm2, for ema = 0.025 , 0.05 and 0.1, respectively. These interactions suggest multiple 'optimal' morphological configurations for tuning m-t power which depend on interactions among limb mass, fin area and ema.

109.5 RICHARDSON, C.S.*; CURLEY, B.; DAVIS, F.; Northeastern University; *c.richardson@neu.edu*

The Effect of Circadian Disruption on Metabolic Rate and Immune Function in Vasoactive Intestinal Protein (VIP) Deficient Mice

We investigated how the disruption of circadian rhythm affects basal metabolic rate (BMR) and immune function in lab mice (Mus musculus). We measured BMR, bacterial killing ability and white blood cell counts in both VIP deficient and wildtype control mice. We hypothesized that VIP -/- mice must invest more energy to compensate for a disrupted circadian rhythm than the wild type mice in order to maintain the same basal metabolic rate. Thus, they will be immunosuppressed as a result. Our results suggest that the VIP -/- mice have a higher BMR than wild type mice in the inactive period but no difference in immune function.

BERN.1 RIDDIFORD, Lynn M.; Janelia Farm Research Campus, HHMI; *riddifordl@janelia.hhmi.org*

How Does Juvenile Hormone Regulate Insect Metamorphosis and Reproduction?

Juvenile hormone (JH) both prevents the switching actions of ecdysone that are necessary for metamorphosis and regulates reproductive maturation in the adult. In holometabolous insect larvae, JH prevents the appearance of the ecdysone-induced, pupal-specific transcription factor Broad during the molts. As growth is completed, JH declines and a small surge of ecdysone initiates metamorphosis and the appearance of Broad. During the prepupal period JH again appears to prevent premature adult development of imaginal discs and the optic lobe of the brain in response to the prepupal peak of ecdysone. Allatectomy (CAX; removal of the corpora allata that produces JH) or loss of the JH receptor Methoprene-tolerant (Met) (a basic helix-loop-helix, Pas domain protein) causes precocious metamorphosis in most insects. In *Drosophila* allatectomy causes death at the time of pupation which is mimicked only by the loss of both Met and a closely related protein Germ cells expressed (Gce). Loss of only Met mimics some of the CAX phenotype, namely precocious adult maturation of the optic lobe. Expression of Met RNAi in various neurons showed that JH acts on the photoreceptors to prevent premature differentiation caused by ecdysone. In *Drosophila* adult females JH regulates the timing of the onset of mating receptivity as well as egg maturation. Genetic allatectomy during adult development caused a delay in the onset of receptivity that was prevented by application of JH at eclosion. The loss of Met causes a similar delay. Expression of Met RNAi in brain neurons known to be involved in female receptivity delayed the onset of receptivity, suggesting that JH acts via Met to promote the maturation of these neurons. Thus, in the regulation of both metamorphosis and reproduction, JH acts primarily via Met.

78.4 RIESCH, Rüdiger*; MARTIN, Ryan A; LANGERHANS, R Brian; NC State University, Raleigh; *rwriesch@ncsu.edu*

Ecological causes of the joint evolution of life history and morphology during a post-Pleistocene radiation of Bahamas mosquitofish (Gambusia hubbsi)

Predation is a well-known driver for morphological and life-history evolution across various taxa and in particular in livebearing fishes (Poeciliidae). Bahamas mosquitofish (*Gambusia hubbsi*) inhabiting blue holes are known to have diverged in body shape between localities with and without bigmouth sleeper (*Gobiomorus dormitor*), a piscivorous fish. Here, we examined life histories of *G. hubbsi* across 14 blue holes, and found clear evidence for the expected life-history divergence as a response to predation, but there was also significant divergence between populations within both low- and high-predation localities in both sexes (a phenomenon also known to exist for body shape). Using model selection we investigated the role of other environmental factors (e.g., population density, primary productivity, salinity, sex ratio) on life-history and body-shape evolution within and between predator regimes. Finally, we investigated the co-variation between life histories and morphologies at the individual, population, and predation-regime levels.

S10-1.6 RITTSCHOF, D.*; DICKINSON, G.H.; WAHL, K.J.; BARLOW, D.; ORIHUELA, B.; VEGA, I.E.; EVERETT, R.; Duke University, University of Pittsburgh, Naval Research Laboratory, Naval Research Laboratory, Duke University Marine Laboratory, University of Puerto Rico; *ritt@duke.edu*

Barnacle Glue, is curing like blood clotting?

We hypothesized that barnacle glue curing is related to biological materials that coagulate in water. We used uncured glue in conjunction with biological, microscopic, biochemical, immunological, chemical, infrared and tandem mass spectrometry and proteomic techniques to gain insight into barnacle glue curing. Our data support the working hypothesis that barnacle glue curing is related to blood clotting. Glue curing includes proteolytic activation of enzymes and structural proteins and cross linking by a transglutaminase and potentially other enzymes. Peptides generated during the activation process serve as barnacle settlement pheromones. Barnacle glue curing seems to be a form of wound healing.

92.3 RIVERA, A.R.V.; Florida Atlantic University, Boca Raton; *arivera@g.clemson.edu*

A comparative examination of forelimb kinematics and muscle function during rowing and flapping-style swimming in four species of turtle

Evolution has resulted in a diverse array of limb-based locomotor strategies. Changes in muscle activation patterns can lead to new locomotor strategies. Aquatic turtles are an excellent group in which to test for such changes because species typically use one of two general swimming styles (rowing or flapping), both of which depend exclusively on limb-based propulsion. Whereas all sea turtles swim using synchronous flapping of foreflippers, all but one freshwater turtle swims using asynchronous rowing of the limbs. The one exception, *Carettochelys insculpta*, has converged on a flapping-like style of swimming using synchronous motions of foreflippers. To examine how different forelimb motions are produced across species with generally similar muscle arrangements, I compared high-speed video and electromyographic (EMG) data from four species, including *C. insculpta* and the sea turtle *Caretta caretta*, as well as specialized and generalized rowing in *Apalone ferox* (sister taxa to *C. insculpta*) and *Trachemys scripta*, respectively. My study provides the first opportunity to evaluate whether the two ‘flapping’ lineages have converged on similar limb kinematics and/or motor patterns, and by including *A. ferox* and *T. scripta*, provides a test of whether ‘phylogenetic relatedness’ or ‘locomotor strategy’ better predicts forelimb kinematics and motor patterns. My findings indicate that ‘flapping’ in *Carettochelys* is only superficially similar to flapping in *Caretta*, and is, in fact, more similar to rowing. My data indicate a general conservation of motor patterns across the species. However, the deltoideous serves a new function in sea turtles; interestingly, *C. inscultpa*, with its intermediate kinematics, exhibits deltoideous activity intermediate to rowers and flappers.

33.4 RIVERA, G*; DAVIS, JN; GODWIN, JC; ADAMS, DC; Iowa State University, Tuskegee University, Alabama Natural Heritage Program; *grivera@iastate.edu*

Parallel evolution of shape divergence in the shells of freshwater turtles inhabiting different flow regimes

Parallel evolution, the process by which similar selection pressures produce repeatable effects across disparate taxa, is considered strong evidence for the generation of adaptive phenotypes. In aquatic habitats, the velocity of water flow is a major selection pressure and has been shown to influence morphology in a broad array of taxa. We tested whether three confamilial species of freshwater turtle (family Emydidae: *Pseudemys concinna*, *Graptemys nigrinoda* and *Graptemys pseudogeographica*) displayed similar patterns of phenotypic divergence in carapace shape between fast- and slow-flowing aquatic environments. We used (1) geometric morphometrics to quantify shell shape, (2) factorial MANOVA to test the effects of species, sex, and flow, and (3) phenotypic trajectory analysis (PTA) to examine patterns of divergence for the six species-sex groups. We found significant effects on shell shape for all factors. In general, ecomorphs from fast-flowing habitats had flatter shells than those from slow-flowing habitats. Furthermore, results of PTA indicate that the degree to which and way in which ecomorphs differed were concordant across all species. Our findings indicate that flow velocity plays an important role in adaptive divergence of turtle shell shape and also highlights the repeatability of the evolutionary process.

99.1 RIVERS, TJ*; PERREAULT, TR; Bowdoin College; *trivers@bowdoin.edu*

Luminescent responses to predation in the scale worm Harmothoe imbricata

Bioluminescence is a phenomenon that has evolved many different times in many different organisms, especially in marine systems. For all that is known about *how* many of these species luminesce (physiologically and chemically), often much less is known about *why* they exhibit this behavior. *Harmothoe imbricata* is a luminescent scale worm found in abundance in the intertidal and subtidal habitats of coastal Maine, whose luminescence has been well studied in laboratory settings for well over 50 years. Luminescence occurs in the elytra (scales), which can emit light while still attached to the worm as well as when shed from the body. In addition, worms can autotomize, with the posterior segments luminescing while the anterior segments remain dark, eventually regenerating. Although these displays have been hypothesized to have evolved as a defense against predation, there have been no specific tests using actual predators to confirm these hypotheses. Using low-light CCD cameras with infra-red (IR) illumination, a night vision device with an IR barrier filter, and a photomultiplier, we recorded the behavior of dark-adapted H. imbricata when attacked in complete darkness by three different species of crab (*Carcinus maenus*, *Cancer irroratus*, and *Hemigrapsus sanguineus*) and by the American lobster, *Homerus americanus*). All but *H. sanguineus* consistently attacked the worms. We have definitive evidence that luminescence does often function as a successful decoy to predators, either by the worms dropping scales or by whole-segment autotomization. In addition to decoy luminescence, we observed instances of worms exhibiting warning flashing before their potential predator even attacked, indicating that *H. imbricata* uses its luminescence in a multitude of ways to avoid predation.

18.2 ROBERTS, C.*; SOCHA, J.J.; Virginia Tech;
carolyn2@vt.edu

Dynamics of the sucking pump in fluid feeding butterflies

Butterflies feed by means of a sucking pump in the head, which creates a pressure gradient to drive food through the proboscis. Although the functional morphology of internal food transport of Lepidoptera has been widely studied, the exact timing of movements in the sucking pump system are unknown. Using synchrotron x-ray imaging, we visualized the internal food transport within the head of living cabbage white butterflies, *Pieris rapae*. Experiments were conducted at the 32-ID beamline at Argonne National Laboratory's Advanced Photon Source. Fasted butterflies were mounted by the wings and allowed to feed on 40% sugar water mixed with an iodine compound (Isovue), as a contrast agent. Using ImageJ to analyze the video records, we quantified timing of events within a sucking pump cycle. Feeding in *P. rapae* involves three main components: the sucking pump, the oral valve, and the esophageal valve. In the dilation phase, food is drawn into the lumen of the sucking pump by expansion of the dorsal wall. Just prior to ejection, the oral valve closes as the pump reaches its maximum fluid volume. In the ejection phase, compressor muscles of the sucking pump contract rapidly, pushing the fluid out of the lumen through the open esophageal valve and into the esophagus. The oral valve then re-opens. The total pump cycle duration was 1.72 ± 0.74 seconds per pump cycle. Our results show that the dilation phase is consistently longer than the compression phase, with a ratio of 4.9 : 1 (SD, 0.4). Our results determine a dynamic model of *P. rapae* feeding, confirming suggested hypotheses developed from anatomical studies. This study will contribute to the development of new analytical models of feeding that aim to understand the functional performance of single-pump fluid feeding systems in insects.

S1-1.3 ROBIE, Alice A.; KABRA, Mayank; BRANSON, Steven; HIROKAWA, Jonathan; KORFF, Wyatt L.; BRANSON, Kristin*; HHMI Janelia Farm; *bransonk@janelia.hhmi.org*

Making Automated Tracking and Behavior Analysis High Throughput in Practice

As part of the large scale effort at Janelia to understand the function of the *Drosophila melanogaster* nervous system through correlation of high-throughput behavioral and neuroanatomical studies, we have combined the tools of FlyBowl, Ctrax, and new machine learning-based behavior classifiers to create a high-throughput behavioral screen of fruit fly locomotor and social behaviors. FlyBowl, a chamber developed to facilitate automated tracking, has been modified to increase throughput and image quality consistency, allowing unsupervised use of an updated Ctrax tracking algorithm. We developed new behavior learning tools that can generalize behavior definitions across over a thousand GAL4 lines. We are currently screening lines from the Rubin GAL4 collection at a rate of 75 lines per week, requiring processing of 400 16-minute videos of 10 male and 10 female flies per week. To provide oversight and visualize behavioral effects in such a large data set, we have been developing visualization tools for examining the stability of experimental conditions, detecting errors in the data collection or analysis, and finding new and interesting behavioral phenotypes. In our TRPA1 screen, we saw significant differences in our automatic metrics for locomotor and social behaviors which recapitulate human annotation. The development of this assay pipeline from data collection through automated analysis allows for the rapid generation of detailed, quantitative descriptions of behavior changes due to sparse neural activation.

S3-1.6 ROCKMAN, Matthew; New York University;
mrockman@nyu.edu

Looking for poecilogony in the Streblospio benedicti genome

Larval traits couple development and ecology. Alleles at loci that influence larval morphology have pleiotropic effects on feeding and predation and on their own gene flow. Though such loci must underlie evolutionary transitions in larval form, the number of loci that contribute to evolutionary transitions, their molecular characteristics, and the population-genetic processes that shape their evolution remain unknown. The abundant benthic polychaete *Streblospio benedicti* provides a unique genetically tractable entry point to these questions. Individuals of *S. benedicti* vary in diverse aspects of development; some females produce small, planktotrophic larvae, and others produce large, yolky larvae capable of settling without feeding. These alternative developmental types breed true in the lab but exchange genes in the wild. I will describe our progress in searching for the genetic basis for poecilogony in *S. benedicti*, beginning with the characterization of basic parameters of the species' genome and its patterns of genetic variation, including determination of genome size and karyotype, estimation of nucleotide heterozygosity and patterns of linkage disequilibrium, and ultimately construction and annotation of genetic and physical maps that will allow use of molecular quantitative genetics to reveal the genes underlying developmental variation.

71.6 ROGNSTAD, R L*; WETHEY, D S; HILBISH, T J; Univ. of South Carolina, Columbia; *rhiannon@biol.sc.edu*

Intertidal population connectivity: limitations of climate and larval supply

In marine systems, connective processes are mainly constrained to the planktonic larval stages, as most benthic species are sedentary as adults. Though larval connectivity has been identified as a driving force in the establishment and maintenance of marine populations, the factors controlling the magnitude and extent of connectivity are not well-defined. Physical transport of larvae is a contributor, but other factors, including larval supply, must also be investigated. Populations of the barnacle *Semibalanus balanoides* in the United Kingdom provide an ideal system for testing the role of larval supply, as this species has a documented critical temperature for reproduction. The recent extreme European winters (2008-2009, 2009-2010, 2010-2011) provide us with a range of relevant temperatures and corresponding larval abundances. In 2010, we identified *S. balanoides* in Southwest England, an area where this species had been rare in recent decades. We predicted that recent cold winters have allowed increased recruitment in Southwest England. We tested this hypothesis by quantifying larval recruitment in Southwest England after the cold winters of '08-'09 and '09-'10. Prior to 2008, *S. balanoides* adults were uncommon in Southwest England, but abundant recruitment occurred in both cold years. Increase in recruitment between 2009 and 2010 allowed us to make predictions about further recruitment or range expansions of *S. balanoides* in Southwest England. Specifically, we predicted the cold winter of 2010-2011 would have allowed another season of abundant recruitment and range expansion into previously unoccupied areas of Southwest England, which we tested by quantifying recruitment during the summer of 2011.

25.5 ROPER, M.L.*; SIMONIN, A.; LEEDER, A.; GLASS, N.L.; UCLA, UC Berkeley; *mroper@math.ucla.edu*

Genomic dynamics in a growing filamentous fungus

The syncytial cells of filamentous fungi may harbor tens, thousands or even millions of genetically diverse nuclei within a single shared cytoplasm. This genetic diversity is acquired by mutations when nuclei divide, or by fusion of neighboring fungi, followed by the exchange of genetic material. Increasing evidence shows that this internal genetic flexibility enhances virulence and the ability of fungi to utilize nutritionally complex substrates like plant cell walls, and is a motor for fungal diversification. However, maintaining genetic diversity during growth poses a difficult biophysical problem, since mycelia grow by the extension of hyphal tips, and this process naturally segregates out different nucleotypes. Using strains of the ascomycete species *Neurospora crassa* in which nucleotypes can be distinguished by fluorescently labeled histone proteins, I'll show that genetic diversity can be maintained at every length scale of the fungus at the cost of continuous physical mixing of nuclei and nucleotypes during growth. Remarkably these complex multidirectional mixing flows are apparently optimized for mixing, but yet must be realized by static and spatially coarse pressure gradient from the interior of the mycelium to the tips. The architecture beneath the apparently random branching of fungal hypha may therefore provide lessons for the design of efficient microfluidic reactors.

61.7 ROS, I.G.*; BIEWENER, A.A.; Harvard University; *ivo.ros@gmail.com*

Heart rate is not modulated with flight speed in cockatiels

We examined how heart (HR) varies as a function of flight speed in a flying bird, examining changes in HR of cockatiels (*Nymphicus hollandicus*) flying in a wind tunnel at different speeds. In mammals, heart rate (HR) correlates well with the rate of metabolism (metabolic power), indicating that heart rate is adjusted to meet the oxygen demand for a particular level of exertion and that increased oxygen demand at higher metabolic power is (at least partially) met by increased cardiac output. Measurements of the rate of respiratory oxygen consumption (VO_2) can be used to estimate metabolic aerobic power for animals that burn fuel using oxidative phosphorylation. However, respirometry is experimentally challenging to achieve for flying birds over a range of sustained flight speeds, and relatively few studies have successfully accomplished this. Assuming a strong correlation between HR and VO_2, HR measurements have been used to estimate the metabolic power requirements of freely flying birds. We therefore hypothesized that HR would correlate with metabolic power in cockatiels across a range of flight speeds. Aerodynamic theory predicts and empirical data confirm that for cockatiels metabolic power varies with flight speed as a U-shaped power curve. HR was measured by implanting EKG electrodes over the dorsum of the bird's thorax. Surprisingly, we found no change in HR during steady flights across a wide range of flight speeds (0-16 m/s), indicating that cockatiels do not adjust HR to alter oxygen supply to their flight muscles. Instead, HR remained constant across the entire range of flight speeds at 817 ± 5 beats/min (mean ± SD across all flight speeds), elevated about 2.3-fold relative to the resting value (356 ± 2 beats/min). We therefore suggest caution when using heart rate as a proxy for estimates of metabolic power during avian flight.

36.7 ROSE, C.S.*; JAMES, B.; James Madison University; *rosecs@jmu.edu*

Plasticity of lung development in frogs

In contrast to previous attempts to raise frogs in normoxic water without access to air, we found that under such conditions *Xenopus laevis* tadpoles can routinely complete climax metamorphosis, albeit more slowly and with a higher percentage of laggards. More importantly, animals that complete metamorphosis appear fully viable with lungs that are highly stunted and uninflated or possibly absent altogether. This is the first demonstration that lung development in a tetrapod can be effectively inhibited by environmental factors and that a postlarval tetrapod that is normally reliant upon a significant amount of lung respiration under unstressed and inactive conditions can be raised to forego this requirement without suffering ill effects. We used histology to examine air-deprived tadpoles and frogs to determine whether inhibition of lung development results from failure of lung buds to develop and grow or from failure of differentiated lungs to inflate. To further test the plasticity of lung development, we scored the ability of air-restored animals to recover lungs of normal size as a function of developmental stage and time after air access is restored. Lung recovery was also correlated with swimming and breathing behaviors to assess their relationship with this process. Levels of cell division in the lung tissue of air-deprived, air-restored and untreated animals were compared to assess its role in the development and inflation of normal and recovered lungs. Experiments were also carried out to determine the effect of inhibiting lung development on growth and developmental rates under varying conditions of water flow.

45.2 ROSEN, Ohad*; MANOR, Rivka; WEIL, Simy; AFLALO, Eliahu D.; ABDU, Uri; SAGI, Amir; Ben Gurion University of the Negev; *roseno@bgu.ac.il*

The identification of Cq-MAG, a novel androgenic gland-specific gene encoding a putative crustacean membrane-anchored protein

In crustaceans, male sexual differentiation and manifestation of secondary masculine sex characteristics are attributed to a proteinaceous androgenic gland (AG)-specific insulin-like hormone. Previously in the Australian red claw crayfish *Cherax quadricarinatus*, the hormone's encoding gene (designated *Cq-IAG*) was identified using an AG cDNA library and its functionality was determined. In the present study, an additional AG-specific novel gene, encoding a putative membrane-anchored protein (termed *Cq-MAG*), has been identified. This is the first non-insulin-like AG-specific gene to be found in crustaceans. At the genomic level, *Cq-MAG* was shown to comprise of two exons and a single intron, and using molecular biology tools (e.g., RT-PCR, northern blot and RNA *in situ* hybridization) have demonstrated its mRNA tissue specificity. *Cq-MAG* was fully sequenced, revealing a cDNA sequence of 920 nucleotides encoding a putative translation product of 189 amino acids with a 42 amino acid-long signal anchor at its N-terminus. The expression of full length, truncated and mutated Cq-MAG fused to green fluorescent protein (GFP) in *Drosophila* Schneider cells, led to the identification of the signal require for anchoring the protein into membranes. Combining *Cq-MAG*'s specific expression localization and its signal anchor, along with the AG's insulin secretion background, requires further investigation of Cq-MAG as a component of the secretion machinery needed for the discharge of the insulin-like AG hormone in crustaceans.

55.6 ROSENTHAL, JJC*; CORREA, RA; PALAVICINI, JP; Institute of Neurobiology, Univ. of Puerto Rico/RCM; *joshua.rosenthal@upr.edu*

The squid nervous system expresses novel RNA editing enzymes

Genome sequencing projects make it clear that an organism's complexity is not proportional to the number of genes that it possesses. Accordingly, other mechanisms must be important to generate genetic diversity. RNA editing, used primarily in the nervous system, is one example. Among eumetazoans, adenosine deamination to inosine is the most common form of RNA editing, however the extent to which it is used to change codons varies greatly. Although it clearly has important consequences in vertebrates, it is infrequently used to modify protein structure. Recoding by A-to-I editing is much more common in invertebrates. For example, in Drosophila an order of magnitude more A-to-I recoding events than in mammals have been identified. In cephalopods, it is even more robust. In fact, more A-to-I recoding events have been uncovered in a handful of mRNAs from the squid nervous system than in the entire human transcriptome. What then are the underpinnings of high level editing in squid? We hypothesized that they have evolved specializations to their editing enzymes. Vertebrates have two ADARs, the enzymes that catalyze A-to-I editing: ADAR1 and ADAR2. Both contain a highly conserved catalytic domain and 2 or 3 double-stranded RNA binding domains (dsRBDs). Squid express an ortholog of each; however in both cases they have unique features. Squid ADAR1 contains a large serine rich domain with close to 70 potential phosphorylation sites that appears to be unique among ADARs. Squid ADAR2 contains an extra dsRBD. In addition, the mRNAs for both squid ADARs are themselves extensively edited, leading to a tremendous diversity of isoforms. *In vitro* assays using recombinant enzymes indicate that both the novel domains, and the self-editing, augment editing site recognition.

92.1 ROSS, C.F.*; BLOB, R; CARRIER, D.R.; DALEY, M.A.; DEBAN, S.M.; DEMES, B.; GRIPPER, J.L.; KILBOURNE, B.; LANDBERG, T.; POLK, J.; SCHILLING, N.; VANHOOYDONCK, B.; University of Chicago, Clemson University, University of Utah, Royal Veterinary College, University of South Florida Tampa, Stony Brook University, Boston University, University of Illinois Urbana-Champagne, Friedrich-Schiller-UniversitÃ¤t, University of Antwerp; *rossc@uchicago.edu*

Evolution of tetrapod rhythmicity

The period of cyclic, oscillating musculoskeletal systems scales with the size of the system in a manner suggestive of resonant tuning. However, the energetic and control benefits of resonant tuning can only be realized if variance in mean cycle period is low. Chew cycle period is less variable among mammals than among lepidosaurs and scales with jaw length in mammals but not lepidosaurs, suggesting clade-specific differences in degree of resonance tuning of musculoskeletal movements. Rhythmicity of locomotor movements was compared across tachymetabolic (birds, mammals) and bradymetabolic (lizards, alligators, turtles, salamanders) tetrapods. Variance in locomotor cycle periods was shown to be significantly lower in tachymetabolic than in bradymetabolic animals using treadmill data, non-treadmill data, or both. When phylogenetic relationships were taken into account, the non-treadmill analysis remained significant, the treadmill analysis became nonsignificant (but only marginally) and the non-treadmill analysis was not significant. It is hypothesized that high rhythmicity has advantages related to resonance tuning, coordination, and control of complex behaviors. Convergently evolved features of bird and mammal sensorimotor systems plausibly linked to rhythmicity include large Ia-afferent nerve fibers, &gamma-motoneurons, and enlarged, elaborated telencephala

110.4 ROTH, TC*; LADAGE, LD; FREAS, CA; PRAVOSUDOV, VV; Kenyon College, Univ. of Nevada, Reno; *rotht@kenyon.edu*

Variation in memory and the hippocampus across populations from different climates: a common garden approach

Selection for enhanced cognitive traits is hypothesized to produce enhancements to brain structures that support those traits. Although many studies suggest that this pattern is robust, there are several mechanisms that may produce this association. First, cognitive traits and their neural underpinnings may be fixed as a result of differential selection on cognitive function within specific environments. Second, these relationships may be the product of plasticity, where differences are produced due to an individual's experiences in the environment. Alternatively, the relationship may be a complex function of experience, genetics, and/or epigenetic effects. Using a well-studied model species (black-capped chickadee, Poecile atricapillus), we have addressed these hypotheses. We found that differences in hippocampal (Hp) neuron number, neurogenesis, and spatial memory previously-observed in wild chickadees persisted in hand-raised birds from the same populations, even when birds were raised in an identical environment. These findings reject the hypothesis that variation in these traits is due solely to differences in memory-based experiences in different environments. Moreover, neuron number and neurogenesis were strikingly similar between captive-raised and wild birds from the same populations further supporting the genetic hypothesis. Hp volume, however, did not differ between the captive-raised populations, yet was very different in their wild counterparts, supporting the experience hypothesis. Our results indicate that the production of some Hp factors may be inherited and largely independent of environmental experiences in adult life, regardless of their magnitude, in animals under high selection pressure for memory, while traits such as volume may be more plastic and modified by the environment.

116.6 ROWE, M. F.*; BAKKEN , G.S.; RATLIFF , J.; HAGAN , D.; THEISON, W.; Indiana State University, Indiana State University , Audubon Nature Institute, Indianapolis Zoo, Pittsburgh Zoo; *mrowe6@sycamores.indstate.edu*

Radiant heat loss in the pinnae of exercising elephants: pinna recruitment or regional non-pachyderm?

Abstract African (*Loxodonta africana*) and Asian elephants (*Elephas maximus*) are characterized by thick skin, gigantic body size and large pinnae. Pinnae are believed to play a significant role in thermoregulation. During locomotion the pinnae are held tightly against the body. Radiant heat transfer occurs in the anterior pinna surfaces. The anterior pinna surfaces accounts for about 7.4% and 2.6% of the total surface area in African and Asian elephants, respectively. The percentage of metabolic heat is often used to reference the amount of heat loss in the pinnae. Heat production in elephants increases 2 to 5 fold as a result of slow to moderate walks. If pinnae are independently recruited, the proportion of radiant heat loss from the pinna relative to total radiant heat loss will increase as a result of exercise. We sought to determine whether post-exercise increases in radiant heat transfer in pinnae of elephants occurred independently of the increases in total radiant heat loss. We performed pre- and post-exercise thermal imaging of the pinnae, and whole bodies of African (n=7) and Asian elephants (n=2). Exercise trials (n= 58 trials, totaling 96 km) were conducted during three seasons, over ambient air temperatures ranging from 5 to 34.5°C.There was no statistically significant difference ($P \geq 0.05$) between the pre- and post-exercise proportion of total radiant heat loss accounted for by radiant heat loss from the pinnae. Regardless of environmental conditions, radiant heat loss from the pinnae accounts for 7.4% of the pre-exercise and 7.8% of the post exercise radiant heat loss in African elephants and 2.5% of pre- and post-exercise total radiant heat loss in Asian elephants.

57.1 RYAN, C.P.*; DAWSON, A.; SHARP, P.J.; WILLIAMS, T.D. ; Simon Fraser University, Burnaby, Canada, Centre for Ecology and Hydrology, Edinburgh, U.K., The Roslin Institute, University of Edinburgh, U.K. ; *calen_ryan@sfu.ca*
Experimental evidence for a role of prolactin in modulating avian clutch-size
Clutch-size is one of the most important contributors to lifetime fitness in birds, and a multitude of ultimate explanations have been proposed to explain observed clutch-sizes in birds. However, surprisingly little is known about the underlying, proximate, physiological mechanisms involved in clutch-size determination. The role of prolactin in incubation behaviour is relatively well-supported. However, the predominant model for hormonal control of clutch size, which predicts an inhibitory role of prolactin on follicle development, currently has very limited empirical support, despite widespread acceptance. Using a repeated-measures design, we investigated the role of prolactin in clutch-size determination in captive-breeding female zebra finches (*Taeniopygia guttata*). We used the dopamine receptor agonist, bromocriptine, to manipulate prolactin levels, and recorded changes in clutch-size and other parameters of maternal investment. In a complementary experiment, we also manipulated clutch-size using an egg removal protocol, and examined effects on circulating prolactin levels. We found a significant effect of bromocriptine on clutch-size, but in the *opposite* direction than predicted from previous findings. The relationship between clutch-size, plasma prolactin levels, and other hormones and measures of maternal investment will be discussed.

S9-2.2 RYAN, J.F.; PANG, K.; SCHNITZLER, C.E.; NGUYEN, A.-D.; MORELAND, R.T.; HAVLAK, P.; PUTNAM, N.H.; NISC, ; WOLFSBERG, T.G.; MULLIKIN, J.C.; MARTINDALE, M.Q.; BAXEVANIS, A.D.*; NHGRI/NIH, Univ. of Hawaii, Rice Univ.; *andy@mail.nih.gov*
The Genome of the Ctenophore, Mnemiopsis leidyi: Insights into the Origins of Morphological Complexity
Whole-genome sequencing of non-bilaterian animal species and their closest non-metazoan relatives has provided invaluable insight into the molecular innovations that have fueled the outbreak of diversity and complexity in the early evolution of animals. Until recently, the phylum Ctenophora was the only non-bilaterian metazoan lineage without a sequenced genome. To fill this void, we have sequenced, assembled, and annotated the 155 Mb *Mnemiopsis* genome at 12x coverage. In addition, RNAseq data from mixed-stage *Mnemiopsis* embryos were aligned to the genome and used as the basis for transcriptome annotation. Manual inspection of gene predictions was also performed against experimentally verified RACE transcripts. Based on this work, the *Mnemiopsis* genome is predicted to contain 16,545 genes and 91,482 exons. The availability of these high-quality, genome-scale sequence data has enabled us to answer some important questions regarding phylogenetic diversity and the evolution of proteins that play a fundamental role in metazoan development. Our initial analysis of the genome shows that many of the transcription factors and signaling pathway components present in other animal genomes are also present in the *Mnemiopsis* genome. However, several important developmental genes present in bilaterians, cnidarians, and placozoans are conspicuously absent in *Mnemiopsis*. These findings are consistent with recent molecular-based phylogenies and support the notion that ctenophores and sponges are the two earliest-branching animal lineages. Analysis of the gene content of these earliest metazoan groups is helping to redefine which components were required for the origin of morphological complexity and shed new light on the actual phylogenetic position of the ctenophores.

106.3 RYERSON, WG*; SCHWENK, K; University of Connecticut; *william.ryerson@uconn.edu*
Why snakes flick their tongues: a fluid dynamics approach
The forked tongue of snakes is used to collect chemical molecules (odorants) from the environment and deliver them to the vomeronasal organs in the roof of the mouth. Snakes use two methods to sample odor molecules: a substrate touch with the tongue tips and oscillatory tongue-flicking in the air. Among fork-tongued squamates, snakes are the only group to employ oscillatory tongue-flicking for chemoreception. We used particle image velocimetry (PIV) to examine the flow of air around the tips of the tongue during tongue- flicking. This revealed that oscillatory tongue-flicks generate two pairs of counter-rotating vortices that are maintained by the movement of the tongue tips. The tongue tips skim along the margins of these vortices moving against their flow during both the upstroke and the down stroke. In addition, the vortices draw fresh air (and chemicals) into the path of the tongue, also in a countercurrent direction. This flow pattern maximizes the encounter rate of the tongue with odorant molecules and because the tongue tips are coated with mucous fluid, it greatly increases the rate of diffusion/sorption of odorants into the fluid by thinning the boundary layer and maintaining a concentration gradient. The pattern of vortex formation is dependent on the number of oscillations, size, and velocity of the tongue, which vary greatly among species. We suggest that changes in these factors maintain tongue movement within a specific Reynolds number regime that maximizes the rate of odorant uptake.

93.5 SACKEY-MENSAH, Cordelia*; RUEPPELL, Olav; Univ. of North Carolina, Greensboro; *c_sackey@uncg.edu*
Investigating intestinal stem cell proliferation rate as an indicator of honey bee (Apis mellifera) health.
The role of honey bees as honey producers and pollinators makes the decline of these bees not just an environmental matter but also an agricultural and economical problem. Exposure to xenobiotics, such as pesticides and antibiotic treatments, might cause physiological changes, contributing to bee health decline. The midgut functions as the first physical barrier after honey bees ingest xenobiotics and could serve as an important indicator of health. The midgut of adult *Apis mellifera* is maintained by intestinal stem cells (ISCs), which usually represent the only large somatic proliferative cell population in adult insects. Therefore, we investigated the effect of twelve relevant xenobiotics on ISC proliferation rate at relatively high concentrations. Three of these xenobiotics (methoxyfenozide, fluvalinate and oxytetracycline) had a significant effect on ISC proliferation rate and fluvalinate and oxytetracycine caused strongly increased mortality. Next, we aimed at detecting sub-lethal effects on ISC proliferation of these xenobiotics. Therefore, three lower concentrations of fluvalinate, oxytetracycline, methoxyfenozide and a potentially synergistic combination of coumaphous and fluvalinate were assessed. To include the possibility of long-term effects, ISC proliferation was measured in treatment and control groups at three different ages. Data collected to test our hypothesis that these xenobiotics will affect ISC proliferation at concentrations that do not significantly affect bee mortality will be presented . This will contribute to our understanding of sub-lethal effects of xenobiotics in a novel, health-relevant context and evaluate ISC proliferation as a honey bee health indicator.

24.6 SALZMAN, RE*; SCHWARTZ, JM; AHN, AN; Claremont McKenna College, Harvey Mudd College; *rsalzman12@cmc.edu*
The Effect of Passive Joint Elements on the Movement Output of the Frog Ankle
In order to understand the role of passive elastic elements in movement, we examine the position output of an intact ankle joint in the American bullfrog (*Rana catesbeiana*). Upon stimulation, the plantaris longus muscle (PL) extends the ankle, which then passively recoils completely to return the ankle to its initial ankle position in less than a second. Similarly upon stimulation, the tibialis anterior muscle (TA) flexes the ankle, which then passively, fully recoils back to its original position. The antagonistic muscle might passively cause this recoil like a rubber band pulling the limb back into place. For this reason, we hypothesized that cutting the antagonistic muscle and tendon would eliminate or reduce the recoil in the ankle joint. The unstimulated, antagonist muscle-tendon unit contributed in determining the rest position of the joint for both the PL and the TA. The rest angle of the ankle joint with the PL intact and the TA cut (N = 7) increased by 15 ± 9° (extension). With the TA intact and the PL cut (N = 7), the rest angle of the leg decreased by 51 ± 11° (flexion). However, after the muscle was stimulated, the antagonist muscle-tendon unit had no effect on the speed or magnitude of recoil of the ankle joint. Beyond the muscle-tendon unit, joint elements such as the ligaments or capsule may play a larger role in the movement of the frog ankle joints than previously expected. These findings could have implications for the design of biomechanical lever systems, such as the use of passive elements in prosthetics and robotics. We thank HHMI, Barbara Stokes Dewey, REBMI (NSF-0634592), a Baker Award, and the HMC Biology Department for funding.

S1-1.2 SAMUEL, Aravi*; GERSHOW, Marc; KANE, Elizabeth; KLEIN, Mason; LUO, Linjiao; AFONSO, Bruno; VONNER, Ashley; Harvard University; *samuel@physics.harvard.edu*
How Drosophila larvae navigate
How do Drosophila larvae navigate their environments? Using high-throughput quantitative tracking methods with single-animal resolution, we have uncovered the behavioral strategies of larva navigating a variety of defined environments. By analyzing the trajectories and time-varying postures of individual animals as they explore gradients in their environments, we found remarkable similarities and differences in the navigational strategies that subserve a variety of orientational beahviors including phototaxis, chemotaxis, aerotaxis, and thermotaxis. These results point to the computational framework for understanding how navigational behavior is encoded in the larval nervous system through regulation of a small set of motor patterns.

40.5 SAMUNI-BLANK, M.*; IZHAKI, I.; DEARING, M.D.; ARAD, Z.; Technion, Haifa, Israel, Univ. of Haifa, Haifa, Israel, Univ. of Utah, Salt Lake City; *michal.samuni@gmail.com*
From a Seed Predator to a High-Quality Seed Disperser: The tale of Acomys cahirinus and Ochradenus baccatus
The ripe fruits of many plants contain plant secondary metabolites (PSMs) in concentrations that could be toxic to vertebrates. The directed-deterrence hypothesis (DDH) states that PSMs in ripe fruit are deterrents for seed predators, but have no or little toxic effect on seed dispersers. *Acomys cahirinus* is a murid rodent usually described as a predominantly seed predator, sharing its habitat with the *Ochradenus baccatus* bush in the Israeli desert. In this study, observations on captive individuals, backed by field observations, revealed *A. cahirinus* as a high-quality seed disperser that: (1) carries the whole fruit cluster away from the parent plant, (2) consumes an average of six fruits per minute, (3) eats only pulp and expectorates the majority (73.8%) of the seeds undamaged, (4) expectorates seeds that have a germination success (74.4%) similar to that of seeds manually separated from the pulp, (5) consumes the fruits mainly between the rocks, a location that may provide favorable conditions for seedling establishment. We suggest that this unique behavior is the result of the presence of PSMs in *O. baccatus* fruits. Glucosinolates (GLSs) located mainly in the pulp of *O. baccatus* are activated upon mechanical injury to the seeds by the enzyme myrosinase. These activated GLSs are known to generate considerable physiological effects on mammals. The compartmentalization of the GLSs and myrosinase in *O. baccatus* fruits may shape the interaction between *O. baccatus* and *A. cahirinus*. Thus, in agreement with the DDH, the PSMs in *O. baccatus* may have transformed the role of *A. cahirinus* from a seed predator to a high-quality seed disperser by modifying its feeding behavior.

20.4 SANDERS, T; KAZMAIER, R; LIGON, D*; Missouri State University, West Texas A&M University; *DayLigon@MissouriState.edu*
Thermal ecology of yellow mud turtles (Kinosternon flavescens) during hibernation
Yellow mud turtles (*Kinosternon flavescens*) are putatively aquatic, yet presence of surface water is seasonal and often unreliable across much of its range. Summertime estivation is frequently necessary to survive periods of drought. Additionally, low winter temperatures necessitate hibernation in the northern parts of the species' range. As a result, individuals frequently spend large portions of the year in terrestrial dormancy. We measured daily and seasonal fluctuations in soil temperatures and body temperatures of hibernating yellow mud turtles at Gene Howe Wildlife Management Area in the Texas panhandle from September 2009 to March 2010. We then used these data to determine: 1) when individual turtles left their pond, burrowed into the soil and began winter dormancy; 2) the depth at which turtles hibernated; 3) the timing and frequency with which they changed depth; and 4) the date on which each turtle emerged from hibernation and returned to the pond. Additionally, temperature-specific metabolic rate data obtained from captive turtles were used to estimate energy consumption during hibernation. Among seven turtles from which data were recovered, hibernation began 20 September–4 October, turtles buried themselves 11–80 cm below the surface, and several turtles burrowed progressively deeper as winter progressed. Spring emergence was asynchronous, occurring 5 March–21 April. Lipids were likely the dominant metabolic substrate fueling hibernation, and turtles used an estimated 38–51 kJ during hibernation.

S5-2.3 SANDERS, K L*; RASMUSSEN, A R; DE SILVA, A; MUMPUNI, n/a; UKUWELA, D B; University of Adelaide, Australia, Royal Danish Academy of Fine Arts, Denmark, Amphibia and Reptile Research Organisation of Sri Lanka, Museum of Zoology, Bogor; *kate.sanders@adelaide.edu.au*

Ecological innovation and speciation in viviparous sea snakes (Hydrophiinae)

The viviparous sea snakes provide a rare model of recent adaptive radiation in the marine environment. We present the first near-complete dated molecular phylogeny for the group, using coalescent analyses of 6 independent mitochondrial and anonymous nuclear loci for 85% of nominal species. Lineage-through-time plots reveal a dramatic increase in diversification rate ~3-5 million years after the initial invasion of marine habitats. Patterns of adaptive radiation and geographic range evolution are explored by: i) reconstructing rates of morphological and ecological (dietary) character change on the phylogeny and fitting alternative (constant and variable rate) likelihood models to these data; ii) generating ordination plots of diet disparity and generalised phenotype to test whether sea snake radiation is characterised by early partitioning of trait diversity among clades or recurrent evolution of ecomorphs within clades (resulting in an overall increase in homoplasy); iii) examining the role and mode of geographic isolation in sea snake speciation by regressing the degree of range overlap between species and clades against the age of their most recent common ancestor. Overall, our results highlight the dynamic and complex history of phenotypic evolution in sea snakes and reveal an important role for adaptive shifts in driving their rapid diversification.

76.5 SANDKAM, B.A.*; WATSON, C.T.; JOY, J.B.; BREDEN, F.; Simon Fraser University; *bsandkam@sfu.ca*

Genomic and lighting environments influence color vision in guppies

Guppies are one of the best known examples of sexual selection in that females prefer to mate with more colorful males. This raises questions of how do guppies see color and why is color so important to them. Color vision is mediated by transmembrane proteins in the retina called opsins. The peak spectral sensitivity of an opsin is a function of its genetic sequence. Understanding how guppies see and perceive color requires knowing the genetic sequence of the opsins that make up their opsin repertoire in addition to how they use their repertoire. The opsin loci of guppies and 15 other species in the Poeciliidae family were sequenced. High gene conversion activity was found to occur between two long-wavelength sensitive loci throughout the Poeciliidae family. This is most likely due to the genomic environment of these genes, which occur in an inverted orientation within a tandem array of multiple homologous genes. The extent to which the lighting environment influences expression profiles was determined by comparing the light environment and the opsin gene expression of guppies collected simultaneously from natural populations. Understanding the visual system of guppies will allow future work to investigate the mechanisms of choice that result in sexual selection.

14.3 SANGER, Thomas J.*; SEAV , Susan M.; LOSOS, Jonathan B.; ABZHANOV, Arhat; Harvard University; *tsanger@oeb.harvard.edu*

Evolution and Development of Sexual Skull Dimorphism among Anolis lizards

Many species exhibit striking sexual dimorphisms in body size and shape. Sexual body size dimorphism is well studied in many biological contexts – ecological, evolutionary, and physiological - but few studies have examined sexual shape dimorphism in the same detail. We have explored patterns of sexual size and shape dimorphism in the skull of 30 Anolis lizard species using geometric morphometrics and found that species with relatively elongate skulls exhibit exceptional sexual shape dimorphism relative to other species. The greatest axis of sexual shape dimorphism is in the length of the rostrum, or snout. In species with relatively short skulls snout length is typically isometric with respect to body size. In contrast, in species with elongate skulls only females exhibit isometry, males consistently exhibit positive static allometry suggesting a fundamental difference in the regulation of skull growth between the sexes. To explore whether this difference is associated with the onset of sexual maturity or is developmentally regulated we studied snout growth and patterns of gene expression at three life history stages: in hatchlings, juveniles, and sub-adults. Gene expression was quantified for a panel of 15 genes involved with the hormonal regulation of growth using quantitative-rtPCR. Male and female skull shape is not sexually dimorphic as hatchlings or juveniles, though females do appear to grow more rapidly and show significant expression differences for several genes. Sexual shape dimorphism in snout length appears around sexual maturity and may be due to a localized down regulation of growth in females rather than a significant physiological change in males. Further molecular studies are needed to examine whether these differences are associated with physiological changes in circulating hormone levels associated with sexual maturity or are locally regulated changes.

26.2 SANTAGATA, Scott; Long Island University; *scott.santagata@gmail.com*

Revaluating spiral-like cell cleavage patterns during the embryonic development of phoronids and brachiopods.

Embryonic patterns in cell cleavage and blastomere arrangements continue to be used as phylogenetically informative characters. However, cleavage patterns are clearly subject to evolutionary modifications especially among the various phyla that exhibit spiral cleavage. Although the prevailing viewpoint is that phoronids and brachiopods exhibit a form of radial cleavage, aspects of both spiral-like and radial-like cleavage have been observed and vary the most at the eight and 16-cell stages. Here, I use time-lapse video microscopy to investigate the early development of the phoronid, *Phoronis pallida* from False Bay, WA (USA). The early development of *Phoronis pallida* deviates from a typical radial pattern at the third, fourth, and fifth cleavages that alternate between dexiotropic and levotropic spiral divisions. These cleavage patterns were also corroborated using confocal microscopy by investigating the angle of the metaphase plate at cell divisions. Review of phoronid and brachiopod developmental patterns along with additional data from the brachiopod, *Terebratalia transversa*, suggests that both radial-like and spiral-like cell divisions occur within and among species, and that spiral-like patterns may be more prevalent in species with smaller eggs. These data coupled with recent phylogenomic analyses support the hypothesis that both phoronids and brachiopods are derived from an ancestor that exhibited a form of spiral cleavage. Considering allelic differences that underlie patterns of chirality in some gastropod mollusks, further research is needed to test whether cleavage variation in phoronids and brachiopods also reflects genetic variation within and among species.

67.1 SANTANA, S.E.*; LYNCH ALFARO, J.; ALFARO, M.E.; University of California Los Angeles; *sesantana@ucla.edu*
Adaptive evolution of facial color patterns in Neotropical primates
The rich morphological diversity of primate faces has captured the attention of naturalists for over a century. Researchers have long proposed that social behaviors have primarily shaped the intraspecific variation and interspecific diversity of primate faces, as predicted by the behavioral drive model of evolution. However, the primate face constitutes a complex structure where the potentially competing functions of communication, ecology and physiology intersect, and the major determinants of facial diversity still remain poorly understood. Here we examine the relationship among facial traits, social and ecological factors within the radiation of New World primates. Through a phylogenetic comparative approach, we provide the first evidence for an adaptive role of facial color patterns and coloration in primates. Consistent with the hypothesis that facial patterns function in communication and species recognition, we find that species living in smaller groups and in high degrees of sympatry with congeners have evolved more complex patterns of facial coloration. The evolution of facial pigmentation and hair length is linked to ecological factors, and ecogeographical rules related to UV radiation and thermoregulation are met by some but not all facial regions. Our results demonstrate the interaction between behavioral and ecological factors in shaping one of the most outstanding facial diversities of any mammalian clade.

55.1 SATTERLIE, Richard; University of North Carolina Wilmington; *satterlier@uncw.edu*
FMRFamide Immunoreactivity and the Diffuse Nerve Net of Scyphozoan and Cubozoan Jellyfish
Two diffuse nerve nets have been described, morphologically and physiologically, in the subumbrella of scyphomedsuae. These nets have mostly parallel distributions, and both appear to influence the swim musculature. One, the Motor Nerve Net (MNN), activates the swim muscles to produce swim contractions. The other, the Diffuse Nerve Net (DNN), appears to serve a modulatory role in alterning swim contractions. Similarly, the two nerve nets show different staining with immunohistochemical techniques--one is labeled with anitbodies to alpha or beta tubulin while the other is labeled with an antibody to FMRFamide. Distribution of stained neurons of both nets suggest the tubulin-immunoreactive net is the MNN while the FMRFamide-immunoreactive network is the DNN. Cubomedusase also show staining with both antibodies, and while the tubulin-immunoreactive networks are consistent with a MNN-like distribution (based on physiological examniation), the FMRFamide-immunorective networks are largely restricted to the centalized nervous system (rhopalia and nerve rings). If the FMRFamide-immunoreactive network retains its modulatory function, it suggests a centralization in which modulation of swimming activity has "moved" from the periphery in scyphozoans to a more centralized location in cubomedusae, most notably within the ganglion-like rhopalia.

19.4 SCHMIDT, André ; Ohio University Heritage College of Osteopathic Medicine; *schmidta@ohio.edu*
Individual locomotor strategies in degus (Octodon degu) – implication for biomechanical constraints on terrestrial substrates varying in orientation
During locomotion animals typically show individual preferences in their locomotor performance (e.g., protraction angle). Previous results suggest that these individual differences gain if substrate orientations become more variable and that wild animals show a higher variability than those kept in captivity. In order to test the effects of different substrate orientations on individual locomotor performances, degus were filmed with a normal light camera as they moved with maximum running speed on terrestrial trackways of different orientations (-30°, -20°, -10°, level, +10°, +20°, +30°). Key spatiotemporal and kinematic parameters were calculated for symmetrical gaits and compared between individuals and substrate orientations. Substantial differences were observed between individuals as they negotiated the substrate challenges. For example, some individual speed ranges were non-overlapping. Consequently, spatiotemporal and kinematic parameters, as well as posture (crouched vs. erect), differ significantly between individuals. However, a smaller magnitude of differences between individuals was observed as degus were confronted with inclines indicating higher biomechanical constraints. (Supported by NSF DBI 0922988)

76.4 SCHMITZ, Lars*; WAINWRIGHT, Peter C.; Univ. of California, Davis; *lschmitz@ucdavis.edu*
Nocturnality limits morphological and functional diversity in the eyes of reef fishes
Ambient light levels are often considered to drive the evolution of eye form and function. Diel activity pattern is the main mechanism controlling the visual environment of teleost reef fish, with day-active (diurnal) fish active in well-illuminated conditions, whereas night-active (nocturnal) fish cope with dim light. Physiological optics predicts several specific evolutionary responses to dim-light vision that are expected to be reflected in visual performance features of the eye. We analyzed morphological traits of the eye in 265 teleost reef fish, with a total number of 849 specimens. 54 species were classified as nocturnal, representing at least seven independent origins of nocturnality. Eye morphology of nocturnal reef fish is characterized by a syndrome that indicates better light sensitivity, including large relative eye size, high optical ratio and large, rounded pupils. Improved dim-light image formation comes at the cost of reduced depth of focus and reduction of accommodative lens movement. Diurnal teleost reef fish, released from the stringent functional requirements of dim-light vision have much higher morphological and optical diversity than nocturnal reef teleosts, with large ranges of optical ratio, depth of focus, and lens accommodation. Physical characteristics of the environment are an important factor in the evolution and diversification of the vertebrate eye. Both teleost reef fish and terrestrial amniotes meet the functional requirements of dim-light vision with a similar evolutionary response of morphological and optical modifications. The trade-off between improved dim-light vision and reduced optical diversity may be a key factor in explaining the uneven trophic diversity in reef teleosts.

105.2 SCHRAM, J.B.*; MCCLINTOCK, J.B.; AMSLER, C.D.; BAKER, B.J.; Univ. of Alabama at Birmingham, Univ. of South Florida; *jbschram@uab.edu*

Impacts of elevated seawater temperature on Antarctic amphipod feeding choices for chemically-deterrent macroalgae

As global temperatures continue to increase as part of the phenomenon referred to as climate change, the Western Antarctic Peninsula (WAP) is predicted to continue to be among the geographical regions with the highest rates of seawater warming. The sensitivity of marine invertebrates to changes in temperature varies widely geographically and by species. Temperature impacts on Antarctic marine invertebrates, a group known to be highly stenothermal, can be dramatic and small changes in temperature can have large effects on aspects of their physiology, growth, and species distribution. We examined the effects of end-of-century predicted seawater temperature (3.5 C) on the feeding choices of the ecologically dominant omnivorous amphipod *Gondogeneiea antarctica*. Amphipods were given a choice between artificial food prepared with and without macroalgal chemical extracts with known, moderately deterrent properties. Identical feeding trials were conducted simultaneously at an ambient seawater temperature of 1.5 C. We observed temperature-induced alterations in amphipod feeding preferences to food pellets containing lipophilic or hydrophilic extracts of the seven macroalgal species examined. Our results suggest that rapidly rising seawater temperature could impact trophic interactions in the macroalgal communities of the WAP.

16.5 SCHREY, AW*; LIEBL, AL; RICHARDS, CL; MARTIN, LB; Univ. of South Florida, Tampa; *aschrey@usf.edu*

The relative significance of genetic and epigenetic diversity for house sparrow colonization of Kenya

House sparrows (*Passer domesticus*) demonstrate considerable phenotypic variation among populations, which is surprising given that many populations were introduced and hence faced reduced genetic diversity due to founder effects or bottlenecks and had few generations to adapt genetically to new conditions. Here, we investigate the relative importance of genetic versus molecular epigenetic variation as a source of phenotypic variation in Kenyan house sparrows, one of the world's most recent invasions. Epigenetic mechanisms, such as DNA methylation, are often inducible and thus can influence gene expression, and ultimately generate phenotypic variation, without altering nucleotide sequences. We characterized genetic and epigenetic variation among nine Kenyan populations partly because of their recent introduction to coastal Kenya (Mombasa) in the 1950s and also because Kenyan sparrows exhibit lower genetic diversity than longer established introduced populations. We used microsatellites to assess genetic diversity and determine the pattern of range expansion in Kenya. We then used MS-AFLP to describe variation in DNA methylation within and among locations and determined whether epigenetic or genetic variation was greater among populations as well as whether epigenetic variation compensates for decreased genetic variation after introduction.

106.1 SCHUECH, Rudi*; STACEY, Mark; KOEHL, Mimi; Univ. of California, Berkeley; *rudis@berkeley.edu*

Numerical Simulations of Odorant Detection by Crustacean Olfactory Hair Arrays

Many marine crustaceans flick sensory antennules through the water to actively sample turbulent odor plumes. An important step in odorant detection is the transport of odorant molecules from the filamentous structures making up the plume to the individual chemosensory hairs (aesthetascs) arrayed on the antennules. Through processes such as advection and diffusion, the geometry and flicking kinematics of an animal's olfactory appendages affect the time course of odorant arrival to neurons, and thus how the animal perceives its odor landscape. We numerically modeled both flow and odorant transport as an odorant filament is sampled by a simple row of flux-detecting sensory hairs. Metrics of odorant flux such as peak flux, peak onset slope, total flux, and duration of stimulation were quantified for both individual hairs and the aggregate array as sampling kinematics and array geometry were varied. The relationship between array size and odorant flux is exhibits several peculiarities, and behavior can be completely opposite at different sampling speeds. These transitions in fundamental behavior suggest both a new advantage of flicking, and the non-intuitive possibility of appendages whose peak flux metrics change little with number of hairs despite increasing surface area. Neurons near the edges of an aesthetasc array experience higher peak metrics and total flux than those near the middle of the array, but will be stimulated for less time; such variation may be important in the context of spatial plume sampling by aesthetasc arrays.

S3-1.5 SCHULT, N.*; MCHUGH, D.; Colgate Univ.; *dmchugh@colgate.edu*

Streblospio benedicti (Spionidae, Annelida) as a model organism for the study of larval evolutionary transitions

Streblospio benedicti represents a rare case of poecilogony and is an ideal model for the integration of approaches to study evolutionary transitions in larval development mode of marine invertebrates. *S. benedicti* is a small, tube-dwelling worm found in dense populations in mudflats along the east coast of North America and the southern Californian coastline. Females either produce numerous small eggs that develop as planktotrophic larvae that spend up to three weeks in the plankton, or fewer large eggs that have no requirement to feed during their abbreviated development. Ecological, quantitative genetic, functional morphological, and phylogeographic work over the past three decades has set the stage for understanding developmental mode transitions by integrating knowledge from multiple levels, from macrohabitat to molecular, in this species. Tools are now available to investigate the genetic architecture shaping the two developmental morphs. We report our characterization of an EST screen for *S. benedicti* and our isolation of regulatory genes associated with gut regionalization (e.g., *Fox* and *GATA*). Using segmental muscle bands as reference points for comparable stages between the two larval forms, our whole mount *in situ* hybridization experiments are revealing similarities and differences in gene expression patterns between the small-egg larvae that must feed early in development and the large-egg larvae that do not require a functional gut until later in development. We hope our work with *S. benedicti*, a single poecilogonous species, will inform our general understanding of interspecific developmental mode transitions that have occurred repeatedly in marine invertebrate taxa.

S4-1.5 SCHULZE, A.*; MAIOROVA, A.; TIMM, L.E.; RICE, M.E.; Texas A and M University at Galveston, Institut of Marine Biology, Smithsonian Marine Station at Fort Pierce; *schulzea@tamug.edu*

Sipunculan Larvae and "Cosmopolitan" Species

Sipuncula are a relatively small taxon with roughly 150 recognized species. Many species are geographically widespread or "cosmopolitan". The pelagosphera larvae of some species are estimated to spend several months in the plankton. However, recent molecular evidence suggests that many of the "cosmopolitan" species actually represent species complexes, some not even monophyletic. Here we present data on three sipunculan species with different developmental modes that occur both in the Sea of Japan and in the Northeast Pacific. The development of the three species – *Thysanocardia nigra*, *Themiste pyroides* and *Phascolosoma agassizii* – is exceptionally well studied in both regions of the Pacific, owing to the extensive work of Mary Rice at the Friday Harbor Laboratories since the 1960s and that of Adrianov and Maiorova at the Institute of Marine Biology in Vladivostok. Interestingly, significant differences have been observed between the two regions with respect to reproductive and developmental timing, gametogenesis and developmental rate. In general, egg sizes are larger and development slower in the Northeast Pacific as compared to the Sea of Japan. These differences have been explained as a result of phenotypic plasticity exhibited under different environmental conditions, in particular temperature, but we show that the populations are also remarkably distinct genetically. Against our expectations, the largest genetic differentiation occurs in *P. agassizii* with the longest pelagic larval duration and the least in *T. pyroides* with the most abbreviated development. We are currently examining whether these counter-intuitive results are a product of over-conserved taxonomy by re-evaluating the morphological characters in each of these species.

36.4 SCHWAB, DB*; ALLEN, JD; College of William and Mary; *dbschwab@email.wm.edu*

Maternal size effects on reproduction and development in the mud snail, Ilyanassa obsoleta

A maternal effect occurs when the phenotype of an organism is influenced by the phenotype of its mother. When the maternal environment is an accurate predictor of the offspring's environment, maternal effects can play an important role in enhancing offspring fitness. Maternal investment (e.g. egg size), which is often a function of maternal size, is one mechanism for the transmission of maternal effects. We use the mudsnail, *Ilyanassa obsoleta*, as a model system for examining the effects of maternal size on offspring phenotypes. Females deposit egg capsules on blades of eel grass, and exhibit high variability in the number of egg capsules laid and the number of eggs per capsule. During their development, encapsulated embryos suffer high levels of predation. To test for the presence of inducible maternal effects, we investigated how egg capsule deposition and embryonic development are mediated by maternal size in the presence of a predator (the green crab, *Carcinus maenas*) by exposing small (15 – 19 mm) and large (21 – 25 mm) adult mud snails to *C. maenas* cue and measuring egg size, egg number, egg capsule number, and egg capsule morphology. Additionally, we measured larvae at hatching to test for effects of predator cues on intracapsule development. We found that large snails lay more egg capsules and eggs per capsule, but that egg size does not vary with female size. In the presence of a predator, egg capsules were wider and possessed significantly longer defensive spines. Larval size at hatching did not vary significantly with either maternal size or predator presence/absence. Overall, our results suggest that maternal effects in I. obsoleta may play an important role in defending embryos from predators during early development, but may not persist post-hatching when the environment is less predictable.

69.6 SCHWARTZ, J.A.*; CURTIS, N.E.; PIERCE, S.K.; Univ. of South Florida, Tampa; *jschwart@usf.edu*

Using fluorescent in situ hybridization (FISH) to localize transferred algal genes in the cells of the sacoglossan sea slug, Elysia chlorotica.

Although horizontal gene transfer (HGT) between unicellular organisms is a common occurrence in nature, only one example of HGT between multicellular species has been experimentally identified. *Elysia chlorotica* has one of the longest endosymbiotic relationships with chloroplasts of the heterokont alga, *Vaucheria litorea*. More than 60 genes of algal origin have been identified in *E. chlorotica* genomic DNA and/or cDNA. Many of these genes are involved in photosynthesis and its maintenance and likely sustain this long-lived endosymbiosis. Although whole genome sequencing is necessary to identify the full complement of algal genes present in the slug, it is of great interest to localize the transferred genes within the host cell. Using FISH probes made from previously identified native algal sequences and confocal microscopy, we have shown that *V. litorea* phosphoribulokinase (*prk*), fucoxanthin chlorophyll a/c binding protein (*fcp*) and photosystem II extrinsic protein O (*PsbO*) hybridize with nuclei of colchicine treated *E. chlorotica* embryos. Furthermore, in preliminary tests, among the 15 chromosome pairs in the *E. chlorotica* karyotype, FISH labeling of both *prk* and *fcp* occurs on the same chromosome. This localization may indicate that larger pieces of DNA rather than individual genes are involved in the transfer mechanism. (Supported by an anonymous donor).

63.1 SCOBELL, Sunny K. *; MACKENZIE, Duncan S.; JAQUES, John T.; JONES, Adam G. ; Department of Biology, Texas A&M University, College Station, Texas Veterinary Medical Diagnostic Laboratory, Texas A&M University, College Station; *sscobell@bio.tamu.edu*

Androgens and female intrasexual aggression in the sex-role reversed Gulf pipefish

Sex-role reversed species provide a unique opportunity to test the assumptions of sexual selection theory. For sex-role reversal to be an evolutionary stable strategy, females that win competitions must also be good mates. Therefore, selection that acts to increase aggressive behavior in females must do so without greatly hindering reproductive function. Little is known about the physiological mechanisms that regulate female aggression, but sex steroids are likely candidates. Several species in the family Syngnathidae (seahorses, sea dragons, and pipefish) are sex-role reversed, all species have male pregnancy, and they exhibit a range of mating systems from monogamy to polyandry. Although there is no reversal of plasma levels of the primary sex steroids in males and females, the androgen 11β-hydroxyandrostenedione is elevated in several female syngnathid species. 11-oxygenated androgens that stimulate male sexual coloration and courtship behavior in many species of fish are likely candidates for mediating sex-role reversed behavior in female syngnathids. We have conducted several studies on the role of androgens in female competitive behavior. We determined that 11-ketotestosterone affects intrasexual competitive behavior in female Gulf pipefish, *Syngnathus scovelli*. The size of the focal female, the competitive behavior of the stimulus female, and the method of hormone delivery also affect the focal female's response to 11-ketotestosterone. Our results suggest that androgens play a role in the mediation of female intrasexual competition in this species.

50.4 SCOTT, DE*; METTS, BS; UGA/SREL, Aiken, SC; *dsopacum@gmail.com*

Shifts in an isolated wetland salamander community over 30 yrs: Has climate change altered wetland hydrology?

Geographically isolated wetlands (GIW) constitute critically important habitat for many species; pond-breeding amphibians rely on GIW for larval development and recruitment of juveniles. Most GIW in the Southeast are seasonal, i.e., not continually filled with water, and amphibian recruitment success is determined largely by wetland hydroperiod (the amount of time a GIW holds water). Most pond-breeding amphibian species have adaptations to subsets of conditions along the hydroperiod continuum; i.e., there are 'short-,' 'intermediate-,' and 'long-hydroperiod' species. Climate change has the potential to exacerbate the increasingly serious problem of amphibian decline by inducing shifts in average hydroperiod, as well as "normal" pond filling and drying dates. Rainbow Bay (RB), a GIW on the Savannah River Site (SC), has been sampled daily for herpetofauna for 32 yrs, a record long enough to begin to examine relationships among environmental variables, amphibian population trends, and climate variability. Since 1978 the average hydroperiod at RB has decreased ($F_{1,28}$ = 6.69, P = 0.01) and the average date of pond filling is later ($F_{1,28}$ = 8.34, P = 0.007). During that time we observed a shift in community dominance from several longer hydroperiod salamander species (*Ambystoma talpoideum*, *A. tigrinum*, *Notophthalmus viridescens*) to a shorter hydroperiod species (*A. opacum*). Community changes appear to be related primarily to drought cycles and accompanying shortened hydroperiods, which differentially affect species' juvenile recruitment. Changes in hydroperiod dynamics of GIW across the landscape are likely to influence local (individual wetland) population persistence, as well as metapopulation dynamics by altering exchange rates of amphibians among wetlands.

35.6 SEARS, Michael W*; ANGILLETTA, Michael J; BUCKLEY, Lauren B; Bryn Mawr College, Arizona State University, University of North Carolina-Chapel Hill; *msears@brynmawr.edu*

Responses of species to climate change: the role of thermal adaptation of thermal reaction norms

Understanding the responses of organisms to changing climates is one of the more pressing questions for ecologists today. Over the past century, global climates have warmed and models predict continued warming into the near future. Given the thermal sensitivities of numerous physiological traits, the fitnesses of organisms will likely be impacted by these climatic shifts. In response, organisms might shift their geographic ranges by tracking climates to which their physiological processes are adapted. Here, we examined how locally adapted thermal reaction norms (TRMs) might contribute to future shifts in geographical range. Using 50 years of historical climate data, we modeled the optimal TRMs for energy assimilation for populations that ranged over a broad latitudinal gradient in North America. TRMs were modeled with and without the inclusion of a thermodynamic effect (i.e., 'hotter is better'). We then estimated the fitness consequences of TRMs by performing virtual reciprocal transplants for all populations along the gradient. Resultant TRMs varied in both their optima and breadth in response to local climate. Generally, optima were correlated with average temperatures for a location and more variable climates produced broader TRMs. If a thermodynamic effect was included in the optimization, TRMs were generally broader with warmer optima. The resultant fitnesses of adapted genotypes across latitudes were enhanced both by temporal variation in temperatures at their locations of origin and by the inclusion of the thermodynamic effect. Our results indicate that the predicted negative effects of local adaptation on responses to climate change might be less pronounced if historical climate series and the thermodynamic effect are considered.

59.5 SELF, ZT*; SPENCE, AJ; WILSON, AM; The Royal Veterinary College; *zself@rvc.ac.uk*

Jump racing: do horses slow down due to a force limit?

Running animals face the challenge of using limb force to support body weight over the time in which their feet are in contact with the ground. As they go faster, the proportion of the stride that the limbs are in contact with the ground (duty factor) drops. It has been proposed, in humans and horses, that one factor that limits speed is the maximum force which the limbs can withstand. This is supported by the observation that both humans and horses run slower on bends (simulating increased gravity), although interestingly this is not true in dogs. Jumping is a task that requires increased impulse (to raise the COM) and therefore the manner in which animals jump can be used to investigate what limits locomotor performance. Horses race over courses with jumps which requires a longer aerial phase between stances. If horses are constrained by limb force, they would have to use a longer limb contact time before and after the jump to maintain duty factor (which is inversely proportional to force). Here we test the hypothesis that jumping horses maintain duty factor in jump strides by increasing stance time and slowing down.

First, we examined speed and position data during jump races and found that horses slow down by up to $2 ms^{-1}$ at fences (a much greater drop in kinetic energy than the gain in potential energy required to clear the jump) which could avoid a limb force limit through increased contact time. However, high speed video data collected during jump training reveals that duty factor is lower in jump strides, suggesting increased limb force. Limited force plate data shows high peak forces during take-off, greater than those experienced during level galloping. These results suggest that limb force may not be a direct limit to racehorse jumping performance.

66.5 SERB, J.M.*; ZHANG, X.; WEST GREENLEE, M.H.; Iowa State Univ.; *serb@iastate.edu*

Applying Seed Networks to Genomic Data in an EvoDevo Context: A New Analysis Tool

Large-scale genomic expression studies have not yielded the expected insight into genetic networks that control complex processes of development. These anticipated discoveries have not been limited by technology, but by a lack of effective strategies to investigate the data in a manageable and meaningful way. We present a strategy that applies a user-determined seed-network of gene relationships under an evolutionary comparative framework. Our approach results in a list of candidate genes for further study and the expansion of the network of interest. Based on the evolutionary conservation of gene relationships, we test the hypothesis that a seed network derived from studies of retinal cell determination in the fly, Drosophila melanogaster, will be an effective way to identify novel candidate genes for their role in mouse retinal development. Our results demonstrate that the seed-network approach is an effective tool for querying datasets and provides a context to generate hypotheses. We identified 46 genes that correlated with the seed-network members. While the majority of these candidates have been previously linked to the developing brain (54%) and the developing retina (33%), our study is the first to link these candidates with specific members of the retinal determination pathway. Five of six candidate genes were validated by spatial and temporal protein expression experiments in the mouse retina. Future implementation of this strategy will be useful to determine the extent of network conservation, not just gene conservation, among species and will facilitate the use of prior biological knowledge to develop rational, systems-based hypotheses in EvoDevo.

73.1 SEYMOURE, Brett*; MCMILLAN, W. Owen; MCGRAW, Kevin; RUTOWSKI, Ron; Arizona State University, Smithsonian Tropical Research Institute; *brett.seymoure@gmail.com*

Heliconius mimicry rings in a new Light

Mullerian mimicry theory states that two or more aposematic individuals (unprofitable individuals that exhibit a warning signal) will converge on a similar signal to share the costs of predator education. However, this is not the case in many organisms that should exhibit Mullerian mimicry. We tested the hypothesis that different mimicry rings (differently colored groups of aposematic individuals) have evolved due to microhabitat segregation in *Heliconius* butterflies. We predicted that individuals in mimicry rings would choose a light environment that confers the strongest signal. In the tropical forest there are four light environments: red, blue, green, and white. We predicted the red and yellow mimicry ring would be found in red light habitats, while the blue and black mimicry ring would be found in blue light habitats. We further predicted that a red and yellow individual would have a stronger signal in the red environment than a blue and black individual and vice versa. We measured light environments (via irradiance and canopy cover) along transects where the mimicry rings are found. Behavioral trails were conducted to determine if butterflies had a preference for a light environment that granted a stronger signal and we employed visual models to verify that light environments would influence the perception of coloration of the different mimicry rings. We found that light habitats did differ among mimicry rings and that butterflies preferred different light environments. We show the effects of disparate light environments on the signal strength of the mimicry rings. This study demonstrates that different mimicry rings could evolve due to signal efficacy in different microhabitats.

93.1 SHAFFER, J.F.*; KIER, W.M.; University of North Carolina, Chapel Hill; *shafferj@unc.edu*

Muscular Tissues of the Squid Doryteuthis pealei Express Identical Myosin Heavy Chain Isoforms

Muscle tissue shows a remarkable diversity of contractile properties. At the molecular level, muscle contraction is generated through the enzymatic (ATPase) activity of the motor protein myosin. Variation in myosin amino acid sequences yield isoforms with a range of ATPase activity. The speed of shortening is generally proportional to myosin ATPase activity, thus, fast contracting fibers typically express a myosin isoform with high ATPase activity. Muscle fibers of the squid, however, may use an alternative mechanism to modulate contractile speed. Squid tentacle extensor muscle fibers possess ten-fold shorter thick filaments than those found in arm muscle fibers, and also contract ten times faster. The difference in thick filament lengths could explain the higher contractile speed of tentacle versus arm muscle fibers. Differences in contractile properties of the two muscle types could also be due to differences in myosin isoform ATPase activity. In order to determine if squid muscle fibers express tissue-specific myosin isoforms that could contribute to differences in contractile speed, we determined the myosin nucleotide and amino acid sequences from the tentacle, arm, fin, mantle, and funnel retractor musculature of the long-finned squid, *Doryteuthis pealei*. Three myosin isoforms were found in all five tissues studied, suggesting that the squid does not express tissue-specific myosin isoforms. This result supports the hypothesis that the contractile properties of squid muscle fibers are modulated by differences in ultrastructure (thick filament length) and not by myosin isoform (ATPase activity). The lack of tissue-specific myosin isoforms in the squid is unique amongst animals with muscles that display variable contractile speeds. Supported by NIGMS K12GM000678 (JFS) and NSF IOS-0951067 (WMK).

1.3 SHARICK, Jeffrey/T*; MEHTA, Rita/S; LAPPIN, A./K; Univ. of California, Santa Cruz, California State Polytechnic University, Pomona; *jeffsharick@gmail.com*

Biomechanical Modeling and In Vivo Bite Force in the Zebra Moray Eel, Gymnomuraena zebra (Muraenidae)

Bite force in vertebrates is often used as a proxy for various performance traits (e.g. food processing, male-male combat, anti-predator strategies). In the context of feeding, studies have shown that biting ability is linked to the biomechanical challenge the prey presents for the predator. In this study, we contribute to the growing comparative work on vertebrate bite force by studying cranial design and how it relates to biting in the zebra moray, *Gymnomuraena zebra*. Within muraenid fishes, zebra morays are thought to be the hallmark of durophagy with their diet consisting mainly of hard shelled prey such as xanthid crabs and reef urchins. Physiological Cross-Sectional Area (PCSA) and Mandiblever 3.3 were used to estimate bite force performance. While Mandiblever uses effective mechanical advantage to estimate bite force, PCSA uses mechanical advantage, possibly resulting in an inflated estimate of bite force. We then compared model output to *in vivo* bite force measures (N = 4) to validate model estimates. Model calculations estimated posterior maximal bite force to be 57.1 N and 59.3 N while posterior maximum *in-vivo* bite force was 159.2 N. Although the estimates of the two models are not significantly different from each other, measures from the *in vivo* bite trials are three times stronger than predicted by the models. We used the geometric mean of head dimensions (length, width, depth) to account for size variation among individuals and found a strong positive relationship between *in vivo* bite force and head size ($r^2 = 0.95$). We compare the bite performance of *G. zebra* to that of other durophagous vertebrates for which bite force has been measured empirically.

16.6 SHARMA, P.P.*; GIRIBET, G.; Harvard University; *psharma@fas.harvard.edu*

Upstream colonization of Australasia by Neotropical Opiliones (Arachnida)

The species richness and endemism of the Southwest Pacific are traditionally held to result from dispersal from Australasian continental landmasses (e.g., Australia, New Guinea, Southeast Asia), in concert with prolonged isolation. In the present study, the phylogeny of the circum-Pacific arachnid family Zalmoxidae (Opiliones, Laniatores) was investigated using a six-gene dataset under dynamic homology using parsimony, and static homology using maximum likelihood and Bayesian inference approaches. Ages of clades were inferred using BEAST v. 1.6.1 and ancestral area reconstructions were inferred using a DEC model, as implemented in the program Lagrange. Topologies across all analyses support the monophyly of Zalmoxidae and a Neotropical origin of this clade. Neotropical lineages within Zalmoxidae form a paraphyletic grade with respect to a derived Indo-Pacific clade. This topology, the molecular dating, and the relative phylogenetic placement of New Guinean and Southeast Asian lineages support a scenario of upstream colonization of Australasia by a Neotropical radiation. This highly uncommon biogeographical signal is contrasted with traditional views of Southwest Pacific biogeography.

60.2 SHARPE, S.S.*; JUDY, K.N.; DAFFON, K.; GOLDMAN, D.I.; Georgia Tech; *ssteinmetz3@gatech.edu*

Burrowing of the ocellated skink (Chalcides ocellatus) in wet and dry granular media

Many terrestrial animals locomote on and within soil in which water content can vary depending on rainfall, geographical location, and time of day. Empirical drag measurements in a wetted granular medium (GM) of 0.3 mm glass particles prepared into a loosely packed state revealed that resistance force increased by a factor of two as water content (W, the mass of water/mass of GM) increased to 3%, after which force became approximately independent of W. We tested if subsurface locomotion was affected by W using the ocellated skink (*Chalcides ocellatus*) (N=6 animals), a generalist burrower. We used high speed x-ray imaging to measure head, body and limb kinematics of the lizard during burial in loosely packed dry and wet (W=3%) GM. No gross differences in locomotor kinematics were observed; in both substrates during burial the body was maintained in a curved posture and the animal moved using a start-stop motion. During movement, the head oscillated and the fore limb on the convex side of the body was used to push the animal forward. Once the lizard was fully submerged, the hind limbs remained alongside the body. All body points posterior to the pectoral girdle followed the same trajectory indicating that the material surrounding the body remained solid during forward locomotion. We hypothesized that the head oscillation is used to decrease resistive force felt by the animal in the forward direction. We performed a test in which a rod, comparable in size to the diameter of the animal, was rotated back and forth by 30° then moved forward by 2.5 cm. In the dry GM the drag forces were independent of the oscillation, but in the 3% W GM forces were reduced by 16 ± 6%. This implies that head undulation can enhance locomotor performance in cohesive soils.

S5-2.4 SHEEHY III, C.M.*; LILLYWHITE, H.B.; PFALLER, J.B.; Univ. of Texas at Arlington, Univ. of Florida; *cmsheehy@uta.edu*

Low genetic diversity across the Pacific Ocean in the pelagic sea snake, Pelamis platurus

The Yellow-bellied sea snake, *Pelamis platurus*, inhabits warm tropical waters of the Pacific and Indian Oceans and is the only extant sea snake species to have colonized the New World. At present, intraspecific patterns of genetic diversity are unknown in these snakes. Although this species is morphologically conserved, two distinctly different color patterns are observed off the northern (N) and southern (S) Pacific coast of Costa Rica. We used two mitochondrial gene fragments, ND4 (632 bp) and Cytb (1109 bp), to compare sequence divergence among individuals from Costa Rica, Panama, and Australia, and to address two questions: 1) is genetic variation correlated with color pattern in the Costa Rican populations? And 2) are large-scale patterns of genetic variation in *P. platurus* associated with geographic distribution in these wide-ranging snakes? Our preliminary results suggest extremely low mitochondrial diversity among comparisons of all populations. Sequence divergence between individuals from N and S Costa Rica ranged from 0.10–0.31% (Cytb) and 0.0–0.32% (ND4). Sequence divergence between Australian, Panamanian and Costa Rican individuals ranged from 0.0–0.41% (Cytb) and 0.0–0.32% (ND4). Several individuals from Costa Rica and Australia (ca. 16,000 km apart) shared identical haplotypes. These low levels of genetic variation may be explained by the natural history of *P. platurus*. Unlike other sea snakes, this species appears to drift passively with surface water currents, which may facilitate movement over large distances and helps to explain our preliminary genetic results. Based on these results, we plan to use more rapidly evolving genetic markers to further investigate population genetics in these pelagic snakes.

56.5 SHELTON, R.M.*; LAUDER, G.V.; Univ. of North Carolina, Chapel Hill; *rmshelto@email.unc.edu*

Undulatory locomotion by flexible foils as a model of understanding fish propulsion

Undulatory locomotion is a common method for creating thrust and maneuvering in many fish species, but our inability to experimentally manipulate key variables such as body length, flexural stiffness, and tailbeat frequency in freely-swimming fish has limited our understanding of the basic mechanics of this locomotor mode. Measuring forces and torques on a freely-swimming fish has also proven quite difficult. In this presentation we describe the use of a self-propelled robotic flapping foil apparatus to swim passive plastic foils by creating a heave motion at their leading edge. We swam foils with two different lengths, two stiffnesses, at four heave frequencies while measuring forces and torques with the flapping foil robotic device, and we simultaneously quantified swimming hydrodynamics with particle image velocimetry. When comparing the two swimming foils to bluegill sunfish (*Lepomis macrochirus*) and clown knifefish (*Notopterus chitala*), we found remarkably similar kinematics, velocities, Strouhal numbers, and patterns of curvature and shape. From the force data we calculated thrust and power coefficients, work, and costs of transport for each foil and found that increasing heave frequency and foil stiffness both produced faster swimming speeds. Increasing the foil length had minimal impact on swimming speeds, but had a large impact on Strouhal number and cost of transport. Stiffer and longer swimming foils had the lowest cost of transport (calculated in $mJ\ m^{-1}\ g^{-1}$) at low cycle frequencies and reached the highest swimming speed at high cycle frequencies.

53.1 SHENOY, K.*; TOYODA, J.H.; Uinv. of Kentucky, Univ. of Kentucky; *kay.yellowtoad@gmail.com*

Latent effects of embryonic exposure to atrazine on mating behaviors in guppies

Endocrine disrupting compounds are ubiquitous in our environment, and impair hormonal functioning in exposed animals. Disruption of hormonally regulated traits, such as sexual behaviors, can potentially affect reproduction. Atrazine, a common herbicide, induces estrogen production in exposed animals. Often, pesticides are applied at specific times of year; environmental concentrations may peak for short periods at these times. This may span crucial developmental periods for many organisms, but the effects of exposure may be manifest at later life stages. We tested the latent effects of embryonic exposure to environmentally relevant doses of atrazine on mating behaviors in guppies (*Poecilia reticulata*), a viviparous tropical fish. Males are brightly colored and court females with characteristic displays. Females prefer males with more orange spots and that display more frequently. Adult female guppies were mated and exposed to treatments throughout the gestation period—control (no treatment), solvent control (DMSO), low dose (1 ppb) and high dose (10 ppb) of atrazine. Offspring born to these females were raised to adulthood without further treatment. Males and females were separated when discernable. At adulthood, males and females were tested for reproductive behaviors in separate trials—for males: frequency of courtship displays to females, and for females: preference strength for bright versus dull males. Atrazine exposed males were significantly less likely to perform courtship displays. But the number of displays was not different across treatments. There was a non-significant trend for atrazine exposed females to have a lower preference index. The results suggest that low sub-lethal doses of contaminants appearing briefly in the environment can have important implications to reproduction.

44.2 SHERRATT, E*; WILKINSON, M; GOWER, DJ; KLINGENBERG, CP; Harvard University, Cambridge, MA, The Natural History Museum, London, UK, The University of Manchester, Manchester, UK; *emmasherratt@fas.harvard.edu*
Evolution of Cranial Modularity in Caecilians
Morphological integration is a biological phenomenon describing the coordination among morphological subunits. The related concept of modularity is the degree of integration within and between these subunits, and can be inferred from patterns of covariation among measured traits. We used geometric morphometrics to investigate modularity in the cranium of 141 species of caecilians - limbless and mostly burrowing amphibians that use their head as a tool for locomotion. Taking a developmental and evolutionary perspective, we examined covariation at three levels of variation: within individuals (fluctuating asymmetry), within species and among species. We evaluated two a priori hypotheses of modularity that defined functionally distinct regions of the cranium as modules, and found support for one, where the cranium is modular with respect to the snout and the braincase with cheek region. The modularity hypothesis was supported at all levels, indicating there is a developmental basis for the modularity, which is shared among all species of caecilians. We examined patterns of evolutionary shape variation for each module and found that they substantially differ, where the snout has undergone greater morphological diversification during history of caecilians than the braincase with cheek region module. We interpret this pattern as support to the theory that modularity may facilitate adaptive evolution by allowing independent changes to underlying developmental interactions within a module without disrupting the function of the entire organism.

39.5 SHIELDS, Vonnie/D.C.*; SANFORD, Jillian/L.; OTALORA-LUNA, Fernando; DICKENS, Joseph/C.; Towson University, Instituto Venezolano de Investigaciones Cientificas, USDA, Beltsville Agricultural Research Center; *vshields@towson.edu*
Do You See What I See?: Visual Orientation Behavior of Colorado Potato Beetle Larvae to Emissive Colors
The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is an important pest of potato, as well as other solanaceous crops. While orientation of adult beetles to visual stimuli has been reported, nothing, up until now, has been known about whether the larvae also display positive phototactic behavior. In this study, we investigated the orientation behavior of Colorado potato beetle larvae in response to emissive colors produced by light emitting diodes of narrow band widths in a dual-choice arena adapted to a servosphere. Our results show that the larvae preferred to orient toward blue (472 nm), orange (590 nm), red (660 nm), white (420-775 nm), yellow (585 nm) and ultraviolet (351 nm) over darkness when both alternatives were offered. No orientation preferences were elicited by infrared (940 nm) or green (570 nm) light. When paired light choices were offered, the larvae showed a strong preference to some wavelengths more than others. This research characterizes visual preferences for Colorado potato beetle larvae and suggests that visual cues may be important in host plant orientation for these larvae, and perhaps, other immature insects. Our results suggest the potential for using photic stimuli for manipulation of larvae for control strategies. This research was carried out during the sabbatical leave of V.D.C.S. at the USDA, Beltsville, MD

66.3 SIKES, JM*; NEWMARK, PA; Univ. of Illinois, Champaign-Urbana, Howard Hughes Medical Institute; *jsikes@illinois.edu*
Exploring the evolutionary loss of regeneration: a comparative genomics study in planarians
Planarians possess extraordinary abilities to regenerate complete animals from small tissue fragments. However, in contrast to most flatworm species, the planarian *Procotyla fluviatilis* is limited in its ability to restore lost structures, failing to regenerate heads when amputated in posterior tissues. To identify the critical mechanistic failure in *P. fluviatilis* regeneration, we have compared the early stages of regeneration following amputation in tissues with different regeneration potentials. While the earliest regenerative phases, such as wound healing and cell proliferation, appear to occur normally in regeneration-deficient tissues, wnt/β catenin and FGF signaling as well as the reestablishment of anterior-posterior polarity fail to occur. To examine and contrast global changes in gene expression at this critical time point, we have conducted comparative transcriptomic analyses using RNAseq. Genes upregulated in regeneration-proficient tissues yet not expressed in regeneration-deficient tissues have been identified as candidates with putative functions important to the regeneration process. In an attempt to identify the permisssive and/or inhibitory factors involved in planarian regeneration, we are determining the specific roles of these genes using RNA interference in *P. fluviatilis* as well as in the related regeneration-competent planarian *Schmidtea mediterranea*.

65.5 SILER, CD; University of Kansas; *camsiler@ku.edu*
Comparative Species Delimitation and Patterns of Cryptic Diversity in an Island Radiation of Fossorial Lizards
The transition from quadrapedal to limbless body plans has occurred repeatedly in numerous independent lineages of squamates. However, only four genera of lizards possess both fully limbed and limbless species. The known species-level diversity of skinks of the genus *Brachymeles* is concentrated in the Philippines, with species exhibiting a full range of limb development, including fully limbed, intermediate, and limbless forms. The results of recent phylogenetic analyses of *Brachymeles* did not support the monophyly of three widespread species in the Philippines. It is clear that the current estimates of species diversity in the genus are greatly underestimated. Island populations within each species complex share high degrees of morphological similarity, making it difficult to diagnose species boundaries. To investigate patterns of cryptic species diversity, I explored methods for species delimitation using both molecular and morphological data, in an attempt to arrive at well-supported estimates of species diversity for the genus. My results indicate that Bayesian species delimitation and model-based clustering methods provide similar results to recent systematic reviews for two of the three species complexes; however, the inferred species boundaries are not always supported to be identical.

S6-2.2 SILVESTRE, Frederic; University of Namur;
frederic.silvestre@fundp.ac.be

Mechanisms of acclimation to pollutants and elevated temperature in aquatic organisms. Changes of the cellular phenotype revealed by proteomics.

Acclimation, in contrast to evolutionary adaptation, can be defined as a “within lifetime” phenotypic adaptation to an environmental parameter involving a suite of adjustments that allow an organism to shift its optimum for numerous physiological activities to new range. As cellular phenotype, a proteome can be adjusted during the acclimation process. Whereas proteomic response to acute stress has been largely studied, only little attention has been given so far to acclimation mechanisms. Here we present protein expression profile changes in different aquatic species, the Chinese mitten crab Eriocheir sinensis, the bullhead fish Cottus gobio, and the least killifish Heterandria formosa, after acclimation to mild elevated temperature or exposure to pollutants (cadmium and copper). Physiological, biochemical or lethality assays enabled the determination of the acclimation window for the studied stressors. After 2D-PAGE protein separation and mass spectrometry-based identification, two proteomes have been distinguished for each acclimation condition. The first one corresponds to a "general stress proteome" which encompasses the most abundant proteins usually differentially expressed under a stressful condition. Secondly, a specific proteome could be defined for each stress condition, and likely represents the cellular responses to specific mode of action. When cross-tolerance is observed, e.g. between elevated temperature and exposure to cadmium, those proteomic signatures can bring clues to understand shared mode of action. The different roles of a general and a specific response are discussed. These acquired traits at a proteomic level can be involved in a rapid form of adaptive evolution.

20.5 SINCLAIR, BJ*; STINZIANO, JR; WILLIAMS, CM; MARSHALL, KE; MACMILLAN, HA; STOREY, KB; University of Western Ontario, Carleton University; *bsincla7@uwo.ca*

Real-time measurements of metabolism during freezing and thawing in wood frogs, Rana sylvatica

The wood frog, *Rana sylvatica*, survives freezing because of a dynamic process of mobilization of glucose from glycogen in response to ice formation. This glucose is restored to glycogen after freezing, but repeated freezing leads to depletion of glycogen, which suggests that freezing and thawing have a metabolic cost. Here, we measure oxygen consumption and carbon dioxide production in *R. sylvatica* during complete freeze-thaw cycles in real time using flow-through respirometry. Initiation of freezing results in a very large increase in metabolic rate. While frozen, metabolic rate is significantly depressed, and there is a spike in metabolic rate upon thawing, although it is unclear whether this reflects a cost of thawing, or the cost of metabolizing anaerobic byproducts accumulated while frozen. The ecological implications of these costs will be discussed in the context of ongoing climate change which modifies the frequency and duration of freeze-thaw cycles.

88.5 SINGER, M.L.*; OSWALD, M.E.; WIEDEBACK, B.D.; ROBISON, B.D.; Univ. of Idaho, Univ. of Notre Dame;
matt@mineral2.com

The genetic architecture of the bold-shy continuum in zebrafish, Danio rerio

Adaptation to captivity causes behavioral divergence among wild and captive populations. This divergence often occurs in a suite of traits related to the bold-shy continuum. The correlated evolution of these boldness behaviors may result from underlying genetic correlations, but the genetic architecture of the bold-shy continuum has seldom been studied. We used the Zebrafish (*Danio rerio*) to study the quantitative genetic architecture of the bold-shy continuum. We chose affinity to a human observer, depth preference, and feeding latency as our three behaviors associated with the bold-shy behavioral syndrome and found them all to be significantly correlated with each other. Using observer preference as a measure of “boldness,” we selectively bred “bold” and a “shy” lines. By the third generation, the lines had significantly diverged in all three of the behaviors measured. We used REML to estimate a G matrix for the three behaviors. All were significantly genetically correlated, and had narrow sense heritability estimates of 0.282 ±0.10 for observer preference, 0.207±0.11 for swim level, and 0.212±0.11 for feeding latency. Individuals from the third generation of the selection lines were subjected to an open field study assessing their behaviors when introduced to a novel environment. We found significant differences in time spent motionless, activity level, and cover usage according to their boldness scores. This study was conducted twice on two independently replicated selection lines, each producing results that were highly consistent with the other. The genetic architecture of the bold-shy continuum indicates that the behaviors stereotypical of domestic fishes may evolve because of genetic correlations.

S9-1.5 SINHA, N R; Univ. of California, Davis;
nrsinha@ucdavis.edu

Evolutionary inferences from transcriptional analysis of wild and domesticated tomato

The domestication of crop species from wild relatives altered human history, while human intervention simultaneously modified the form, physiology, and life history of the domesticated plant species. The process of domestication thus provides us with a outstanding opportunity to understand the process of response to selection. We used genome-wide deep-coverage short-read sequencing to analyze the transcriptomes of one accession of domesticated tomato and three wild relatives for changes in gene expression, coding sequences, and gene regulation. Sampling from seven different organ and tissue types from plants grown in two environments allowed us to capture of the best representation of expressed genes in the tomato complex. We compared our identified transcripts to the recently completed tomato genome sequence and a partially complete sequence of Solanum pennellii, a green-fruited wild relative of tomato, to identify sequence polymorphisms and make differential gene expression calls. In addition, we sequenced miRNA loci, and also placed on the genome repeated regions with a high density of siRNA reads. Our analysis of the transcripts identifies those genes that show the largest expression differences between domesticated tomato and wild species, and in addition allows us to preliminarily identify genes and gene categories that show the strongest signatures of selection.

90.2 SKIBIEL, A.L.*; HOOD, W.R.; Auburn University; *skibiam@auburn.edu*
Building better babies: Impact of individual variation in milk composition on differential reproductive performance of Columbian ground squirrels
In mammals, maternal care is an integral part of a species life history strategy and variation among females in maternal effort provides the raw material upon which natural selection can act. Consequences of variation among females in size and reproductive timing on offspring mass and survival are ubiquitous in the literature, but the underlying link between maternal traits and reproductive performance is poorly understood. Mammals have a protracted period of offspring dependence during the lactation period; thus, differential reproductive performance is likely to occur through variation among females in lactation performance, such as milk composition. The objectives of this study were to examine impacts of maternal size, condition, and reproductive timing on milk composition and to determine if variation among females in milk composition contributes to variation in weaning mass, growth and differential survival of offspring. Females differed in the proximate composition of milk, gross energy, proportion of energy from proximate constituents, and milk sodium and potassium concentrations. Maternal condition and size did not impact milk composition whereas parturition date had a significant curvilinear relationship with milk lipid concentration, gross energy, and the proportion of energy from lipids. Carbohydrate and potassium concentrations in milk had a positive effect on weaning mass and growth rate. Probability of over-winter survival was greater for pups receiving milk higher in lipids, gross energy, potassium, and a higher proportion of energy from protein and lipids. These results indicate that reproductive timing is an important factor influencing milk composition and thus juvenile survival in this species.

101.2 SLATER, G.J.*; HARMON, L.J.; ALFARO, M.E.; Univ. of California, Los Angeles, Univ. Idaho; *gslater@ucla.edu*
FOSSILS, MOLECULAR PHYLOGENIES, AND MODELS OF TRAIT EVOLUTION
Evolutionary biologists are increasingly interested in assessing the fit of evolutionary models to phylogenetic comparative data. By identifying the best-fitting model of trait evolution, such as an early burst or constrained random walk, evolutionary biologists attempt to draw conclusions about the tempo and mode of evolution in their clade of interest. Several empirical studies have demonstrated the significance of including data from fossil taxa for parameter estimates, such as ancestral states. However, because phylogenies including both fossil and extant taxa are rare, these methods are typically only applied to time-calibrated molecular phylogenies of extant taxa with associated phenotypic data. Here we introduce a Bayesian model fitting approach that treats fossil taxa as nodes and their traits as prior distributions. We show that even a small number (~5%) of nodes with associated fossils can dramatically alter and improve both model selection and parameter estimation from macroevolutionary models. Simulations suggest that this finding is robust to both phylogenetic and phenotypic uncertainty in the calibrations. We end by applying our approach to an example of body size evolution in caniform carnivores. Incorporating a few fossil calibration points dramatically alters both parameter estimates and identification of the best-fitting model for this dataset.

96.3 SMALL, Thomas W*; BRIDGE, Eli; SCHOECH, Stephan; University of Memphis, University of Oklahoma; *twsmall@memphis.edu*
Physiological stress responsiveness is transferable from parent to offspring in free-living Florida Scrub-Jays
The rapid stress induced elevation of plasma glucocorticoids is well documented in a variety of animals. In Florida Scrub-Jays (*Aphelocoma coerulescens*) the magnitude and time course of increased corticosterone (CORT) during a restraint stress can vary greatly between individuals and these differences are correlated with a number of behavioral differences, such as nest attendance. The differences in physiological stress response can be detected within a few months after fledging, and are largely consistent between years, suggesting they are a persistent aspect of the individual's phenotype. Parental phenotype, parental behavior, early life nutrition, and habitat structure could all play a role in the development and expression of an individual's phenotype. To investigate which factors are most important in the development of the CORT stress response we are using a novel "SmartFeeder" design that utilizes RFID technology to selectively target dietary treatment to specific individuals within a population of free-living Florida Scrub-Jays. With these feeders we are able to provide food supplementation to specific nests, and to potentially modify parental behavior at those nests, by selective supplementation of either the breeding male or the breeding female. To date, we have found that an individual's stress responsiveness is significantly correlation with its parent's stress responsiveness and with parental nest attendance. Continuing experimentation will help determine the specific modes by which the parent's phenotype is transferred to the offspring as well as the long term impact of these different phenotypes on an individual's success.

57.5 SMITH, H.A.*; SNELL, T.W.; Georgia Institute of Technology; *hilary.smith@gatech.edu*
Rapid evolution of sex frequency selected by requirement for dormancy and hydroperiod adaptation
In many cyclical parthenogens that alternate between asexual and sexual reproduction, dormant stages produced by the sexual generation allow survival in ephemeral habitats. For example, in monogonont rotifers an asexual phase allows rapid population growth, whereas sex in these zooplankton results in resting eggs (diapausing embryos) capable of surviving desiccation. Few studies have experimentally tested whether sex-dormancy associations in temporary waters reflect evolution of sex in response to environmental conditions selecting for the diapausing stage, and whether evolution occurs via de novo mutations versus standing genetic variation and clonal replacement. Here we demonstrate higher sex propensity and diapausing embryo formation in ephemeral cultures mimicking temporary ponds, contrasted with permanent cultures. We report rapid evolution (in 385 d, ~80 generations) of lower sex propensity in permanent cultures, with data suggesting evolution occurred via new mutations. Mean sexual female frequency evolved to levels ~45% lower in permanent than ephemeral cultures, but asexual female density was twice as high—demonstrating a twofold cost of sex in cultures merely differing in sex frequency. Despite studies proposing occasional sex as a way to capture most of its benefits and minimize costs, cyclical parthenogens are shown to incur substantial costs from sex.

54.4 SMITH, A*; CORFE, I; JERNVALL, J; HAKKINEN, T; GILL, P; Umass, Amherst, Uni of Helsinki, Finland, Uni of Bristol, UK; *ajsmi1@cns.umass.edu*

The Developmental Basis of 200 Million Year Old Mammal Teeth

One difficulty of applying insights from developmental genetics to extinct animals is the limited number of ontogenies preserved in the fossil record. However, fossils do provide information about population variation, which can be investigated using developmental biology. To bridge the gap between development and genetics, we analyzed morphological population variation in a large dental sample of the early triconodont-like mammal *Morganucodon* from 200 Ma fissure deposits in Glamorgan, Wales. We compared these results with a dentally similar population of the extant ringed seal (*Phoca hispida ladogensis*) and a virtual population of *Morganucodon*-shaped teeth generated by a gene-network based computer model of tooth development. Using geometric morphometrics, we found that variation within *Phoca* and *Morganucodon* dentitions are generally quite similar. Furthermore, small changes in two of the tooth development model parameters were able to transform a seal tooth into a *Morganucodon* tooth. Comparison with variation generated by systematically manipulating computer parameters of the developmental model indicates that the same parameters can explain much of the variation in seals and *Morganucodon*. Finally, *Morganucodon* teeth show incipient decoupling of the anterior and posterior molar cusps, with less decoupling toward the posterior end of the tooth row. This is a prerequisite for the evolution of tribospheny, which arose 34 Ma before fully tribosphenic teeth first evolved. We infer that the same core genetic pathways present in living seal teeth were already established in the teeth of the earliest mammals, some 200 million years ago, and that this developmental course has required only minor changes in genetic architecture.

26.3 SMITH, K E*; THATJE, S; University of Southampton; *Kathryn.Smith@noc.soton.ac.uk*

Darwin in a nutshell – the subtle intracapsular survival of the fittest in the common whelk Buccinum undatum

Life history theories suggest parental fitness is maximised by investing equally into all offspring. The common whelk *Buccinum undatum* shows large differences in offspring investment. This species has intracapsular development, with nurse eggs consumed by developing embryos (adelphophagy). In most species exhibiting adelphophagy, nurse egg consumption occurs over weeks to months and nutritional distribution is about equal within a capsule. In *B. undatum*, nurse egg consumption occurs rapidly over a few days in which veligers compete for nurse eggs. Eggs are stored in the middle gut, 'secured' for later use. Asynchronous development leads to large differences in numbers of nurse eggs consumed by each veliger. One third of capsules examined held at least 1 veliger containing no nurse eggs. Number of developing veligers, nurse egg consumption and energetic fitness of veligers varied with capsule size and developmental temperature (6 to 18°C). During development 'accidental cannibalism' was observed. Older embryo's consumed undeveloped embryo's, morphologically identical to nurse eggs. Consumed embryos then developed and took up nurse eggs from inside the older embryo, which eventually died. Intracapsular resource partitioning observed in *B. undatum* is highly unusual, especially given the maternal energy investment put into each developing embryo. The high level of competition seen in each capsule leads to very uneven resource partitioning amongst offspring affecting size and energetic predisposition for later life. Ultimately this selection for the fittest inhibits the number of embryo's successfully developing as some outcompete others for the limited resources.

67.5 SMITH, S.M.*; ANGIELCZYK, K.D.; SCHMITZ, L.; WANG, S.C.; Johns Hopkins University, Field Museum of Natural History, University of California, Davis, Swarthmore College; *smsmith383@gmail.com*

How well do orbit dimensions predict diel activity in sciurid rodents?

Eye dimensions are good predictors of diel activity patterns because they relate directly to light sensitivity of the eye. Osteological characters such as scleral ring dimensions also are reliable proxies, but orbit dimensions have proven difficult to use because soft tissues other than the eye affect orbit size and shape. Nevertheless, it would be useful if orbit dimensions could be used as proxies because it would allow predictions of activity patterns for fossil taxa such as non-mammalian synapsids, which infrequently preserve scleral rings and have poorly ossified braincases. We measured four orbit dimensions and six body size proxies in 429 sciurid specimens from 51 species. No individual measurement differed significantly among nocturnal, diurnal, and crepuscular species, but a MANOVA indicated that the three groups had significantly different orbit dimensions. Nocturnal species also had a significantly higher intercept than diurnal and crepsucular species for a regression of orbit length on skull length, although the three groups had similar slopes. The intercepts of the nocturnal taxa remained significantly higher when the regression was run using phylogenetic independent contrasts. To simulate the conditions of a fossil data set, we used logistic regression and classification trees to determine whether we could classify specimens without a priori binning. We obtained overall correct classification rates as high as 95%. The analyses based only on orbit dimensions had consistent difficulty correctly identifying nocturnal specimens, but we obtained better results when additional skull measurements were included. This raises the possibility that such a combined data set might be useful in inferring activity patterns in fossils.

51.3 SMITH, FW*; TENLEN, JR; GOLDSTEIN, B; JOCKUSCH, EL; University of Connecticut, University of North Carolina; *frank.smith@uconn.edu*

Development of Hypsibius dujardini (Tardigrada) lobopodal appendages and the origin of the arthropod appendage

The unparalleled success of Arthropoda can be partly attributed to the ventral appendages defining this phylum, which exhibit an incredible diversity of both form and function even within single individuals. Although appendage diversity within Arthropoda is based on a jointed-appendage groundplan, evidence suggests arthropods evolved from an ancestor with homonomous unjointed lobopodal appendages. This ancestral morphology is retained in the arthropod sister phylum Onychophora and also the Tardigrada, which together with Arthropoda comprise the Panarthropoda. Across Arthropoda, the leg gap genes *Distal-less*, *dachshund*, *extradenticle*, and *homothorax* act as master regulators of appendage patterning. These genes have recently been implicated in the development of onychophoran appendages, but no published genetic data concerning tardigrade appendage development is available. Investigations of tardigrade appendage development would allow phylogenetic reconstructions of ancestral appendage generating mechanisms, and provide insight into the developmental genetic changes underlying the transition from a lobopodal appendage to the segmented arthropod appendage. Here we present results of both morphological and genetic investigations of appendage development for the tardigrade *Hypsibius dujardini*. Orthologs of *Distal-less*, *dachshund*, and *extradenticle* have been cloned from embryonic *H. dujardini* cDNA. Preliminary results of an investigation into both the function and expression patterns of these genes during *H. dujardini* embryogenesis will be presented, and the implications for the evolution of the arthropod appendage will be explored.

S9-2.3 SMITH, J; Marine Biological Laboratory, Woods Hole; *joelsmith@mbl.edu*

Evolution of Developmental Gene Regulatory Networks

The Gene Regulatory Network approach to Evo-Devo promises the discovery of mechanisms of evolutionary innovation as well as of deeply conserved "cassettes" governing fundamental developmental processes. However, defining regulatory interactions on a network scale remains a formidable challenge. We present data from the sea urchin network controlling pattern formation to illustrate two points concerning (1) network methodology in the era of high-throughput genomics and (2) the utility of developmental networks for gaining insight into evolutionary change. First, lessons learned from earlier network studies suggest how next-generation technologies might best be employed to capture critical developmental mechanisms leading to specific and testable hypotheses, or in other words, to produce meaningful networks with real predictive value. Thus, high-throughput does not necessarily have to mean low-resolution. Falling costs, meanwhile, put these goals closer in reach. Second, our data on network dynamics in a euechinoid sea urchin, Strongylocentrotus purpuratus, provide the basis for comparison with development in a cidaroid sea urchin, Eucidaris tribuloides, and a sea star, Patiria miniata. A general finding is that network interactions produce strikingly reliable, robust developmental mechanisms. Next, we identify specific network connections that arose in the euechinoid lineage. Crucially, these appear to have been layered on top of the pre-existing network while leaving ancestral functions intact, thus illustrating the evolutionary principle of accretion as opposed to wholescale replacement. We examine how the result is a complex, multi-layered network, with superficially redundant elements and a highly robust structure.

S8-1.3 SNELL-ROOD, Emilie; University of Minnesota; *emilies@umn.edu*

Exploration in Development: implications for the costs, consequences and evolution of phenotypic plasticity

Exploration, or "phenotype sampling," is a common theme in development, from the growth of muscles and the circulatory system to learning and acquired immunity. This talk argues that applying a perspective focused on exploratory mechanisms is necessary for understanding the evolution of phenotypic plasticity and complex traits more generally. Greater investment in exploration, in particular with the possibility of environmental feedback, increases the probability that an individual will develop a phenotype best matched to the local environment. However, such exploration is costly in terms of time, energy and investment in the machinery necessary to process information. This suggests that evolutionary increases in phenotypic plasticity will require major life history changes such as increased development time and investment in individual offspring. This talk discusses implications of this focus on exploration in development, from predicting adaptive responses to novel environments to understanding other mechanisms of plasticity.

110.2 SNELL-ROOD, EC*; WHITE, WA; ESPESET, A; KENZIE, SA; University of Minnesota; *emilies@umn.edu*

Nutritional Constraints in the Evolution of Cognition: effects of host shifts on neural investment in butterflies

Understanding why organisms vary in cognition is key to predicting how individuals will respond to changing and novel environments. Diet has been hypothesized to play a role in constraining the evolution of large, costly brains. This work provides the first systematic test of this idea. Butterflies were used as a system because nutrient availability is easily manipulated in artificial diets and nutrition of larval diets varies widely across species. We focused on both the availability of limiting macronutrients (phosphorus, nitrogen) and micronutrients (potassium, sodium) in diets that varied within and across species. Given that over 70% of the butterfly brain is dedicated to visual processing, we use relative eye size as a proxy for neural investment. We found that across 28 species of butterflies, evolutionary shifts in the availability of phosphorus and electrolytes in host plants influenced relative eye size and the density of ommatidia (the units of the compound eye). We have additionally performed a series of artificial diet manipulations within cabbage white butterflies (*Pieris rapae*) to determine the contribution of development to variation in relative eye size and to test evolutionary changes in dietary requirements across populations that differ in learning ability. Overall, this work suggests that nutrition may indeed constrain the evolution of neural investment, at least in the short term.

72.6 SOCKMAN, K.W.; Univ. of North Carolina, Chapel Hill; *kws@unc.edu*

Real-Time Modulation of Egg Size in an Altricial Bird

The size of a female's eggs can affect the size of her offspring, her survival, and her lifetime reproductive success. Female birds modulate egg size according to several factors, such as diet and reproductive experience, but the capacity for modulating egg size in real time — as the eggs are being formed on the ovary and in the oviduct — would enhance the ability of females to respond rapidly to recent environmental stimuli. Using a wild, free-living population of Lincoln's sparrows (*Melospiza lincolnii*), I tested the hypothesis that females use cues from the first-laid egg in modulating the size of the subsequently laid eggs in their clutches. Specifically, I exchanged the first-laid eggs between synchronous nests on the day those eggs were laid, measured the length and width of subsequently laid eggs, and regressed their calculated volumes against the volume of the substitute egg, while controlling for the volume of the first-laid egg. If the first laid egg was smaller than its substitute, then, regardless of laying order, the volume of subsequently laid eggs increased with the size of the substitute, thus minimizing within-clutch variation in egg size. However, if the first-laid egg was larger than its substitute, I found no such relationship. That is, females increased egg size in response to a large substitute egg but did not decrease egg size in response to a small substitute egg. These results show that females can use cues from the first-laid egg to modulate in real time the size of subsequent eggs, even egg two, which is already in the oviduct at the time the first is laid. In an effort to understand the adaptive significance of this capacity, I also discovered that, in unmanipulated nests, hatching delay increased as the egg deviated in volume from the clutch mean. Therefore, minimizing within-clutch variation in egg size through real-time modulation may benefit the female by reducing hatching delays.

115.3 SOMJEE, Ummat*; ABLARD, Kelly; CRESPI, Bernard; SCHAEFER, Paul/W; GRIES, Gerhard; Simon Fraser University, Vancouver, Canada, US department of Agriculture, Newark, DE; *ummat.s@gmail.com*

Sex ratio adjustment in a solitary parasitoid wasp

Sex ratio theory has yielded some of the clearest examples of adaptive evolution in animal behavior. A highly studied aspect of sex ratio theory is termed Local Mate Competition (LMC), which occurs when brothers compete with each other for mating opportunities, resulting in the selection for strongly female-biased sex ratios. LMC predicts that if two females oviposit in the same patch, their sons compete for mating opportunities also with non-brothers. Thus, females in the presence of other females should produce relatively more sons. The mating system of the parasitoid wasp *Ooencyrtus kuvanae* meets assumptions of LMC. Females insert a single egg into each accessible egg of gypsy moth, *Lymantria dispar*, host egg masses. Wasps complete development inside host eggs and emerge en masse as sexually mature adults, resulting in intense competition among (sibling) sons. We tested the hypothesis that *O. kuvanae* exhibits LMC by investigating the effect of number, size and relatedness of wasp foundresses on egg masses with identical number of eggs. As predicted by the LMC theory, with increasing numbers of wasp foundresses on an egg mass, the proportions of emerging sons increased. In contrast, the presence of a sibling or a non-sibling female during oviposition, or the size of a female, did not affect the number or sex ratio of offspring produced. With no Local Resource Competition (LRC) among *O. kuvanae* larvae, the sex ratio of emergent son and daughter wasps is due entirely to the sex allocation by ovipositing wasp foundresses on host egg masses. This is the first study to have experimentally decoupled the effect of LRC from that of LMC.

S4-2.3 SOTKA, E.E.; College of Charleston; *sotkae@cofc.edu*

Selection, dispersal and the geography of phenotype in the sea

Population-level differences in phenotypic traits (a.k.a., the geography of phenotype) have been the research focus of evolutionary ecologists since and including the studies of Charles Darwin. One of the great challenges that remains is to understand the extent to which the geography of phenotype reflects neutral processes (demographic history, dispersal and genetic drift), adaptation to local environments or a mix of neutral and non-neutral processes. The debate has broad implications for understanding the dispersal of marine larvae. When phenotypic differences among populations reflect neutral processes, then larval dispersal is limited by principally physical or oceanographic barriers. When phenotypic differences among populations reflect local selection, then organism-environment mismatches limit dispersal distance. In this talk, I will discuss the status of this challenge using coastal organisms that span the Atlantic coast of the United States as case studies.

45.4 SOWER, Stacia *; OSUGI, Tomohiro; DAUKSS, Dana; GAZDA, Kristen; UBUKA, Takayoshi; KOSUGI, Takayoshi; TSUTSUI, Kazuyoshi; Univ. New Hampshire, Durham, USA, Waseda University, Japan; *sasower@cisunix.unh.edu*

Evolutionary Origin of Gonadotropin-Inhibitory Hormone (GnIH): Isolation, localization and Biological Activity of Lamprey GnIH Ortholog

Gonadotropin-inhibitory hormone (GnIH) is a novel hypothalamic neuropeptide that regulates pituitary hormone secretion in various vertebrates. GnIH has a LPXRFamide (X = L or Q) motif at the C-terminal that has been identified in representative species of gnathostomes. On the other hand, neuropeptide FF, has a PQRFamide motif at the C-terminal. A controversy exists as to the evolutionary origin of these two peptide groups, i.e., LPXRFamide group and PQRFamide group. In this study, we identified a LPXRFamide peptide orthologous gene in the brain of sea lamprey, the Agnatha, the most ancient vertebrate species. Subsequently, we purified three mature orthologous peptides that all have the PQRFamide motif at the C-termini. In situ hybridization revealed that the lamprey LPXRFamide peptide precursor mRNA was expressed in the bed nucleus of the tract of the postoptic commissure in the hypothalamus. One of the identified lamprey LPXRFamide orthologs stimulated the peptide expression of lamprey GnRH-III in the hypothalamus and mRNA expression of gonadotropin beta in the pituitary. The lamprey GnIH ortholog may thus act as a stimulatory factor on GnRH neurons in the lamprey, an agnathan, unlike in gnathostomes, suggesting the diverse functions of LPXRFamide peptides among vertebrate species. Therefore, we hypothesize that the identified LPXRFamide peptide may be an ancestral form of GnIH. Supported by Grants-in-Aid for Scientific Research, Japan (18107002, 22132004 and 22227002 to K.T.); NSF Grant (IOS-0849569 to SAS, and UNH SURF to K.G. and D.D.) and by NHAES to SAS.

64.3 SPAGNA, J.C.*; LARABEE, F.J.; SUAREZ, A.V.; William Paterson University, University of Illinois, Urbana-Champaign; *spagnaj@wpunj.edu*

Evolution of jaw-morphology and kinematics in ponerine trap-jaw ants

Trap-jaw ants in the genus *Odontomachus* and *Anochetus* are known for their oversized jaws that can be cocked and rapidly released in the form of devastating strikes on prey or enemies. In some species, these strikes have been co-opted for locomotion; by striking their jaws against hard surfaces, the ants can launch themselves many body-lengths into the air. Though trap-jaw morphology is polyphyletic, the subfamily Ponerinae includes both *Odontomachus* and *Anochetus*, covering a broad range of body size, morphological variation, and ecological variation. As a basis for comparative hypothesis-testing on these species, we developed a multi-gene molecular phylogeny for the ponerine ants. We sequenced the genes *wingless*, Cytochrome oxidase 1, long-wavelength rhodopsin, histone H3, 28S rDNA, and 18S rDNA from a total of 40 species (20 *Odontomachus*, 9 *Anochetus*, and 11 exemplars of potential ponerine outgroup genera) to produce the matrix, which was analyzed using partitioned Bayesian analysis. Ultra-high speed videography (50,000-120,000 frames per second) was used to estimate maximum angular jaw velocities for a subset of these species, which was used to model maximum jaw momentum during a strike. Mapping kinematic capabilities onto the phylogeny and performing comparative analyses demonstrated that kinematic variation is tied primarily to jaw and body size, and controlling for phylogenetic effects has a small influence when modeling jaw strikes based on animal size within each genus.

76.3 SPEISER, DI*; GAGNON, YL; CHHETRI, RK; OLDENBURG, AL; JOHNSEN, S; Univ. of California, Santa Barbara, Duke University, Univ. of North Carolina, Chapel Hill, Univ. of North Carolina, Chapel Hill; *dispeiser@gmail.com*

Optical coherence tomography (OCT) reveals that scallop eyes may have bifocal optics

Eyes that use a single focusing mechanism to form multiple images are quite rare in nature. In these eyes, two images formed simultaneously by a multi-focal lens fall separately on stacked retinas. Scallop eyes contain a pair of stacked retinas, but these eyes, unlike any known multi-focal eye, are thought to use a mirror, not a lens, to focus light. It is possible that scallops employ bifocal optics to place a focused image on each of their retinas, but if they do, they must do so through a novel, mirror-based mechanism. Complicating matters is the observation that the scallop proximal retina lies against the mirror, a position too close to receive an image by reflection. To ascertain whether or not scallops gather spatial information with both of their retinas using bifocal optics, we re-evaluated scallop eye morphology using optical coherence tomography (OCT), an imaging method that allows the non-invasive cross-sectioning of live, intact biological samples through the use of interferometry with broadband near-infrared light. By using this cutting-edge imaging technique, which avoids the artifacts introduced by the more invasive classical methods of morphological examination, we have produced the most accurate account of scallop eye morphology to date. Using OCT, we have made several discoveries concerning the eyes of the bay scallop *Argopecten irradians*: 1) there is a gap between the proximal retina and mirror; 2) the lens has a more elliptical front surface than previously thought; and 3) the pupil is narrower than previously thought. By combining this new morphological information with ray-tracing models, we provide evidence that bifocal optics likely allow both scallop retinas to receive spatial information.

S9-1.1 SPERLING, Erik*; ERWIN, Douglas; LAFLAMME, Marc; TWEEDT, Sarah; PISANI, Davide; PETERSON, Kevin; Harvard University, Smithsonian National Museum of Natural History, National University of Ireland, Maynooth, Dartmouth College; *sperling@fas.harvard.edu*

The Cambrian Conundrum: Early divergence and later ecological success in the early history of animals

The sudden appearance of diverse bilaterian clades during the early Cambrian remains a contentious subject, with a range of proposed environmental, developmental, and ecological causes. A new compilation of the patterns of fossil diversification, new molecular clock results and comparative developmental data, and information on ecological feeding strategies illustrate a lag between the divergence of major metazoan clades and the establishment of their developmental toolkits during the Cryogenian, and their later ecological success during the Ediacaran and Cambrian Periods. Bilaterian crown groups appeared during the Ediacaran and Cambrian, largely coincident with the canonical ‘Cambrian Explosion’. We argue that their diversification involved the establishment of controls on cellular differentiation and new forms of developmental regulation, as well as innovations in networks of ecological interaction within the context of permissive environmental circumstances.

52.2 SPONBERG, S*; FAIRHALL, AL; DANIEL, TL; Univ. of Washington; *bergs@uw.edu*

Extracting within-stroke features of torque reveals how power muscles combine to act as a motor control channel

Understanding locomotor control requires revealing feedback signals and their impact on body dynamics. We frequently use summary descriptions of motor outputs (e.g. mean force or velocity), which make analyses tractable, but can obscure within-cycle control consequences. However, considering the full time course of dynamics is necessary to test hypotheses of whether muscles act together as a single “control knob” (a synergy) or have independent control authority. In the hawkmoth, *Manduca sexta*, recent results show that timing differences between left and right downstroke power muscles (DLMs) can modulate net torque over a wingstroke. However, what specific features of torque are controlled and whether the left and right muscles independently contribute remains elusive. To test this, we recorded muscle activations and torques during > 3000 wingstrokes from six animals during left-right yawing responses to a moving visual stimulus. We used standard spike-triggered averaging and covariance analysis, as well as a new method using partial least squares (PLS) to extract the within-stroke features of torque correlated with both independent and pairwise measures of muscle activation. The PLS method produces fewer, more highly correlated features. Feature analyses extract a significant effect of muscle stroke-to-stroke timing on torque related to frequency modulation that was not detected using net torque alone. However, the left-right timing difference alone explained the visually driven torque modulation. Power muscles control yaw torque through a mechanical power differential that combines left-right muscle timing, rather than through independent left, right channels of control. These computational techniques reveal how muscles work together to control relevant features of the motor output.

39.6 SPRAYBERRY, Jordanna/ D. H.*; RIFFELL, Jeff/ A.; Muhlenberg College, Univ. Washington; *jsprayberry@muhlenberg.edu*

Impacts of Non-Insecticidal Agricultural Chemicals on Olfactory Behaviors in Bumblebees

Our research focuses on potential indirect effects of non-insecticidal agricultural chemicals. Agricultural chemical treatments such as fertilizers or fungicides could add to the mélange of incoming sensory information that bumblebees experience while foraging. Chemicals with strong scents may be aversive to bumblebees, or they may combine with floral odors and change the blend structure of natural signals. Two chemicals, Turf Builder and Manzate, were used in prior experiments on olfactory navigation in *Bombus impatiens*. We found that Manzate decreased the accuracy with which bees located a feeder within a maze, and increased the time it took them to navigate to the feeder. Turf Builder had no significant effect. Continued behavioral investigation has focused on whether or not these chemicals alter bumblebee preference for a learned odor. Bees are trained to a linalool scented feeder in a single foraging chamber. After a training period the foraging chamber is replaced with a T junction leading to two foraging chambers, each containing a linalool scented feeder. One chamber (in non-control trials) also contains a chemical treatment (Manzate or Turf Builder). Given the demonstrated impact these chemicals have on olfactory-driven foraging behavior, we ran a GCMS analysis on the volatile components of Turf Builder and Manzate. We also analyzed Turf Builder and Manzate combined with common floral odorants to determine whether or not they change emission rates of those odorants. Neither Turf Builder nor Manzate change emission rates of the tested odorants. However, Turf Builder does have constituents that overlap with common floral odorants and may therefore alter blend structure.

66.2 SRIVASTAVA, Mansi*; REDDIEN, Peter W; Whitehead Institute, Whitehead Institute, Massachusetts Institute of Technology, HHMI; *mansi@wi.mit.edu*
A comparative approach to animal regeneration
Members of most animal phyla are able to replace damaged or missing tissue. A comparative approach can reveal whether the genetic mechanisms underlying regeneration in different animal species are shared or independently evolved. With the capacity to replace virtually all missing tissues, a sequenced genome, and RNAi tools for studying gene function, the planarian *Schmidtea mediterranea* has become a model system for uncovering genes involved in the processes of regeneration. Cnidarians are well-known for their regenerative ability. The starlet sea anemone, *Nematostella vectensis*, has emerged as a model cnidarian species for evolutionary developmental studies and is able to regenerate its primary body axis. A member of the phylum Acoelomorpha, the three-banded panther worm, *Hofstenia miamia*, is also able to regenerate both anterior and posterior missing tissues. We are seeking genes that are common to regenerative processes in planarians, cnidarians, and acoels. We are currently developing tools to study conserved gene function during regeneration in *Schmidtea*, *Nematostella*, and *Hofstenia*.

10.5 SRYGLEY, R.B.*; JARONSKI, S.T.; USDA-Agricultural Research Service; *robert.srygley@ars.usda.gov*
Adaptive melanism and immunity to fungal infection in the migratory grasshopper
Many ectotherms respond to cooler temperatures by increasing their ability to absorb sunlight via adaptive melanization of exposed surfaces. In insects, phenoloxidase (PO) is a key enzyme for both cuticular melanization and the generalized immune response of insects to invasion. Hence, higher temperatures might impact susceptibility to disease making populations more vulnerable to climate change. We asked: is decreased melanism in response to higher temperatures associated with less enzymatic immunity and greater vulnerability to fungal attack? Migratory grasshoppers *Melanoplus sanguinipes* were reared from the 3rd instar in either a hot (39°C) or cool (27°C) environment. To control for physiological age, adults were moved to a common 33°C. We assayed PO and proPO activity of the blood and measured cuticular darkness. In a second group of adults, we assayed survival to attack by the entomopathogenic fungus *Beauveria bassiana*. We topically applied a dose of fungal spores that typically causes high mortality within 14 days and followed survivorship. Application of sunflower oil alone served as a control group. Grasshoppers reared in the hot environment were paler and blood PO and proPO titers were significantly less than those reared in the cool one. Consistent with PO and proPO activities, those reared in the hot environment had greater mortality from fungal infection and shorter median survival time. We have shown experimentally that melanism in response to ambient temperature is also associated with changes in immunity. Although the change in coloration is generally considered adaptive for thermoregulation, its association with enzymatic immunity makes it detrimental from the standpoint of combating invasion. More importantly, adaptive melanism may be detrimental to a population's resilience to climate change.

116.5 STAHLSCHMIDT, Z/R*; BUTLER, M/W; ARDIA, D/R; DAVIES, S; DAVIS, J/R; GUILLETTE, L/J; JOHNSON, N; MCCORMICK, S/D; MCGRAW, K/J; DENARDO, D/F; Arizona State Univ, Franklin and Marshall College, Rhodes College, Medical Univ of S. Carolina, U.S. Geological Survey, Univ of Massachusetts; *zrs@dal.ca*
Thermal performance of innate immunity in vertebrates
Innate immunity is the chief mechanism of host defense for most taxa, and temperature is a ubiquitous environmental factor that may affect immunity because it profoundly influences a broad range of biological processes—from biochemical reactions to locomotor performance. Thus, we examined the temperature dependence of two components of innate immunity (natural antibody agglutination and complement-mediated lysis) in 13 species spanning the seven major vertebrate groups: Agnatha, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves, and Mammalia. We measured *in vitro* immune function of plasma at nine different temperatures (5 – 47°C) to generate thermal performance curves of immunity. By using analyses of variance and principal components analyses, we found that (1) ectotherms generally had higher lysis and agglutination titers than endotherms, (2) temperature affected lysis and agglutination titers in all species, and (3) the optimal temperature for innate immune function only occasionally matched preferred body temperature, actual body temperature, and/or the optimal temperature of other performance measures (e.g., growth rate) in most species. Our results suggest that innate immune function is strongest at or below vertebrates' typical body temperature. In sum, we clarify the role of temperature in immune performance across vertebrate taxa, which is an understudied aspect of ecological immunology that may have implications related to global climate change.

41.8 STANLEY, S.G.*; GARCIA, M.J.; VAUGHN, S; TAYLOR, D.S.; EARLEY, R.L.; Univ. of Alabama, Tuscaloosa, Brevard County Environmentally Endangered Lands Program, Melbourne, Florida; *sgstanley@crimson.ua.edu*
Going to great lengths: population and genotypic effects on growth and development in the mangrove rivulus
The mangrove rivulus (Kryptolebias marmoratus) is a powerful model organism in which to evaluate differences in growth rates and morphology among genotypes during ontogeny. Populations of this self-fertilizing hermaphroditic vertebrate are genetically diverse with a mixture of heterozygous and homozygous genotypes. We raised F2 generation offspring derived from 33 homozygous wild-caught fish from seven Florida populations. Every 14 days, subsequent to hatching and preceding maturity (e.g. time to first egg lay), we measured total length (mm), standard length (mm), depth (mm, circumference/girth of individual), and mass (g) allowing for an ontogenetic survey of specific growth rates from lineages throughout rivulus habitats in the Florida mangrove ecosystem. Additionally, morphometric analysis software was utilized to quantify ""*form*"". We employed Procrustes-based geometric morphometrics (e.g. centroid morphometrics) to elucidate developmental changes in ""*form*"", uncover patterns of covariation between geographical origin and various measures of size and shape, and decode the genetic contribution to morphological variation. Preliminary data provides evidence for population-level diversification in the ontogenetic trajectories for growth and form.

40.2 STEFFENSON, M.M.*; FORMANOWICZ, D.R.; University of Texas at Arlington; *mmsteff@uta.edu*

Predation ability in the wolf spider Hogna helluo

Spiders are classically used as an example of sexual size dimorphism among invertebrates. Theories postulated to explain the evolution of such gender differentiation include sexual selection for increased female size, differentiation in reproductive roles, and intersexual niche divergence to reduce competition in resource acquisition. Spiders of the genus Lycosidae are relatively unique among the Araneomorphae in that the degree of sexual size dimorphism is greatly reduced, but is however still present. Genders may also exhibit behavioral foraging contrasts. Male wolf spiders tend to wander more while females are more sedentary. Such morphological and behavioral dichotomies among sexes may result in differential predation success. The objective of this study was to identify differences in predation ability among gender groups in *Hogna helluo* (a cursorial Lycosid with an extensive geographical range), as well as to examine dissimilarities in morphology and behavior associated with prey capture. Spiders were captured by headlighting in local parks after dusk. Males, gravid females, and non-gravid females were introduced into experimental chambers with several levels of prey density to identify differences in foraging strategies and predation aptitudes. Morphological variation was examined using digital microscopy. Preliminary analysis indicates that morphological differentiation exists between males and females, but not between gravid and non-gravid females. At low prey densities, no differences in predation ability were detected. However, at higher cricket densities, gravid females captured the highest proportion of prey available, males captured the lowest proportion, and non-gravid females fell somewhere between the two. Results indicate that gravid females may be capturing higher proportions of prey due to the physiological consequences of offspring production.

16.7 STEGNER, M. Allison; FERRER, Elizabeth A.*; UC Berkeley; *astegner@berkeley.edu*

Holocene biogeography of Neotoma: Mandibular geometric morphometrics and implications for climate change

The modern biodiversity crisis has generated great interest in historic species response to climate change. Hundreds of fossil specimens have been recovered from Mescal Cave in San Bernardino County, California, estimated to be from 10,000 to 20,000 y.a. Mescal Cave is located on the edge of the Mojave National Preserve, in an arid desert ecosystem. *Neotoma* (woodrats) are abundant in this fossil site and are common in the area today; like many other rodents, *Neotoma* are good indicators of climate. Although some teeth were found, much of the material is comprised of toothless mandibles, and loose teeth of *Neotoma* are notoriously difficult to identify to species. We used geometric morphometrics on extant *Neotoma* jaws to (1) determine if we could identify toothless mandibles to species, and (2) determine if food preference, elevation, habitat, or sexual dimorphism correlate with differences in mandible shape. We photographed lateral views of 121 right mandibles from 8 species of *Neotoma* found in the Western US. A procrustes analysis was conducted on 12 landmarks, and also on a reduced number of landmarks (8) in order to include 20 of the best-preserved fossil mandibles from the site. *N. cinerea* is distinct from the other species, dominating the right section of the morphospace and over-lapping with one of the fossil morphotypes. The presence of *N. cinerea* at this site also suggests a cooler ecosystem when the fossils were deposited. This kind of analysis in synergy with analysis of teeth by more traditional comparative methods can provide much information on the identity and ecology of fossil populations. Future studies include more species life history data, landmarks, morphometrics on other skeletal elements, and inclusions of other associated taxa.

103.4 STEWART, WJ*; CARDENAS, GS; MCHENRY, MJ; University of California, Irvine; *wstewart@uci.edu*

Zebrafish larvae evade predators by sensing water flow

The ability of prey fish to evade predators is central to the ecology and evolution for a diversity of fishes. However, it is largely unclear what sensory systems mediate predator-prey interactions in fishes and what kinematic variables matter most to predator evasion. We evaluated the role of flow sensing by exposing larval zebrafish (*Danio rerio*) to adult predators of the same species in a cylindrical arena. Larvae were able to escape predators in almost three-quarters of encounters (probability of escape=0.77, N=53). However, when we pharmacologically ablated the lateral line system of larvae, evasion was rarely successful (probability of escape=0.090, N=11). In order to investigate the detailed kinematics of these interactions, we recorded freely-swimming predators and prey at high speed with high spatial resolution using a custom-built camera dolly. This device permitted two-dimensional camera motion to manually track prey as they moved through the experimental arena. Using this device, we found that prey responding with an escape maneuver before the predator's suction-feeding strike were more than three times more likely to escape than prey responding after the start of a strike. In addition, we found that prey were most successful at escape when responding to an approaching predator from an intermediate distance (probability of escape =0.88 when responding 0.5–0.8 cm from the predator, N=8). These results suggest that successful larvae are responding from a strategically optimum distance after sensing water flows produced by an approaching predator.

15.2 STILLMAN, JH; San Francisco State University; *stillmaj@sfsu.edu*

Transcriptomic profiles of thermal acclimation in cardiac tissues of the porcelain crab, Petrolisthes cinctipes

The intertidal zone porcelain crab, *Petrolisthes cinctipes*, acclimates cardiac thermal performance (CTmax and CTmin) within the first days of transfer to warm and cold temperatures, and differences in tolerance to extreme cold are evidenced within hours of thermal acclimation. We have used a 25K unigene cDNA microarray to examine the kinetics of transcriptomic changes in porcelain crab cardiac tissues from 6h to 28d of acclimation to warm and cool temperatures. There were no differences observed until 12h of thermal acclimation, when cold acclimation caused strong upregulation of genes encoding glucose transport, transcriptional regulation, and cytoskeletal/structural modification. Early strong induction of genes in warm acclimated crabs included immune and stress response, protein synthesis and degradation, and extracellular and cuticular processes. Between 3-7 days of thermal acclimation both warm and cold acclimated specimens induced genes involving nucleic acid and chromatin regulation, and regulation of the proteome. Proteome associated genes induced in cold acclimated crabs were all involved in protein synthesis, whereas warm acclimated crabs induced genes involved with inhibition of proteases (58%), degradation of proteins (17%), and synthesis of proteins (25%). Cold acclimation for 3-7d also caused elevated expression of genes involving signal transduction, and oxidative phosphorylation. At 17d of thermal acclimation cold acclimated crabs induced genes involving protein synthesis, protein degradation, cytoskeletal genes, heat shock and chaperone proteins, and signal transduction genes, whereas there were few genes strongly upregulated in warm acclimated specimens. By 28d of acclimation there were smaller differences in transcript abundance between warm and cold acclimated specimens, suggesting that the acclimation process had reached its conclusion.

3.3 STIMOLA, M.*; MUñOZ, M.M.; LANDESTOY, M.A.; CONOVER, A.; RODRIGUEZ, A.J.; LOSOS, J.B.; Columbia University, Harvard University, University of California, Davis; *mas2298@columbia.edu*

A comparison of heat and cold tolerance among closely related anoles from different thermal environments.

The adaptive radiation of *Anolis* lizards in the Greater Antilles (Cuba, Hispaniola, Jamaica, and Puerto Rico) is often studied in the context of convergence in morphological adaptation to different microhabitats. However, anoles on these islands have also diversified to occupy a broad range of thermal habitats. In Hispaniola, a single clade of trunk- and ground-dwelling anoles, termed the cybotoids, has diversified to occupy a broad range of thermal habitats. Some species in this clade are restricted to cool highland forests or are exclusively lowland species, while others are found throughout the range of island habitats. Sensitivity to low temperatures has been shown to vary in anoles depending on habitat, although the same is not always true for heat tolerance. Here we tested the hypothesis that temperature tolerance in this closely related group of anoles is correlated with environmental temperature. Specifically, we predicted that highland species have the greatest cold tolerance, but that heat tolerance would be comparable among all populations. The widespread species, *Anolis cybotes*, was predicted to have the broadest tolerance range relative to regional endemics. We compared field-measured thermal tolerances to heating and cooling with GIS-based estimates of thermal environment. We found that while species in cooler environments have correspondingly greater thermal tolerance to freezing, those found in hotter environments do not possess greater tolerance to heating. Consequently, the high elevation species, though more restricted in altitudinal range than most of the other cybotoids, have the broadest thermal tolerances. We examine these measures of thermal tolerance in the context of the cybotoid phylogenetic history, habitat variation, and altitudinal range.

91.1 STOVER, KK*; BURNETT, LE; MCELROY, EJ; BURNETT, KG; College of Charleston; *stokris@gmail.com*

Exposure to hypoxia impacts hexapedal locomotion in the blue crab, Callinectes sapidus Rathbun

The Atlantic blue crab, *Callinectes sapidus* (Rathbun), is an important commercial and recreational fishing species that resides in the estuarine waters of the Atlantic Ocean and Gulf of Mexico. These highly mobile crustaceans must locomote to find food, evade predators, find a mate and avoid adverse conditions such as hypoxia. In effect, maintaining continuous activity and resisting fatigue for extended periods of time may be necessary for the daily survival of blue crabs. Previous studies on hexapod locomotion have focused on forward-moving cockroaches; while work on crab locomotion has concentrated on terrestrial species utilizing 8 limbs. In this study we tested the effects of 2 levels of hypoxia (4 kPa, 20% air saturation; 10.4 kPa, 50% air saturation) on fatigue during sustained continuous exercise. Fatigue was induced by an exercise trial that entailed continuous sideways hexapedal walking on an underwater treadmill. Fatigue was quantified as the percent decrease in holding performance, which was assessed with a repeated hold force test that mimics the way a male holds a female during mate guarding. Fatigue was defined as a 33% decrease in hold force from pre-exercise values. Fatigue was reached after 6 h of walking for crabs in normoxic seawater, 4 h in 50% air saturation and 2 h in 20% air saturation. Fatigue-resisting behaviors (180˚ turns, stopping and riding to the end) increased from the initial time point by 0.9 behaviors per h in normoxia, 4.1 in 50% air saturation, and 13.8 in 20% air saturation. The force and behavioral results indicate that performance is decreased and fatigue is reached more quickly as the level of hypoxia intensifies. (NSF IOS-0725245)

64.1 STRONG, E.E.; Smithsonian Institution, Washington D.C.; *stronge@si.edu*

Large, common and variable: re-assessing the monophyly and diversity of Cerithiidae (Cerithioidea, Caenogastropoda)

The gastropod family Cerithiidae is a primarily shallow-water, marine group, comprising one of 17 families in the superfamily Cerithioidea. The family contains ~185 species currently recognized as valid and accounts for ~15% of known cerithioidean diversity. They are typically abundant and gregarious grazers in intertidal to subtidal habitats around the world, with a center of diversity in the tropical and sub-tropical Indo Pacific. Several species are known to inhabit bathyal depths to ~1200 m. The family is essentially subdivided into two subfamilies: the generally small-sized Bittiinae, and the Cerithiinae with large, solid shells. High levels of conchological variability within and between species have confounded efforts to understand the biodiversity of the family and its evolution. The ruling paradigm has been of common, highly-variable, broadly-distributed species. Intensive sampling programs targeting under-explored offshore hard bottoms in coral reef environments, coupled with new morphological and molecular data (partial COI, 12S, 16S sequences), are challenging this paradigm, revealing species complexes of small, rare and geographically circumscribed species complexes, species pairs differing in mode of larval development, and unsuspected relationships among recognized genera. Monophyly of the family as currently circumscribed is not supported. Actual diversity of the family is likely two to three times higher than currently recognized, requiring the description of many new species, and rescue of some of the roughly 1000 available names that have been sunk in synonymy or have fallen from use.

22.5 STROTHER, JA*; NGO, V; MCHENRY, MJ; Univ. of California, Irvine; *mmchenry@uci.edu*

The role of viscoelasticity in flow sensing

Fish sense water flow with receptors, called neuromasts, that are composed of a glycosaminoglycan gel. It is not clear how the viscoelastic properties of this gel affect how a neuromast filters flow signals. We therefore measured the mechanical properties of this material using a micro-aspiration technique. Using the enlarged neuromasts of the mexican blind cavefish (*Astyanax mexicanus*), we measured the deformation of 15 picoliter samples of the neuromast material in response to a rapid change in pressure. We were able to fit a generalized maxwell model to these deformation measurements in order to characterize the dynamic behavior of the gel. Our measurements demonstrate a major influence of viscoelasticity on determining the filtering properties of a neuromast.

S2-1.7 SUCAR, S.; NEWSOME, J.M.; MOORE, G.L.; RING, B.C.*; Valdosta State University; *bcring@valdosta.edu*
Establishing Developmental Genetics in the Mangrove Killifish (Kryptolebias marmoratus)
The mangrove killifish is a synchronous hermaphroditic fish, which utilizes an ovotestis for reproduction resulting in isogenic lineages analogous to the invertebrate nematode model system, *Caenorhabditis elegans*. This fish develops externally, is easy to maintain and reaches sexual maturity in about 100 days making it a desirable but underutilized developmental genetic model organism. Here we present an ongoing forward genetic screen with the commonly used chemical mutagen, N-ethyl-N-nitrosourea (ENU). Parental isogenic lines Hon9, Hon11, and 50.91 were chosen for mutagenesis based on their genotype, fecundity, viability, average developmental stage of oviposition, and ease of husbandry. ENU treated parents were self-crossed (P; N=34) followed by observation of their offspring across three generations. Mortality, egg production, and fertility of the P fish were recorded over a 10 week period and compared to untreated controls and pre-treatment values. 61% of 7,350 F1 embryos collected were viable of which 1,334 were hatched and raised to maturity (18%) and 284 (genomes) were self-crossed and their F2 offspring screened for zygotic defects during early development. 73 F1 fish produced mutant phenotypes belonging to six different phenotypic classes. We are currently confirming these zygotic mutants into the F3 generation and simultaneously identifying sterile mutant adults. The types and frequencies of mutants in our ongoing genetic screen are documented and compared to other fish models. Taken together, the mangrove killifish represents a powerful and economical model organism which will complement future developmental genetic screens in vertebrates.

S8-1.7 SULTAN, S. E. ; Wesleyan University; *sesultan@wesleyan.edu*
Inherited adaptation via transgenerational plasticity: a case study in annual plants
An intriguing aspect of plasticity that has recently been documented in both animals and plants is the capacity for environmentally stressed parental (generally maternal) individuals to alter traits of their offspring in specific ways that enhance offspring success under those same stresses. This transgenerational aspect of plasticity constitutes a developmentally based mode of inherited adaptation that influences individual fitness, population dynamics, and species distribution. A case study is presented based on multi-generation norm of reaction experiments with naturally evolved genotypes from two well-studied annual plant species. Drought-stressed parent plants of the ecological generalist *Polygonum persicaria* produced seedling offspring with longer, more rapidly extending root systems and significantly greater seedling growth in dry soil, compared with the offspring of genetically identical parents that had been given ample water. In contrast, the closely related, ecologically restricted species *P. hydropiper* expressed maladaptive plasticity: in this species, drought-stressed parents simply produced smaller seedlings with correspondingly slower-extending root systems. Further studies with *P. persicaria* revealed that adaptive transgenerational drought plasticity persisted over two generations. When both parent and grandparent plants were drought-stressed, offspring size and root extension increased significantly. These seedlings also had lower mortality in very dry soil than genetically identical seedlings whose parent and/or grandparent had been amply watered, confirming the fitness impact of these inherited environmental effects. Variation in transgenerational plasticity across genotypes, taxa, environmental factors, and seed architectural position are discussed in evolutionary terms.

22.4 SUMMERS, Adam P.; Friday Harbor Labs, UW; *fishguy@uw.edu*
Burrowing in sand - can surface reduce friction?
Several species of fishes burrow quickly and apparently effortlessly into sand of various grain sizes. Sandlances exhibit a marked preference for one particular grain size and burrow by driving the head directly into the substrate. Since there is no obvious fluidization of the substrate during burrowing we explored the morphology of the fishes skin. The scales are unusual in that they are fused into oblique bands that run dorsoventrally. Is it possible that the scale row spacing is related to the size grain that is preferred?

81.4 SUSTAITA, Diego*; RUBEGA, Margaret; University of Connecticut; *diego.sustaita@uconn.edu*
Anatomy of a shrike bite: force, speed, and pressure in relation to bill shape in loggerhead shrikes (Passeriformes: Laniidae: Lanius ludovicianus)
Shrikes are small predatory passerines that feed on arthropods and vertebrates, and rely heavily on their beaks for catching, killing, and processing their prey prior to feeding. Given the importance of bill shape for feeding in birds in general, and the unusual nature of their bill for a passerine (e.g., a curved, hooked maxilla with tomial teeth) it stands to reason that variation in the shape of the maxilla should have important functional implications. Our previous analysis of upper bill shape in museum specimens suggested that most of the variation in shape is characterized by four main axes along which populations, subspecies, and species differentiate: hook length, maxillary depth, distal hook curvature, and dorsal culmen curvature. Here we examine the functional consequences of this intra- and interspecific variation in shape. We measured voluntary bite force, speed, and pressure of wild-caught loggerhead shrikes using force and pressure transducers coupled with high-speed digital videography, and extracted digital images of their bills for further geometric morphometric analysis. We tested for relationships among aspects of bill morphology (e.g., shape) and bite performance (e.g., force) to examine potential trade-offs in bill form and function. Certain characteristics, such as a longer bill hook, that may be favorable for seizing and processing vertebrate prey, may be disadvantageous for the production of powerful bite forces important for subduing and dispatching them (e.g., due to greater risk of fracture). Thus, predictions for morphology and performance may lead in opposite directions, resulting in complex interactions between them.

S9-1.3 SWALLA, B.J.; Univ. of Washington; *bjswalla@u.washington.edu*
Origin, Evolution & Development of the Chordates: Notochord gain or retention?
Hemichordates and echinoderms are crucial for understanding the evolution of the vertebrate central nervous system (CNS), deuterostome evolution and chordate origins. Hemichordates share many chordate features, including a post-anal tail, gill slits, and a CNS. Morphological and developmental evidence suggests that hemichordates have a CNS that rolls up from the ectoderm via neurulation, but do not have a notochord. Homologs to key neural proteins and developmental genes have been found in the Saccoglossus kowalevskii genome; this available genomic information was used to clone specific genes, and make RNA probes for in-situ hybridization on the Pacific hemichordate species S. bromophenolosus and an indirect developing Pacific species, Ptychodera flava. Results showed unusual complexity in the hemichordate nervous system with a set of cells expressing neuronal markers surrounding the stomochord and heart/kidney complex, but no recognizable notochord. The results suggest that the deuterosome ancestor was a complex benthic worm, with gill slits, a cartilaginous skeleton, and a CNS. Notochord loss in echinoderms and hemichordates is as parsimonious as notochord gain in the chordates. We are now investigating this question with genomics and development gene expression studies. We thank the NSF #DEB-0816892 for funding.

48.1 SWANSON, David L*; THOMAS, Nathan E.; Univ. of South Dakota, Vermillion, Shippensburg Univ., Shippensburg, PA; *david.swanson@usd.edu*
Are intraspecific correlations between minimum and maximum metabolic output in birds consistent with the aerobic capacity model for the evolution of endothermy?
The underlying assumption of the aerobic capacity model for the evolution of endothermy is that basal (BMR) and maximal aerobic metabolic rates are phenotypically correlated. However, because BMR is largely a function of central organs whereas maximal metabolic output is largely a function of skeletal muscles, the mechanistic underpinnings for their correlation is not obvious. Interspecific studies in birds generally support a phenotypic correlation between BMR and maximal metabolic output. If the aerobic capacity model is valid, these phenotypic correlations should also extend to intraspecific comparisons. We measured BMR, M_{sum} (maximum thermoregulatory metabolic rate) and MMR (maximum exercise metabolic rate in a hop-flutter chamber) in winter for dark-eyed juncos (*Junco hyemalis*) and American goldfinches (*Carduelis tristis*; M_{sum} and MMR only) and examined correlations among these variables. For both raw metabolic rates and residuals from allometric regressions, BMR was not significantly correlated with either M_{sum} or MMR in juncos. Moreover, no significant correlation between M_{sum} and MMR or their allometric residuals occurred for either species. These data suggest that central organ and exercise organ metabolic levels are not inextricably linked and that muscular capacities for exercise and shivering do not necessarily vary in tandem in individual birds. Why intraspecific and interspecific avian studies show differing results and the significance of these differences to the aerobic capacity model are unknown, and resolution of these questions will require additional studies of potential mechanistic links between minimal and maximal metabolic output.

57.3 SWANSON, E.M.*; DANTZER, B.; Michigan State University; *eliswanson@gmail.com*
The relationship between insulin-like growth factor-1 and life history across Mammalia
Life history traits describe parameters associated with growth, reproduction and survival. Life history variation is a hallmark of biological diversity, yet persistent patterns of variation are apparent among life history traits. A common observation is that as body mass increases species tend to have less rapid development, slow reproduction and long lifespan. This is often referred to as a 'fast-slow' life history axis. A similar fast-slow axis is still observed after correcting life history traits for body mass, though species tend to fall along this mass-corrected fast-slow axis at very different places than they do on the axis including mass. These persistent patterns of covariation have engendered a search for shared mechanisms than are important in the mediation of life history patterns. Neuroendocrine traits represent an important mechanism for the mediation of life history traits. Within species, insulin-like growth factor-1 (IGF-1) increases with increasing growth rate, increasing reproductive rate, and decreasing longevity. We used phylogenetic comparative methods to investigate the relationship between IGF-1 and multivariate axes of life history variation across the Class Mammalia. We find that increased IGF-1 is associated with fast life histories when mass is included. We also found that mass-corrected IGF-1 is associated with slow life histories after correcting life history traits for body size. Finally, we find that species with high levels of IGF-1 tend to have altricial young, with rapid prenatal development and extended postnatal development. We suggest that this association with fast-slow life history continua provides a plausible mechanism for a previously observed negative correlation between mass and IGF-1, and that the broad comparative relationship between IGF-1 and life history is similar to the intraspecific pattern.

68.6 SWARTZ, Brian; Univ. of California, Berkeley; *Brian.Darwin@Berkeley.edu*
The origin and early evolution of terrestrial locomotion
The origin of terrestrial vertebrates involved an integrated series of changes to the ancestral sarcopterygian bauplan. However, many traits often considered apomorphic for tetrapods have a much deeper origin in vertebrate history. Terrestrial locomotion integrates many such plesiomorphies that facilitated the diversification of vertebrate life on land. In a phylogenetic assessment of over 150 modern and fossil taxa, I incorporate data from osteological, myological, and locomotor records to test how gaits have evolved over gnathostome evolution, and how variation in the historical, constructional, and functional components of the axial and appendicular systems underpins these changes. I show that (a) the trot evolved at least three times in gnathostome evolution; (b) similarities in the trunk muscles of extant lungfishes and tetrapods suggest that the tetrapod myaxial condition evolved in water ~35 million years before the origin of amphibious sarcopterygians; (c) trackway data from modern and fossil records cannot verify whether the lateral sequence diagonal-couplet gait evolved by the end of the Devonian; and (d) the original function of the physical neck—i.e., a space between head and shoulder—was more likely related to the origin of terrestrial locomotion than to any requirement for neck mobility. A pluralistic approach to thinking about macroevolutionary changes—those that distinguish aptations and nonaptations in a continuum of historical, constructional, and functional influences—better elucidates evolutionary transformations than a functionalism that focuses on the cycling of adaptations and exaptations.

29.6 SWEARINGEN, R.L.*; VAGLIA, J.L.; DePauw University, Greencastle, IN; *jvaglia@depauw.edu*

Persistence of embryonic axial patterning markers in adult Eurycea cirrigera tails

Post-embryonic addition of segments in salamanders (Amphibia:Urodela) suggests that the tail tip retains aspects of embryonic cell organization and gene expression throughout life. Knowledge of how spinal cord and associated tissues continue to develop, and what genes are expressed could reveal mechanisms that also underlie tail regeneration. Our research investigates tissue organization and protein expression in the posterior tail of the salamander *Eurycea cirrigera* (Plethodontidae). Our goals were to 1. Describe relations amongst tissues such as spinal cord, notochord and muscle in the posterior tail 2. Determine when during development MF20, Pax6, and Pax7 are expressed in the tail, and 3. Document expression of those proteins along the posterior tail. Embryo, larval and adult specimens were collected from field sites in central Indiana and fixed and processed for whole mount (MF20) or frozen section immunostaining (MF20, Pax6, Pax7). Whole mounts were visualized using a DAB conjugated secondary antibody; sections were visualized using fluorescence. Notochord and spinal cord were present in tails of all life stages, and spinal cord consistently extended more posterior than notochord. Somites were not present in post-embryonic tails, suggesting that ongoing patterning of the spinal cord originates from either within the cord, or from nearby progenitor cells. MF20 expression was absent from tail tips of all stages, but present in differentiated muscle cells positioned more anteriorly in the tail. Dorsolateral spinal cord exhibited Pax6 expression; however, only neural crest expressed Pax7. Consistent with MF20, neither Pax6 nor Pax7 were expressed in tail tips. Our study suggests that genes important for axial patterning in embryos are relevant to post-embryonic development.

76.1 SWEENEY, A.M.*; HOLT, A.L.; GAGNON, Y; MORSE, D.E.; Univ. of California, Santa Barbara, Duke University; *sweeney@lifesci.ucsb.edu*

Giant clam iridocytes optimize photosynthetic symbiosis

Symbioses between metazoans and the brown alga *Symbiodinium* are a major component of the coral reef ecosystem. While the algal symbiosis with corals is the most famous, giant clams in the genus *Tridacna* also exchange nitrogen and carbon with *Symbiodinium* in their tissues, allowing the clams to grow to their storied size. These clams are also valuable in the aquarium trade for the bright, varied color patterns caused by iridocytes in clam tissue, which are closely spatially associated with actively metabolizing brown algae. Although a few hypotheses about the function of these iridocytes have been advanced in the literature, their role in clam physiology is not well understood. Based on detailed histological and optical measurements of these clams, we developed a monte-carlo based optical model to investigate the function of iridocytes in giant clams. Our results show that the clam's iridocytes create a deep layer within the clam tissue where irradiance is optimized for the photophysiology of *Symbiodinium*. Without the iridocytes, only a thin layer of algae deep within the clam could function at an irradiance level that would not cause algal bleaching, thereby not providing enough photosynthate to the clam to support it. On the other hand, our models show that other plausible but non-observed optical arrangements in the clam cause too much shading. Our results show that the distribution and makeup of iridocytes in clam tissue is a precisely optimized optical solution allowing these symbiotic organisms to efficiently harvest photons in some of the most intense light environments on earth without bleaching symbiotic algae.

56.2 SZYMIK, Brett G*; SATTERLIE, Richard A; Longwood University, University of North Carolina at Wilmington; *szymikbg@longwood.edu*

Gait selection in a pteropod mollusk? Examining the kinematics of Clione limacina's swimming for evidence of a gait change.

Discreet locomotory gaits have been defined in many ways, among them the energetic costs/savings of changing gait, the neural and muscular changes that affect limb coordination, and the kinematic changes associated with different locomotory speeds. *Clione limacina* is a pteropod mollusk that swims by flapping its parapodial wings. *Clione* demonstrates two distinct locomotory speeds: a near-constant slow swim speed that positions it in the water column and a fast swim speed used during escape and hunting behaviors. The neuromuscular patterns of *Clione*'s swimming have been extensively studied. The neural control of slow swimming has been well characterized, as have the neural and muscular changes that bring about fast swimming. Here, we present results from a kinematic study of *Clione*'s two swim speeds and consider our findings with respect to the literature of gait selection. We find that *Clione* may well present an example of a two-geared locomotory system wherein specific neural and muscular changes bring about a distinct increase in speed akin to a gait change, yet the phase-based kinematics of the swim speeds are remarkably similar.

42.6 TAHIR, U*; EDWARDS, D.H; Georgia State University; *utahir1@student.gsu.edu*

Suppression of inappropriate reflexes during centrally commanded movements

During centrally orchestrated movements, the nervous system must distinguish between appropriate and inappropriate reflex responses. For example, a contact-evoked startle response may be appropriate when the contact is unexpected but inappropriate when the contact is expected. In crayfish, a tail flip escape evoked by a phasic abdominal stimulus is suppressed when the animal is walking backward or escaping. In either of these contexts, abdominal contact is expected as the animal moves backward and the escape response would be inappropriate. In the present study we generalize this finding to postural reflexes of the crayfish abdomen that can also be evoked by unexpected touch. An isolated abdomen preparation was used that permitted recording and stimulating tailfan primary afferents, ventral nerve cord interneurons, and abdominal postural motor neurons. A brief (0.3 ms) electrical shock of the sensory tailfan nerve evoked an abdominal postural flexion response. The postural flexor motor nerve recording was analyzed to identify each of the six different evoked spikes with one of the six motor neurons of the motor nerve. An abdominal flexion motor program was then excited by repetitively stimulating bundles of descending interneurons. Sensory nerve stimulation evoked a smaller motor nerve response when delivered during the motor program than either before or afterwards, even though the motor neuron activity was higher during the motor program. These results indicate that postural reflex responses are inhibited during the motor program at a site presynaptic to the motor neurons. The most likely targets of inhibition are the presynaptic terminals of the primary afferents, which are known to receive primary afferent depolarization (PAD) during either an escape response or backward walking.

118.6 TARRANT, A.M.*; REITZEL, A.M.; KWOCK, C.K.; GOLDSTONE, J.V.; JENNY, M.J.; WHOI, Chinese University of Hong Kong, Univ. of Alabama; *atarrant@whoi.edu*

Activation of cellular defenses in the sea anemone Nematostella vectensis by PAHs and crude oil

Throughout evolution, animals have needed to detect and respond to chemical and physical stressors. Cellular defenses such as xenobiotic metabolism, antioxidant metabolism, and chaperone activity are mediated through deeply conserved gene families including cytochrome P450s, superoxide dismutases (SODs), and heat shock proteins (HSPs). While these functions are broadly conserved, diversification within gene families has resulted in lineage-specific adaptations as well as variable sensitivity to stressors. The specific roles for individual genes in mediating stress responses are unknown in most invertebrates, particularly aquatic species. Using qPCR and a targeted microarray, we are characterizing the effects of exposure to polycyclic aromatic hydrocarbons (PAHs) and crude oil on the expression of defensive genes in the sea anemone *Nematostella vectensis*. *Nematostella* has a sequenced genome, is amenable to laboratory manipulation, and inhabits a dynamic estuarine environment in which it may be routinely exposed to coastal pollutants. Exposure of *Nematostella* to benzo[a]pyrene (10-500 ppb) for 96 hours induced expression of a manganese SOD and catalase. Co-exposure to benzo[a]pyrene and ultraviolet light resulted in altered gene expression consistent with phototoxicity. Exposure of *Nematostella* to water equilibrated with crude oil (Macondo sweet crude oil, up to 20 ppm), in the presence or absence of dispersant (2 ppm Corexit) resulted in modest and variable induction of cytosolic HSP70, and little to no induction of SODs or catalase. Microarray experiments are in progress to determine whether expression of other defensive genes is affected by oil exposure. Collectively, these studies conducted within *Nematostella* provide insight into both the evolution of animal stress responses and their diversification within Cnidaria.

S2-1.3 TATARENKOV, A.; Univ of California, Irvine; *tatarenk@uci.edu*

Population genetics and phylogeography of a selfing killifish, Kryptolebias marmoratus

The mangrove rivulus, *Kryptolebias marmoratus*, is one of only two related vertebrate animals known to self-fertilize. Mitochondrial DNA (mtDNA) divergence from the related species, *K. ocellatus*, shows that selfing in *K. marmoratus* persisted for hundreds of thousands years. Populations of this fish in the Caribbean consist primarily or exclusively of hermaphroditic individuals, although gonochoristic males occur at about 20% in some populations in Belize. Here, microsatellite loci and mtDNA are used to describe mating system, geographical population structure, and phylogeography of *K. marmoratus*. The mangove rivulus reproduces by a combination of selfing and outcrossing, known as mixed-mating system. Selfing is predominant in most populations in Florida and Bahamas where it can reach 90%-100%, but in some localities in Belize the degree of selfing is much lower, about 45%. Distribution of individual heterozygosity indicates that within each locale fish have equal chances to outcross, in accordance with average outcrossing rate of that locale. Populations with high rates of self-fertilization consist of highly homozygous individuals, which are effectively clonal. The “clonemate” lineages are transient and restricted to narrow area. Significant population structure is detected at spatial scales ranging from a few hundred meters to hundreds of kilometers in Florida, Belize, and Bahamas. Pattern of variation at mtDNA shows decrease of population size in the last several thousand years. Such decline is probably a result of inability of mangrove forests to keep up with rapid sea level rise following last glacial event.

61.4 TATE, KB*; SLAY, CE; HICKS, JW; CROSSLEY II, DA; U N Texas, U C Irvine; *kevtate@gmail.com*

Chronic Hypoxic Incubation Stress and the Plasticity of Humoral Regulation of cardiovascular function in the American alligator (Alligator mississippiensis)

The stress conditions of the incubation environment can impact an *in ovo* developing embryo. One natural stressor for developing reptiles is reduced micro-environmental oxygen content (hypoxia). Hypoxia has been documented in embryos of the American alligator (*Alligator mississippiensis*) to alter the capacity for reflexive regulatory system suggesting plasticity. However, the plasticity of humoral regulatory systems in response to developmental hypoxia is unknown. In this study we assessed the response of known adult humoral regulators arginine vasotocin (AVT), adenosine (ADO) and endothelin-1 (ET-1) in embryos incubated chronically in 10% O_2 (H-10) and 21% O_2 (N-21). H-10 embryos were markedly smaller, hypertensive, and bradycardic compared to N-21 embryos. Injection of AVT (through a tertiary chorioallantoic artery) induced an immediate hypertensive response in both H-10 and N-21 embryos, concurrent with a bradycardia. ADO injection resulted in a brief hypotensive bradycardia, in both H-10 and N-21 groups. Injection of ET-1 failed to induce a response, in either H-10 or N-21 embryos. The data suggest that, as demonstrated in adult vertebrates, AVT and ADO are vasoactive components, and appear to be involved in the cardiovascular regulation in embryonic alligators. NSF CAREER IBN IOS-0845741 to DAC

30.6 TAVONI, Stephen*; CHAMPAGNE, Cory; HOUSER, Dorian; CROCKER, Dan; Sonoma St. Univ., UC Santa Cruz, National Marine Mammal Foundation; *tavoni@seawolf.sonoma.edu*

Lactate turnover and glucose production in free-ranging northern elephant seal pups Mirounga angustirostris.

The most extreme examples of fasting adaptation are species that undergo natural fasts during energy intensive periods. These species must conserve tissues while fasting under the constraint of high rates of nutrient commitment to energy metabolism or development. Elephant seal pups *Mirounga angustirostris* combine a post weaning fast with development of diving capacity. During this period they undergo dramatic changes in blood volume and blood and muscle respiratory pigments that are critical to foraging effectively in the marine environment. Elephant seals lack the characteristic suppression of glucose metabolism during fasting; production greatly exceeds the estimated needs of glucose dependent tissues and gluconeogenesis from glycerol and amino acid precursors is minor. This suggests high rates of glucose carbon recycling, potentially through Cori cycle activity. To investigate this hypothesis, lactate and glucose turnover rates were measured by a primed constant infusion of [U-^{14}C] lactate and ^{3}H- labeled glucose. Measurements were taken after 14 and 35 days of fasting in 8 weaned pups. When controlled for changes in body mass, glucose and lactate turnover rates did not change across the fast. Lactate turnover varied significantly with glucose turnover, suggesting glycolytic flux as a major avenue of glucose disposal. The minimum lactate contribution to glucose production was high (>33%) and increased across the fast, supporting the hypothesis that high rates of glucose turnover in fasting elephant seals are due to glucose recycling. These features may be adaptive in the prevention of ketoacidosis while fasting and are consistent with metabolic defenses associated with hypoxia.

S2-1.1 TAYLOR, D. Scott; Brevard County Environmentally Endangered Lands Program; *scott.taylor@brevardparks.com*

Twenty-four years in the mud: what have we learned about the natural history and ecology of Kryptolebias marmoratus?

Although first described in 1880, *K. marmoratus* avoided scientific scrutiny until 1961, when it was identified as the only known selfing hermaphroditic vertebrate. The subsequent intense interest in the fish as a lab animal, continuing to this day, might explain the paucity of wild collections, but our collective knowledge now suggests that the inherent difficulty of wild collection is more a matter of ‘looking in all the wrong places.’ Long thought to be rare in the mangal, and it can be in certain human-impacted habitats, *K. marmoratus* can be quite abundant, but in microhabitats not typically targeted by ichthyologists: ephemeral pools high on the swamp elevation profile and fossorial or even terrestrial haunts. Field studies of this enigmatic fish have revealed almost amphibious behaviors allowing emersion and survival during dry-down, tolerances to both high and low temperature, high levels of hydrogen sulfide and depleted DO, a catholic diet and a geographically variable sex life. A clearer picture is emerging of adult life, but juvenile habitat and adult oviposition sites remain unknown.

59.6 TAYLOR, KR*; PACE, CM; MORTIMER, SA; NISHIKAWA, KC; Northern Arizona University; *kt375@nau.edu*

Vertical jumping among mdm mouse genotypes

Jumping is a ballistic locomotor behavior that can help elucidate how muscles work. During jumping, elastic components in the limbs store and recover energy to increase jump height. The protein titin contributes to the elastic properties of muscle. *Mdm* mice have a deletion in the N2A region of titin and exhibit different in vitro muscle properties compared to wildtype mice. Studying vertical jumping in the *mdm* genotypes is an interesting biomechanical test of whether variation in titin affects locomotion. The goal of this project was to determine whether *mdm* genotypes differ in vertical jumping ability. Each genotype was filmed jumping using a high-speed imaging system. Mice were age matched; however, wildtype and heterozygous mice are larger than mutants, so data were examined both in absolute terms and relative to body mass. There was no difference among the genotypes in take-off time. Jumps by mutant mice were shorter, slower, and produced less force than the other genotypes. However, when data were scaled to account for differences in body mass, the average jump velocity and height of the mutants were not different from the other genotypes. The lack of variation between genotypes when scaled for mass is surprising given that previous research found differences in walking among all genotypes. Lever experiments with *mdm* mutant and wildtype muscles have shown that mutant muscles are stiffer than wildtype muscles when passive but more compliant when active. Perhaps the increased passive stiffness is in some way compensating for the increased active compliance in jumping but not in walking. By studying whole animal locomotion in addition to mechanical studies of *mdm* muscle, we will broaden our understanding of how titin contributes to muscle function. Supported by NSF IOS-1025806.

15.1 TERWILLIGER, NB; University of Oregon, Charleston; *nterwill@uoregon.edu*

Crustacean ion and oxygen tranporters: research by David Towle and Steve Morris, and new findings on hemocyanin

This presentation on crustacean biology will discuss recent studies by our friends and esteemed colleagues, David Towle and Steve Morris, plus new directions in hemocyanin research. First, David Towle showed that crustaceans and vertebrates share similar ion transporters. In his worldwide travels David encouraged collaborators by example to integrate molecular techniques into comparative biochemical and physiological approaches to understanding ion regulation in crustaceans. I will revisit some key findings in one of his recent projects, in collaboration with Ray Henry and me, that explored the global expression patterns of the green crab in response to hyposalinity. Second, Steve Morris provided a mosaic of global patterns of hemocyanin function related to life histories of crabs from terrestrial to marine, Christmas Island to South Africa. His interest in the relatedness of thermal and hypoxic challenge, behavior, and modification of gene expression in crustaceans led to his examining regulation of key metabolic enzymes in hypoxia. Third, I will discuss new findings from the laboratory of Heinz Decker and colleagues that describe how hemocyanin undergoes a conformational flip from reversible oxygen binding to phenoloxidase. Their structural analyses using high resolution electron cryomicroscopy and pseudoatomic models coupled with enzyme analyses show how arthropod hemocyanin could participate in providing oxygen to respiring tissues, hardening the newly molted exoskeleton, and catalyzing the early steps of melanin synthesis, a factor in the immune response.

S4-1.3 THATJE, Sven; University of Southampton, School of Ocean and Earth Science, National Oceanography Centre, Southampton; *svth@noc.soton.ac.uk*

Dispersal capabilities, barophysiology and the evolution of Antarctic community structure

The apparent scarcity of planktonic larval development in polar invertebrates has caused heated discussion amongst ecologists for most of the last century. In this paper I review the knowledge of reproductive traits in marine invertebrates thriving in Antarctica from an evolutionary perspective of cold adaptation. I will examine the means by which polar invertebrates may overcome physical, physiological (presented by temperature or hydrostatic pressure), and geographical barriers, and critically assess current views of ecological as well as evolutionary driving forces behind reproductive trade-offs in cold waters. The ‘mobility’ of any kind of life history stage is particularly important in the isolated Southern Ocean where continental shallow-water benthos had to contend with the threat to species survival presented by the advancing continental ice sheets of late-Cenozoic climate oscillations; these by far exceeded local physical disturbance by grounded ice seen in shallow Antarctic waters today. Increasing molecular and phylogeographic evidence suggests that the mobility of invertebrates during those times may have been crucial for survival. Possible refugia, either in isolated continental shelf pockets, the circum-Antarctic deep sea, or Southern Ocean Islands, or emigration to lower latitudes have been proposed for periods of glacial conditions. I will discuss the question of whether larvae or any other kind of drifting stages played a predominant role in defining benthic community resilience over geological periods of time in Antarctica. Finally, I will provide a highly personal view on a necessary cross-disciplinary scientific revolution for the sake of better understanding how life in cold waters has evolved.

78.2 THAWLEY, C.J.*; ROBBINS, T.R.; LANGKILDE, T.; Pennsylvania State University; *cjt171@psu.edu*
Survival under pressure: lethal and sublethal effects of an invasive predator, the red imported fire ant, on a spiny lizard
Environmental interactions play a major role in structuring communities and determining the life histories of species. Anthropogenic impacts, such as climate change and introduced species, alter these interactions and, as a result, change existing selective pressures. The strength of these pressures and species' capacity to respond to them will determine whether populations and communities can persist under these novel threats. While much research has focused on lethal impacts of global change, sub-lethal effects are common and can present serious challenges for native species. We conducted a transplant experiment to examine the effects of red imported fire ant (*Solenopsis invicta*) presence on the survival, growth, and behavior of a common lizard (*Sceloporus undulatus*) in the southeastern U.S. We show that selective pressures imposed by fire ants differ across ontogeny. Adult lizards have decreased survival in the presence of fire ants while juveniles survive equally well. Sub-lethal effects also vary, as fire ant presence results in lower growth rates and body condition in juvenile lizards and a behavioral shift in perch height in adults. These data show that invaders can alter selective pressures in multiple, nuanced ways across the life history of native species. Insight into diverse pressures imposed by invasive species may allow us to understand longer-term consequences for native communities and more effectively manage remaining biodiversity.

84.1 THERRIEN, Sara*; CARR, Catherine; WELLS-BERLIN, Alicia; University of Maryland, College Park, U.S. Geological Survey, Patuxent Wildlife Research Center; *therrien@umd.edu*
Auditory Brainstem Response in Sea Ducks and Diving Ducks
The Auditory Brainstem Response (ABR) is a valuable physiological technique used to describe an animal's auditory sensitivity in a minimally invasive and time-efficient manner. The ABR is a scalp-recorded potential resulting from synchronized neural discharge (population response) following an auditory stimulus. This synchronized response is manifested as a series of four or more waves occurring within the first 10 ms following stimulation and represents the progressive propagation of auditory neural activity through the ascending auditory pathway. In this study, we have used the ABR to test hearing in one species of diving duck (Lesser Scaup, *Aythya affinis*), as well as several species of sea duck, including Long-tailed ducks (*Clangula hyemalis*), Surf Scoters (*Melanitta perspicillata*), White-Winged Scoters (*Melanitta fusca*), Black Scoters (*Melanitta americana*), and Harlequin ducks (*Histrionicus histrionicus*). The typical duck ABR waveform showed two to three prominent peaks. Peak amplitude of the response increased and peak latency of the response decreased with increasing stimulus sound pressure level (SPL). Threshold was defined as 2.5 dB below the lowest SPL that evoked a visual response (visual detection method). The best range of hearing for all six species was from 1000 Hz to 4000 Hz, with sensitivity peaking between 1500 Hz and 3000 Hz. Both the waveform morphology and response characteristics of the peaks to changing stimulus intensity are similar to those found in other avian species, such as screech owls (*Megascops asio*) and budgerigars (*Melopsittacus undulatus*). These results represent the first measurement of auditory sensitivity of any sea duck or diving duck.

112.2 THOMPSON, J.T.*; SHELTON, R.M.; KIER, W.M.; Franklin and Marshall College, University of North Carolina; *joseph.thompson@fandm.edu*
Non-uniform strain in squid mantle muscle: relating the length-tension curve to in vivo muscle performance
Non-uniform strain occurs during contraction and re-expansion of the hollow, muscular mantle of squids, with up to 1.8-times greater circumferential strain at the inner lumen surface than at the outer surface during a single jet. This gradient of strain may result in muscle fibers near the inner and outer surfaces of the mantle operating over different regions of the length-tension curve during the same mantle contraction. We investigated this phenomenon in long-finned squid (*Doryteuthis pealeii*) by developing a method to relate the length-tension curve for sheets of circular muscle fibers to the *in vivo* circumferential strains experienced by those fibers during swimming and ventilation. The mean ranges of excursion lengths (i.e., full extension to full contraction) for the circular fibers near the inner surface were 1.0-0.67 L_0, 0.94-0.79 L_0, and 0.93-0.87 L_0 for escape jets, slow swimming, and ventilation, respectively (n=10 squid, 60 jets/squid; L_0, preparation length at peak isometric force), but only 0.95-0.71 L_0, 0.92-0.77 L_0, and 0.88-0.83 L_0 (n=12, 60 jets/squid) for the circular fibers near the outer surface. In addition to being lower, the ranges of excursion lengths for the outer fibers were shifted about 0.05 L_0 to the left on the length-tension curve. Our data show that the obliquely striated circular muscle fibers operate along the ascending limb of the length-tension curve for most jets, reaching L_0 and the descending limb only during large hyperinflations. The leftward shift on the length-tension curve for the circular fibers near the outer surface is intriguing and may imply that resting sarcomere lengths change with depth in the mantle wall. Funded by NSF grants IOS-0950827 and IOS-0951067.

95.4 THOMPSON, JT*; VALVERDE, RA; Southeastern Louisiana University; *judd.thompson@selu.edu*
Influence of Polychlorinated Biphenyls on Gene Expression and Corticosteroid Secretion within the Neuroendocrine Stress System of the red-eared slider turtle, Trachemys scripta elegans
In order to adequately address anthropogenic environmental degradation, it is necessary to the physiological effects experienced by biota present in the impacted area. Of particular interest is the introduction of bioactive compounds, such as polychlorinated biphenyls (PCBs), which have been shown to disrupt growth and development of the reproductive and nervous systems. The influence of these compounds on the endocrine stress response has yet to be described. The vertebrate ability to maintain homeostasis in response to a stressor is mediated by the neuroendocrine stress system (NSS). The purpose of this study was to determine the effects of PCB exposure on the NSS by quantifying expression of thyroid stimulating hormone (TSH) and pro-opiomelanocortin (POMC), as well as plasma concentrations of corticosterone (CORT) in response to prolonged immobilization stress.

1.4 TKINT, T*; DE MEYER, J; HELSEN, P; VAN HOOREBEKE, L; VERHEYEN, E; ADRIAENS , D; Ghent University, Belgium, Antwerp University, Belgium, RBINS, Brussels, Belgium; *Tim.tkint@ugent.be*
Phenotypic plasticity of feeding performance as a response to diet in cichlids: suction versus biting.
The explosive radiation of cichlids in the East-African Lakes is considered an important model system for evolutionary research. To explain their very high rates of speciation several hypotheses have been suggested. The decoupling of the oral and pharyngeal jaws is considered their most important key innovation, but recently it has been found that several other factors may also play a role in their adaptive radiation. Local adaptive responses, resulting from phenotypic plasticity allow species to adapt to immediate environmental changes during their lifetime, which has the potential of becoming a heritable trait through processes like genetic assimilation. We investigated phenotypic plasticity in response to different feeding modes in two cichlid species from Lake Victoria: *Haplochromis piceatus*, a suction feeder and *H. fischeri*, a biter. We raised groups of both species on food with the same nutritional quality, but different physical characteristics, simulating different feeding modes: suction feeding from the water column, scraping food and biting on hard pellets. To visualize the plastic response we performed a geometric morphometric analysis and we also compared feeding performance based on morphological proxies (theoretical bite force, KT,...). Ossification patterns of the lower jaw were compared using µ-CT data. To some degree, the observed morphological variation between treatments seemed to be related to improving the imposed mode of feeding.

70.5 TOLLEY-JORDAN, L. R.*; CHADWICK, M. A.; Jacksonville State University, Kings College London; *ljordan@jsu.edu*
Significance of snails as habitat patches for their concomitant parasites in novel environments.
Melanoides tuberculata and *Thiara granifera* (Caenogastropoda: Thiaridae), snails native to Asia, were introduced to the Comal springs, Texas, USA in the 1960s. Subsequently, the introduction of invasive, trematode parasites, *Centrocestus formosanus* and *Haplorchis pumilio* (Heterophyidae) infected *M. tuberculata* and *Philophthalmus gralli* (Philophthalmidae) infected both snail species. We determined 1) infection rates among parasites within a snail population and 2) if host selection of *M. tuberculata* or *T. granifera* was related to snail abundance and snail size. Snails were sampled from October 2001 to April 2002 from a range of habitats. Snail lengths (mm) and parasites found in snail tissues were recorded. Differences in infection rates between host species and among parasites within each host population were tested by comparing 95% confidence intervals estimated by bootstrapping numbers and lengths of collected snails. In total, 841 *M. tuberculata* ranging from 6-56 mm and 1,978 *T. granifera* ranging from 1-31mm were collected. Infection rates in both snail populations ranged from 0.1 -2.0%. No snails smaller than 20 mm (70% of *M. tuberculata* and 95% of *T. granifera*) were found infected. No significant differences in *P. gralli* infection between *M. tuberculata* and *T. granifera* occurred. In *M. tuberculata*, *C. formosanus* was the dominant parasite. Thus, as larger snails occurred infrequently in the springs, available patch size for parasites was reduced. The limited availability of suitable snail hosts may have led to the dominance of *C. formosanus* infecting *M. tuberculata* and low levels of infection of *P. gralli* in both snail species.

S6-1.6 TOMANEK, Lars; California State Univ., San Luis Obispo; *ltomanek@calpoly.edu*
Environmental Stress Proteomics of the Mussel Mytilus
The warm-adapted Mediterranean blue mussel species *Mytilus galloprovincialis* invaded southern California during the last century and has since replaced the cold-adapted native *M. trossulus* from its southern range, possibly due to climate change. Furthermore, *M. galloprovincialis* tolerates higher salinity levels than the native. Both, temperature and salinity changes have been hypothesized to contribute to the range shifts. Using proteomics, we were aiming to characterize the underpinnings of interspecific differences in thermal and salinity tolerance limits. We conducted several experiments: an acute heat stress experiments to 24°C, 28°C and 32°C, followed by a 24 h recovery at 13°C; a 4-week long temperature acclimation (7°C, 13°C and 19°C) experiment and an acute hypo-saline (100%, 85% and 70% salinity) stress experiment for 4 h followed by a 0 h and 24 h recovery period. Using gill tissue, we applied 2D gel electrophoresis and tandem mass spectrometry to separate and identify proteins. The results suggest that acute heat stress triggers a shift from pro-oxidant NADH- to anti-oxidant NADPH-producing pathways to reduce the production of reactive oxygen species (ROS) and increase the cell's capacity for ROS scavenging. Temperature acclimation showed that *M. trossulus* induces molecular chaperones at 19°C. Cold acclimation increased oxidative stress proteins and molecular chaperones in both congeners, although more so in *M. galloprovincialis*, suggesting a ROS-induced challenge to protein homeostasis at lower temperatures. The response to hypo-salinity stress suggests oxidative-stress induced changes in energy metabolism in *M. trossulus* but not in *M. galloprovincialis*. Together, these results link ROS production to changes in metabolism that may contribute to setting tolerance limits.

5.3 TRAN, C*; HADFIELD , MG; University of Hawaii at Manoa; *cawa@hawaii.edu*
Sensory mechanisms utilized by coral planulae to detect settlement cues
Coral planulae require environmental cues on substrata to settle and metamorphose into polyps. Sensory cells used to detect settlement cues are located in the apical region of many other marine invertebrate larvae. To determine what region of the body in coral larvae bears sensors for environmental cues, individual larvae were transversely sectioned into two separate oral and aboral fragments at various levels ¼, ½, and ¾ of the body length from the aboral pole. These separate ends heal and continue to swim until a suitable substratum, such as a marine biofilm, is introduced. A comparison was done with larvae of two coral species, *Pocillopora damicornis* and *Montipora capitata*. When provided with a settlement-inducing substratum, aboral ends of *M. capitata* settled while oral ends continued to swim as expected, given the aboral end is the point of attachment to the substratum. However, in larvae of *P. damicornis*, ¾ oral ends, i.e., lacking the aboral pole, were also able to settle. This is consistent with the results when larval sections were also provided with an artificial inducer, cesium chloride. These results suggest that the cells used to detect cues may not be limited to the aboral pole, but are instead distributed along the sides of the body as well in the aboral half. This is further supported by the observation of planulae rotating on their sides when exploring a biofilmed surface. The results of this study suggest that different coral species either utilize different sensory cells for chemoreception of settlement cues, or the cells are located on different regions of the larval body.

S4-2.2 TREML, EA; University of Queensland, Qld, Australia; *e.treml@uq.edu.au*

Bridging ecological and evolutionary timescales with spatially-explicit network analysis of marine population connectivity

Marine population connectivity describes the likelihood that an individual of a population can disperse some distance from its natal habitat patch to settle in available downstream habitat. This connectivity is often critical for metapopulation persistence, range size expansion, and a species' ability to cope with climate change. Unfortunately, identifying the important biophysical drivers and the resultant patterns in connectivity poses one of the greatest challenges in marine ecology. We quantify the complex interaction between the dynamic seascape and species' life history characteristics to (1) highlight the influence of key biological and physical parameters on population connectivity and (2) map the spatiotemporal patterns emerging from these interactions. We describe a spatially-explicit biophysical modelling approach that effectively quantifies population connectivity across species, from demographically relevant to evolutionarily significant scales. These population connectivity estimates are transformed into marine population networks where we apply graph-theoretic algorithms to re-evaluate connectivity, identify network-wide properties, and quantify each site's contribution to system dynamics. Finally, we highlight multi-species dispersal corridors, semi-permeable barriers, critical stepping-stones, and the emergent spatial structure of marine population connectivity. We close with recommendations on how population connectivity estimates can be explicitly integrated within the conservation planning framework.

77.1 TROWBRIDGE, C.D.*; LITTLE, C.; PILLING, G.M.; STIRLING, P.; MILES, A.; Univ. of Oregon, Univ. of Bristol, Secretariat of the Pacific Community; *cdt@uoregon.edu*

Decadal-scale changes of shallow subtidal benthos in an Irish marine reserve

Long-term annual monitoring of rocky intertidal and shallow subtidal shores of an Irish sea lough (1990-2011) documented major regime shifts in the last decade. Shortly after the population densities of the purple urchin *Paracentrotus lividus* plummeted in Lough Hyne Marine Reserve in SW Ireland, the warm-water fucalean alga *Cystoseira foeniculacea* and ephemeral algae proliferated. Release from herbivory and/or climate change may have facilitated this algal proliferation, which blanketed the benthos. Smothering of the benthos has led to shallow subtidal hypoxia. Furthermore, the invasive fucalean alga *Sargassum muticum* has made repeated incursions into the reserve. Although currently being reduced by persistent eradication efforts (2003-2011), *Sargassum* is spreading within the lough. Limited seawater flushing and propagule dispersal within the lough as well as eutrophication in coastal waters may have contributed to community-level changes. Whether the regime change is cyclical (contingent on re-establishment of urchins within the lough and continued eradication of *S. muticum*) or irreversible (due to critical transitions) currently remains unclear.

68.4 TSAI, Henry P; HOLLIDAY, Casey M*; University of Missouri; *hollidayca@missouri.edu*

Ontogeny of the alligator cartilago transiliens and its significance for sauropsid jaw muscle evolution

The cartilago transiliens is a fibrocartilaginous structure within the jaw muscles of crocodylians. The cartilago transiliens slides between the pterygoid buttress and coronoid region of the lower jaw and connects two muscles historically identified as m. pseudotemporalis superficialis and m. intramandibularis. However, the position of cartilago transiliens, and its anatomical similarities to tendon organs suggest the structure may be a sesamoid linking a single muscle. Incompressible sesamoids often form inside tendons that wrap around bone. However, such structures rarely ossify in reptiles and have thus far received scant attention. We tested the hypothesis that the cartilago transiliens is a sesamoid developed within in one muscle by investigating its structure in an ontogenetic series of American alligators using dissection, iodine-enhanced 3D imaging, and polarizing and standard light microscopy. In all animals studied, the cartilago transiliens receives collagen fibers and tendon insertions from its two main muscular attachments. However, whereas collagen fibers were continuous within the cartilaginous nodule of younger animals, such continuity decreased in older animals, where the fibrocartilaginous core grew to displace the fibrous region. Whereas several neighboring muscles attached to the fibrous capsule in older individuals, only two muscles had significant contributions to the structure in young animals. Our results indicate that the cartilago transiliens is likely a sesamoid formed within a single muscle as it wraps around the pterygoid buttress. This tendon organ is ubiquitous among fossil crocodyliforms indicating it is a relatively ancient, conserved structure associated with the development of the large pterygoid flanges.

11.2 TSAI, Henry P.*; WARD, Carol V.; HOLLIDAY, Casey M.; University of Missouri; *hptkr7@mail.missouri.edu*

Pelvic anatomy of Alligator mississippiensis and its significance for interpreting limb function in fossil archosaurs

Reconstructing joint anatomy and function of extinct vertebrates is critical to understanding their posture, locomotor behavior, ecology, and evolution. Major changes occurred in hip joint morphology during archosaur evolution. However, the lack of soft tissues, such as cartilage, ligaments, and tendons in fossil taxa makes accurate inferences of joint function difficult. We test the hypothesis that hard-tissue manipulation alone is insufficient to accurately predict in-vivo range of motion in hip joint of the American alligator. We also describe the anatomy of extant archosaur appendicular joints by providing the first description of the acetabular anatomy of the American alligator, coupled with comparative data from other sauropsids. Hip joints of ten specimens ranging from hatchling to adult individuals were subjected to dissection, iodine-enhanced 3D imaging, and histology. Our results show that alligator hips possess two capsular ligaments, as well as a ligamentum teres capitus. The lunate surface has two distinct cranial and caudal regions of articular cartilage, bounded caudally by menisci and dorsally by the supraacetabular labrum. During femoral abduction, the ligamentum teres capitis limits movement of the proximal femur, allowing it to slide dorsoventrally within the acetabulum. Posture-specific, reconstructed CT data show that the femoral center of rotation is localized inside the metaphysis, a condition different from epiphysis-centric COR in mammals, and previously overlooked for archosaurs. This study provides new insight into soft tissue structures and their osteological correlates in the archosaur hip joint. Continuing identification and testing of these osteological correlates in fossil archosaurs will greatly enhance our understanding on evolution of locomotor capabilities such as bipedality and posture of fossil archosaurs and other reptiles.

S5-1.7 TU, Ming-Chung*; LIU, Yu-Ling; National Taiwan Normal University; *biofv026@ntnu.edu.tw*

New perspectives on the extent of terrestriality in three species of sea kraits and their habitat selection

Three species of sea kraits, *Laticauda* spp., require fresh water, and both the evaporative water loss rate on the land and the extent of terrestriality differ among them. *Laticauda semifasciata* has the greatest water loss rate and least extent of terrestriality, while *L. colubrina* exhibits the reverse and *L. laticaudata* is in between. These sea kraits tend to be more abundant at places where there are sources of fresh water. Nevertheless, they are rarely found at river mouths where there is plenty of fresh water. Clearly, more than one factor influences their habitat selection. To clarify the factors, we investigated the number of each species of sea krait at six different habitats and the availability of each type of habitat on Orchid Island, Taiwan. The six types of habitats were high coral reef without fresh water (HR) and with fresh water (HRF); low coral reef without fresh water (LR) and with fresh water(LRF); sand or gravel coast, which has no coral reef without fresh water (NR), and with fresh water (NRF). The extent of safety for retreat – from high to low – is HR, LR and NR among these habitats. More than 75% individuals of each species were found in HRF. We found no sea kraits in NRF and NR. The most available habitat is LR, but no *L. laticaudata* or *L. semifasciata* were found in this habitat. We found 3.3 and 16.7% of *L colubrina* in LR and HR, respectively. For *L colubrina*, the second abundant habitat was HR. Whereas for *L. laticaudata* and *L. semifasciata*, the second abundant habitat was LRF. Both safety of the retreat site and fresh water appear to be important to the habitat selection of sea kraits. *Laticauda colubrina* is characterized by a higher extent of terrestriality and depends on fresh water less than do the other two species.

53.3 TUDOR, M Scarlett*; MORRIS, Molly R; University of Florida, Ohio University; *studor@ufl.edu*

Frequencies of alternative mating strategies influence female mate preference in the swordtail Xiphophorus multilineatus

While studies demonstrating variation in female mating preferences are increasing, we still know very little about the factors that contribute to this variation, and we are therefore unable to predict how selection on males will vary due to female preference. A previous study of Xiphophorus multilineatus detected variation in female mate preference, where smaller females had a weaker strength of preference for males that court (courters) as compared to small males that use sneak-chase behavior (sneakers). We tested the hypothesis that female experience with biased frequencies of courter and sneaker males would result in negative frequency-dependent selection on these male alternative mating tactics through female mate choice. We examined the preferences of naive females, females given experience with different frequencies of courter/sneaker males in laboratory mesocosm treatments, and wild-caught females collected when the frequencies of males were sneaker biased, and equal. The frequency of courter to sneaker males experienced in the laboratory significantly influenced female preference for courter males, but not in the direction we predicted for one end of the frequency distribution: the weakest strength of preference for courter males was from the treatment where courter males were less frequent. The pattern detected in wild-caught females was similar to the pattern detected in the laboratory-mated females, and together they suggest that when frequencies are biased towards either type of male, smaller females had a weaker preference for courter males.

72.2 TUMULTY, J. P.*; SUMMERS, K.; East Carolina University; *tumultyj09@students.ecu.edu*

Male Removal Experiments Support the Biparental Care Hypothesis for the Evolution of Monogamy in Ranitomeya imitator.

Levels of parental investment by each sex are important factors in determining the mating system of a species. Selection for biparental care can favor a monogamous mating system if it becomes crucial for offspring survival and parents can achieve higher reproductive success through exclusive cooperation in care for mutual offspring than through polygamy. The mimic poison frog, *Ranitomeya imitator*, exhibits both biparental care, characterized by trophic egg feeding, and social and genetic monogamy. Males typically guard egg clutches and transport tadpoles to arboreal pools of water in leaf axils, then periodically call to females, stimulating them to lay trophic eggs. These behaviors are associated with the use of very small, nutrient-poor pools for tadpole deposition, which lack sufficient food for tadpole survival without the provisioning of trophic eggs. Male removal experiments were used to determine the role males play in trophic egg feeding and to test the hypothesis that selection for cooperative biparental care is maintaining monogamy in this species. Results show decreased growth and survival of tadpoles belonging to widowed females compared to those of un-manipulated control families. These results suggest males play a critical role in trophic egg provisioning and thus offspring success, and provide support for the biparental care hypothesis for the evolution of monogamy in *R. imitator*.

81.1 TURINGAN, R.G.*; WITTENRICH, M.L.; BECK, J.B.; SAMARCO, T.J.; Florida Institute of Technology, University of Florida, NOAA, St. Petersburg, Florida; *turingan@fit.edu*

Determinants of feeding performance in marine-fish larvae

Over five decades of research on post-metamorphic (i.e., juvenile- and adult-life history stages) fishes have resulted in our current, substantial understanding of the functional morphology, mechanics, performance, diversity and evolution of fish-feeding systems. In contrast, we have a limited understanding of these features of the feeding system in pre-metamorphic (i.e., post-hatch larva stage) fishes despite our knowledge that the environmental regimes that conspecific fishes experience are extremely different between the two life-history stages. In an attempt to contribute to our understanding of the feeding system in marine-fish larvae, we present empirical evidence of the pre-metamorphic ontogeny of functional morphology, kinematics and feeding performance in several species of marine fishes. In addition, we test some hypotheses concerning fish feeding systems by contrasting key performance metrics between post-larval and larval marine-fish conspecifics. Our studies indicate that (1) earlier stage larvae feed on a restricted type of prey, whereas older larvae feed on more diverse prey types; (2) the prey-capture kinematics of fish larvae is stereotypical across prey types; (3) key functional-morphological components of the feeding mechanism become more complex and integrated as larva develops from hatching to metamorphosis; and (4) the scaling of key feeding-morphological metrics is different between pre-metamorphic and post-metamorphic fishes. We postulate that the functional-morphological determinants of feeding performance, as well as the pattern of morphology-performance relationships in juvenile and adult fishes may be different from those of larval conspecifics.

41.4 TURKO, A*; COOPER, C; WRIGHT, P; University of Guelph; *aturko@uoguelph.ca*

Terrestrially induced gill remodelling reduces the aquatic respiratory function of Kryptolebias marmoratus

Amphibious fish use a suite of reversible plastic changes to their behaviour, physiology, and morphology when switching between aquatic and terrestrial habitats. Some of these responses occur rapidly (i.e. behaviour), while others occur over days or weeks (i.e. morphology). The mangrove rivulus, *Kryptolebias marmoratus*, may spend weeks in terrestrial habitats. During these periods the gills are remodelled, reducing surface area. I tested the hypothesis that this remodelling would negatively impact respiratory function upon returning to aquatic breathing. I predicted that air-acclimated fish would show a hypoxic ventilatory response at a higher level of dissolved oxygen, and have a higher critical oxygen tension (P_{crit}), than brackish water controls. Custom-built chambers were used to non-invasively measure gill ventilation as fish were exposed to stepwise decreases in dissolved oxygen. Closed respirometry was used to measure metabolic rate and P_{crit}. Fish with reduced gill surface area increased ventilatory activity at a significantly higher oxygen concentration than control fish, and took longer to recover from hypoxic exposure. P_{crit} was unaffected by gill morphology. The increased sensitivity to hypoxia in air-exposed fish indicates that reversible gill remodelling has consequences for respiratory function upon switching respiratory media. Increased gill ventilation was able to compensate for gills with reduced surface area during acute hypoxic exposure, as P_{crit} did not differ between groups. However, the increased recovery time of air-exposed fish suggests that increased gill ventilation may not suffice over longer time scales. Overall, these results demonstrate how behavioural and morphological plasticity are temporally integrated in mangrove rivulus during the transition between aquatic and terrestrial habitats.

77.5 TURNER, KR*; SEBENS, KP; Univ. of Washington; *krturner@uw.edu*

Lingcod and rockfish impacts on benthic community structure

Management decisions affect not just the species targeted by management, but also unharvested species related to those target species through ecological networks. Removal of top predators from subtidal communities releases prey species from predation, allowing prey populations to increase. Examples from around the world have shown that impacts from predator removals can cascade to harvestable species at lower trophic levels. Predator removals can also significantly change the composition of the entire marine community. We are studying the effects of large carnivorous fishes (lingcod, *Ophiodon elongatus*, and rockfishes, *Sebastes* spp.) on the rocky subtidal communities of San Juan Channel. Predatory fish abundance is variable within San Juan Channel, in part due to marine protected areas, which allows us to study community structure across a range of predator abundance. We use surveys of all trophic levels in this system, combined with exclusion cages designed to restrict fish access from large swaths of the benthos, to determine the community-wide impacts of predatory bottom fishes. Our preliminary results show that predator abundance does vary across San Juan Channel sites, as do species at lower trophic levels. However, correlations between predators and other trophic levels are not consistent at all sites. We have also examined the diets of two species of rockfishes to aid in the construction of a food web for this subtidal community. Our non-lethal analysis of the diet of copper rockfish (*S. caurinus*) demonstrates close agreement with the findings from previous studies, although the individuals in our study were less reliant on fish prey. The results from this research may be used to support ecosystem-based management goals by informing fisheries managers about the potential community-wide impacts of recovering bottomfish populations.

37.6 TWOMEY, Evan*; SUMMERS, Kyle; East Carolina University; *evan.twomey@gmail.com*

Sexual selection in the mimic poison frog Ranitomeya imitator

Understanding mechanisms that promote population divergence has been a central topic in evolutionary research and is key to our understanding of speciation and global biodiversity. In several examples of Müllerian mimicry, where two or more toxic species resemble each other, a single species is known to resemble more than one model species. This situation would seem to provide a good scenario for speciation: as populations diverge to resemble different models, both pre-mating and post-mating isolation could evolve. *Ranitomeya imitator* is a species of poison frog from central Peru which is involved in Müllerian mimicry with 4 other species of poison frogs. There are four primary mimetic morphs of R. imitator, each of which occurs in different geographical regions. We conducted mate choice experiments on four populations (representing two morphs) to determine whether frogs preferred to mate with their own morph. Furthermore, we designed the study in such a way as to test for reproductive character displacement, that is, whether strength of mate preference (if any) was increased in areas where these two morphs are sympatric. With the exception of one population, we were unable to detect significant mate preferences in *R. imitator*. Furthermore, there was no evidence that the strength of preference was enhanced where these morphs were sympatric. Current research is focused on testing mating preferences on additional color morphs, and using alternative methods for measuring mating preferences.

S7-1.3 TYTELL, E.D.*; HSU, C.-Y.; COHEN, A.H.; WILLIAMS, T.L.; FAUCI, L.J.; Johns Hopkins Univ., Feng Chia Univ., Univ. of Maryland, College Park, Princeton Univ., Tulane Univ.; *tytell@jhu.edu*

Neuromechanical phase lags in swimming lampreys

When fish swim, they bend their bodies in a traveling mechanical wave that moves from head to tail. At the same time, they activate blocks of muscle successively, resulting in a wave of neural activity that moves down the body. The two waves do not usually move at the same speed, though, meaning that muscle activity and bending are relatively in phase rostrally, but grow increasingly out of phase caudally. The result of this neuromechanical phase lag is that when caudal muscle is active, it is overpowered by external fluid forces so that the muscle is lengthened and absorbs energy. Although this effect appears at first glance to be inefficient, it may actually facilitate swimming by stiffening the tail region against the fluid, resulting in a better transmission of force from the body into the wake. We developed a computational model of swimming lamprey in which a flexible body was fully coupled to the fluid environment, so that the body deformed in response to both internal muscular forces and external fluid forces. We found that such a model, with no sensory feedback, could develop a neuromechanical phase lag similar to that observed in fishes when the internal forces were relatively weak compared to the fluid forces. Models with a relatively large neuromechanical phase lag had a lower cost of transport at a steady speed, supporting the idea that the phase lag facilitates effective force transmission during steady swimming. However, our results were strongly dependent on the frequency of the swimming pattern, while fishes have been observed to maintain the phase lag over a wide range of frequencies. Therefore, we conjecture that neural feedback may be required to maintain a phase lag over the range of swimming frequencies.

120.6 UEDA, N.*; DEGNAN, S.M.; The University of Queensland; *nobuo.ueda@uqconnect.edu.au*

Nitric oxide as a regulator of marine invertebrate metamorphosis: behavioural and molecular insights

The nitric oxide (NO) signalling pathway plays multiple roles in biological systems, one of which appears to be regulation of the initiation of larval settlement and metamorphosis in diverse marine invertebrates. For several species representing divergent animal phyla, it has been experimentally demonstrated that reducing endogenous NO in larva via chemical inhibition of nitric oxide synthase (NOS) results in the induction of settlement and metamorphosis. These results, together with the antiquity and conservation of the NO signalling pathway, has led to the hypothesis that NO may be a universal negative regulator of marine invertebrate metamorphosis across the metazoa. We have tested this hypothesis in three tropical, southern hemisphere animals that represent three divergent animal phyla, and provide the first evidence of a contrasting role for NO in marine invertebrate metamorphosis – as a positive, rather than a negative, regulator. In each of our three taxa - a demosponge, a vetigastropod, and a solitary ascidian - the chemical application of NOS inhibitors resulted in repression of larval metamorphosis. Consistent with this, chemical application of an exogenous NOS donor alone was sufficient to induce metamorphosis of the sponge and ascidian larvae. We complement these settlement behaviour experiments by assaying both temporal (by quantitative RT-PCR) and spatial (by whole mount in situ hybridisation) expression of the NOS gene through larval competency and settlement. Our molecular data provides insights into the way in which chemoreception of environmental signals deriving from suitable benthic settlement substrates are mediated by the NO pathway to regulate metamorphosis in diverse marine invertebrates.

73.4 UHRIG, E.J.*; LEMASTER, M.P.; MASON, R.T.; Oregon State University, Corvallis, Western Oregon University, Monmouth; *uhrige@science.oregonstate.edu*

Chemical Ecology of the Red-spotted Garter Snake, Thamnophis sirtalis concinnus

To date, most studies of garter snake chemical ecology have focused on the female sexual attractiveness pheromone of the red-sided garter snake (*Thamnophis sirtalis parietalis*). This pheromone, identified as a series of methyl ketones sequestered within the skin lipids of females, elicits male reproductive behaviors during the breeding season. In the current study, we demonstrate that female skin lipids of another *Thamnophis sirtalis* subspecies, the red-spotted garter snake (*T. s. concinnus*), contain methyl ketones similar to those produced by red-sided garter snakes. The ability of male red-spotted garter snakes to detect and follow trails composed of isolated female methyl ketones is further evidence that the reproductive role of these compounds is not limited to the red-sided garter snake system. Comparisons of red-spotted and red-sided garter snake pheromone profiles indicate that the relative concentrations of individual methyl ketones differ between subspecies. This variation, however, is apparently not great enough to preclude inter-subspecific courtship behavior. We also examine whether the red-spotted garter snake pheromone exhibits annual variation or, as occurs in red-sided garter snakes, variation based on female body size. Comparing the chemical ecology of these two subspecies, the red-spotted garter snake and the red-sided garter snake, is of particular interest as they have somewhat disparate life histories despite their close phylogenetic relationship.

98.3 USHERWOOD, JR; The Royal Veterinary College; *jusherwood@rvc.ac.uk*

Free-flight dynamics of peregrine and pigeon – predator and prey.

Newly developed GPS and inertial loggers record high rate and quality in a small package. This allows direct measurements of free flight and flock dynamics in birds down to the size of pigeons. Findings from a flock of 18 racing pigeons, and from a male and female peregrine, demonstrate contrasting aerodynamic strategies between predator and prey. FAST-FLYING pigeons make flapping turns at up to 2g, banking, yawing and pitching consistent with aerodynamic optimality. In response to the resulting increase in effective weight, they increase flap frequency (from 7 to 9Hz) but reduce flap amplitude (from 1cm down to 0.5cm). This is not expected from purely muscle power considerations, and indicates a shifting compromise between flapping with high aerodynamic efficiency (high frequency, low amplitude) and low inertial power (low frequency). When flying near neighboring birds, pigeons increase flap rate (by around 0.1Hz), suggesting an energetic cost to flying within a flock. PEREGRINES are well known for their speed. However, they appear incapable of prolonged ascending flight in still air, and are largely reliant on harvesting energy from the environment. In the cases studied here, this consisted of either slope-soaring or being carried by the handler up a 42m tower. Vertical stoops initiated from the top of the tower began with flapping downward acceleration, and a non-flapping pull-out at 5g; maximum speeds for these stoops only got up to 22m/s – achievable in level flight by racing pigeons. However, peregrines can use height as an effective energy store: free-fall increases kinetic energy at 50 W/kg – a rate close to the maximum for a pigeon powering flight directly through muscles – after only 0.5s, or 1.25m. THE SUCCESS of peregrines as predators of pigeons may thus be attributed to aerodynamic cunning during ascent, and gravity-powered acceleration during descent. Racing pigeons are, however, very much more impressive athletes.

42.3 VAN BREUGEL, Floris*; DICKINSON, Michael; California Institute of Technology, University of Washington; *floris@caltech.edu*

Flight Decisions: Target Orientation, Landing, and Obstacle Avoidance in Fruit Flies

Landing behavior is one of the most critical, yet least studied, aspects of insect flight behavior. In order to safely land, an insect must recognize a visual feature, navigate towards it, decelerate, and extend its legs in preparation for touchdown. Although previous studies have focused on the visual stimuli that trigger these different components – relying extensively on tethered preparation - none have been able to characterize the full sequence of landing behavior in freely flying insects. By using a real-time 3D tracking system in conjunction with high speed video recordings, we were able to study landing behavior in freely flying *Drosophila* from the moment they first recognized a visual target to the point of touchdown. This analysis was made possible by a custom-built feedback system that actively maintained the fly in the focus of the high speed camera. The results suggest that landing is comprised of three distinct behaviors. First, the flies actively turn towards the target via directed body saccades. Next, the flies begins to decelerate is at a point determined by the rate and extent of retinal expansion. Finally, they extend their legs when the visual target reaches a threshold retinal size of approximately 60 deg. Non-landing flies also actively turn towards the target until the retinal size of approximately 30 deg is reached, at which point they make a directed evasive saccade away from the target. Collectively, the results provide insight into the organization of sensory motor modules that underlie landing behavior in insects.

61.2 VAN SANT, M.J.*; HAMMOND, K.A.; Univ. of California, Riverside; *mvans001@ucr.edu*

Limits of the blood oxygen carrying capacity in the deer mouse, Peromyscus maniculatus

Animals have evolved physiological systems capable of dealing with certain loads experienced in nature. It has often been shown to be beneficial for an animal to have physiological systems with an "excess capacity" for dealing with higher loads that may be encountered due to natural variation in the load. It is not known exactly how costly it is to have excess capacities; however, if the cost is low and the benefit is high we should find physiological systems with excess capacities. During exercise, respiration and heart rate increase in an effort to deliver oxygen to muscles at a faster rate. Although previous work has shown a large surplus of pulmonary diffusive capacity in some mammals, VO_2max sets an upper limit to the exercise intensity that can be maintained for prolonged periods and has therefore presumably been a target of natural selection. If lung capacity is not limiting, we asked if, perhaps, blood oxygen carrying capacity was a limit to further increases in exercise performance. As exercise intensity increases, the amount of oxygen consumed and delivered to tissues increases; however, the blood never completely releases all of its oxygen. As an initial effort to understand limits to blood oxygen carrying capacity during intense activity, we measured VO_2max of deer mice before and after taking blood. We found that after removal of 10-20% of blood volume (typical for blood chemistry) VO_2max declines by up to 12%. Immediately following blood loss the blood volume can be replaced (by water), but it takes over a week to recover the lost red blood cells and VO_2max. From these data we can estimate the excess carrying capacity of oxygen in the deer mouse. We also provide a note of caution on measuring performance too soon after blood measurements.

94.5 VAN WASSENBERGH, S.; Univ. Antwerpen, Antwerpen; *sam.vanwassenbergh@ua.ac.be*

Three-dimensional model of force transmission in the suction feeding system of seahorses

Seahorses and other sygnathid fishes rely on a quick increase in the volume of the snout to suck prey into the mouth. This volume increase is observed as snout widening due to abduction of the suspensoria, the bones outlining the lateral sides of the snout. However, in contrast to other fishes, the start of suction is postponed until completion of the dorsal rotation of the neurocranium, a movement that brings the mouth close to the prey. In addition, the hyoid, which is generally considered the most important transmitter of force to the suspensoria in fish, rotates over more than 90 degrees in the sagittal plane during feeding in seahorses. This is considerably higher than what's observed in all other suction feeders studied so far. To explain how seahorses abduct the suspensoria, we performed mathematical simulations with a model of force transmission via the hyoid and lower jaw. This analysis was based on three-dimensional reconstructions of the anatomy of the feeding system of the long-snout seahorse *Hippocampus reidi*, together with high-speed video data on hyoid and lower jaw rotation during prey capture in this species. Our results show an important role for the inclined orientation of the hinge joint between the left and right ceratohyals, and suggest that force transmission also occurs via the lower jaw to produce suction in seahorses. The function of the peculiar arrangement of the three separate connections between the hyoid and the lower jaw in this process will be discussed as well.

54.1 VANDENBROOKS, John M. *; MUNOZ, Elyse E.; WEED, Michael D; HARRISON, Jon F.; Arizona State University, Penn State University; *jvandenb@asu.edu*

Developmental and fossil evidence that changes in atmospheric oxygen drove historical patterns in insect body size

Recent geochemical models predict that over the last 500 million years atmospheric oxygen has varied from 12% to 31%. The major rise in oxygen during the late Paleozoic has been correlated with the evolution of insect gigantism. However, the correlation between oxygen and insect body size has never been rigorously tested and not all groups of insects exhibit gigantism. We've carried out a unique combination of modern rearing and fossil studies to test this link. The results of our fossil studies support the oxygen-size link: 1) the maximal and average size of *Protodonata* and *Paleodictyoptera* fossils correlate positively with modeled atmospheric oxygen, 2) *Blattodea* fossils showed little variation in maximum size, but average size was correlated with atmospheric oxygen, and 3) the giant arthropods, such as *Arthropleura* , are outliers to an overall pattern of oxygen-mediated body size change. Given the variation in responses of modern insects to oxygen, our rearing studies have focused on groups related to Paleozoic insects – dragonflies, related to the giant *Protodanta* and cockroaches, a group with no known giant fossils. The results were that: 1) dragonflies grew larger in hyperoxia and smaller in hypoxia, 2) cockroaches showed only a mild effect of hyperoxia on size, while hypoxia reduced size, 3) development, growth, and fecundity of the cockroaches were affected by oxygen and 4) cockroach tracheal volumes were inversely proportional to rearing oxygen. These results show that Paleozoic oxygen could have influenced insect size, physiology and fitness, even in groups that exhibit no gigantism, strengthening the link between oxygen and insect evolution. Supported by NSF EAR 0746352.

37.4 VANHOOYDONCK, B*; HERREL, A; University of Antwerp, Antwerop, Belgium, National Museum of Natural History, Paris, France; *bieke.vanhooydonck@ua.ac.be*

The growing dewlap - comparing growth trajectories in sexually and naturally selected traits in male and female Anolis baracoae

Anolis lizards are characterized by an extendable throat fan, called a dewlap. Dewlaps vary greatly in size, shape, pattern and colour among species and among populations. In addition, the degree of sexual dimorphism in dewlap traits varies, with some species being highly dimorphic whereas in some, males and females do not differ greatly. The dewlap has been suggested to serve multiple purposes, including courtship, territorial interactions, species recognition and predator deterrence. In this study, we aim to understand how the dewlap grows and whether growth differs between the sexes in *Anolis baracoae*, a crown-giant from Cuba. In addition, we compare the growth trajectory of the dewlap with other aspects of morphology (i.e. SVL, head and limb dimensions) typically considered to be relevant in a natural selection context. To do so, we raised 23 *A. baracoae* individuals (Nmales = 14, Nfemales = 9) under identical conditions in the lab. Dewlap size, SVL, head and limb of each individual were measured twelve times at set intervals over a total time period of 36 months. To estimate the growth curve of all traits for each individual, we fitted a cubic function using the repeated measurements of a particular morphological trait as dependent variable and age as independent variable. The parameters of this function differed significantly among traits and sexes, with the dewlap growing relatively faster than the other traits. Also, comparing the relative growth between males and females showed that dewlap size increases at a greater rate in males, with growth curves starting to diverge around the age of 8 months. Growth curves of head and limb dimensions, on the contrary, did not differ between the sexes.

3.7 VAUGHN, D. *; TURNROSS, O. ; CARRINGTON, E.; Univ. of Washington, Friday Harbor Laboratories, Univ. of California, Santa Barbara; *dvaughn@u.washington.edu*
Effect of increased aerial temperature on sex-specific foraging and growth in rocky intertidal snails
Temperature influences species across a range of organizational scales – from individual performance to ecosystem function. Effects of global climate change, including elevated temperatures and increased frequency of extreme climatic events, are predicted to measurably impact organisms at each of these scales. The consequence of temperature for individual performance is determined in part by an organism's physiology. For ectotherms, warmer temperatures may increase demand for energy by increasing metabolic rate, which may then reduce energy available for growth and reproduction. Given differences in reproductive physiology, temperature-related increases in metabolic demand may be experienced differently by males and females of a species. In this study we manipulated low-tide aerial temperature to test the predicted effects of climate change on sex-specific differences in foraging and growth in the intertidal predatory whelk, *Nucella ostrina*. Snails foraged periodically (every two weeks) and subjecting snails to either chronically or acutely elevated aerial temperatures did not alter the timing or magnitude of this pattern. However, despite a similar foraging pattern across treatments, a sex-specific difference in snail growth was pronounced; females exposed to chronic increases in temperature lost body mass over the month-long study. These results suggest differences in the thermal tolerance of male and female *N. ostrina* that may reflect differential costs for the production of eggs and sperm. Moreover, these results suggest the importance of sex-specific differences that, if widespread, could have considerable consequences for species persistence in an increasingly warm world.

S3-1.3 VENDETTI, J. E. *; KRUG, P. J. ; California State Univ., Los Angeles; *jannvendetti@yahoo.com*
Origins of poecilogony and shifts in larval type in photosynthetic sea slugs: a phylogenetic perspective
The Sacoglossa are a clade of specialized algae-eating sea slugs, some of which retain functional chloroplasts in their own tissues for weeks to months. As larvae, sacoglossans vary in developmental mode with many producing lecithotrophic larvae with a brief planktonic period or lecithotrophs that metamorphose before hatching. Larvae can also be planktotrophic and several species are poecilogonous. Interestingly, some taxa make additional maternal investments of nutrient-rich extra-capsular yolk (ECY) to their egg capsules, which influences larval size, independently of egg size. Because of these life-history characters, we have developed the sacoglossa as a model system for studying developmental transitions in molluscs, and specifically to identify factors that favor the evolution of lecithotrophy within or among species. To resolve whether lecithotrophy increases rates of cladogenesis or, alternatively, evolves often and independently, we present a molecular phylogeny of 155 sacoglossan species (of 400 known) based on four genes. Bayesian ancestral character state reconstructions reveal five independent origins of poecilogony and at least 24 origins of lecithotrophy. Bayesian support for correlated models of trait evolution indicates that increased maternal investment in ECY biases a lineage towards evolving lecithotrophy at higher rates. Notably, ECY is the first trait associated with developmental transitions in any invertebrate, which suggests that high levels of per-offspring investment may favor evolutionary shifts in larval type. However, only two of five poecilogonous species have ECY, signifying the likely role of ecological factors in the rapid evolution of lecithotrophy in this clade.

16.3 VERVUST, B; HUYGHE, K; VANHOOYDONCK, B; HERREL, A; BACKELJAU, T; VAN DAMME, R*; Univ. of Antwerp, Belgium, MusÃ©um National d'Histoire Naturelle, Paris, Royal Belgian Institute of Natural Sciences, Brussel; *raoul.vandamme@ua.ac.be*
Rapid divergence in morphology, physiology and behaviour among island populations of lizards
Insular populations often differ considerably in morphology and behavior from related populations on the mainland, and even from populations on similar islands nearby. Although the distinctiveness of insular populations has prompted much evolutionary and ecological research, how, why and how fast populations diverge remains poorly known. In this study, we followed up on an historical transplant experiment involving the introduction of ten specimens of the lizard *Podarcis siculus* from one small island in the Adriatic Sea to another, 5 kilometers further. The introduction succeeded, the offspring of the introduced lizards replacing a native population of the related species *P. melisellensis*. After 35 years, the newly founded population has diverged from the source populations in aspects of its morphology (size and shape), physiological performance (sprint speed, endurance, digestive abilities), and behavior (aggressiveness towards conspecifics). We have evidence that at least some of these changes can be considered adaptive responses to change in predator pressure and food availability.

46.2 VIEYRA, M.L.*; GILMORE, J.A.; University of South Carolina Aiken, University of Texas Austin; *michellev@usca.edu*
Involving underrepresented groups in undergraduate research: A case for required participation
Minorities and women are historically underrepresented in the sciences. Studies have shown that students who participate in undergraduate research are more likely to be retained in science. Underrepresented groups are less likely to participate in research so requiring undergraduate research as part of a degree program may be a viable means for engaging these students. USC Aiken requires all biology majors to conduct one semester of research. Students may also elect to participate in additional semesters of research. Biology freshman were asked to comment on the research requirement. Overall, a higher percentage of males indicated that they would elect to participate in independent research and had more favorable opinions of research as compared to the female students. 43% of Caucasian females said they would elect to participate in research and 70% had favorable opinions of research while 28% of minority females said they would conduct research and 39% had favorable opinions of research. Of the students who had favorable views of research but who would not independently participate, all were female or a minority. Alumni of the program were also surveyed. All of the Caucasian students indicated that they would have considered participating in research but only 20% of the African American students said that they would have participated if it had not been required. A review of actual research participation supports this. Only 9% of African American graduates since 2007 participated in research for longer than the required semester while 49% of the Caucasian students participated in two or more semesters of research. All of the alumni reported that their research experiences were worthwhile and fostered further interest in science. Several African American students cited their research experience as helping them decide to go to graduate school.

38.4 VITOUSEK, Maren N.*; STEWART, Rosemary A.; SAFRAN, Rebecca J.; University of Colorado, Boulder, Indiana University; *maren.vitousek@colorado.edu*

Signal color drives seasonal oxidative stress and testosterone profiles in a songbird.

Social interactions are commonly mediated by morphological signals. To present reliable information, signals should reflect an individual's ability to physiologically cope with challenges, both social and ecological. However, it is unclear how static morphological signals convey accurate information about dynamic physiological parameters. Here we report that the seasonal physiological profile of female barn swallows, *Hirundo rustica*, is driven by static signal expression. Females manipulated to display darker ventral plumage decreased oxidative stress, reactive oxygen metabolites, and testosterone, thereby adopting the physiological profile of naturally darker individuals. Signal-hormone relationships in females were opposite those documented in males, suggesting that the same trait conveys different information in the sexes. Direct causal links between signal trait expression and physiology represent a novel mechanism that continually maintains the information content of static signal traits.

25.1 VOLKENBORN, N*; CHENNU, A; MATSUI, GYM; POLERECKY, L; WETHEY, DS; WOODIN, SA; University of South Carolina, Columbia, Max Planck for Marine Microbiology, Germany; *nils@biol.sc.edu*

Bioirrigation revisited: Infaunal hydraulic activities and porewater advection in marine sediments

Marine sandy sediments, which cover the largest part of the Earth, are a mixture of sediment particles and interstitial porewater with a volumetric ratio of approximately 1:1. Over the last years we have documented substantial movement of porewater into, through, and out of the sediment due to hydraulic activities of various infaunal polychaete, bivalve and crustacean species. The magnitude and spatial extent of the biologically induced dynamic porewater pressure gradients are governed by the sediment's resistance to interstitial porewater flow, i.e., hydraulic conductivity (or permeability). In this talk we will present new insights into a range of physical aspects related to a life in porous media with permeabilities varying by 3-4 orders of magnitude. Based on porewater pressure time-series with live animals and artificial irrigation systems, and using oxygen as a reactive tracer for porewater transport, we show that many infaunal organisms are capable of increasing the local hydraulic conductivity of the sediment by means of hydraulic cracking. The formation of sedimentary cracks results in (i) a reduction of the energetic investment for ventilation/feeding on the individual level, and (ii) an extension of the suitable habitat towards low permeability muddy sand on the population level. Moreover, such biologically created "highways" of porewater transport may be one reason for the well-documented enormous small-scale variability of many benthic ecosystem functions, such as benthic productivity, organic mineralization, infaunal interactions and recruitment.

17.4 VOLTZOW, J.; Univ. of Scranton; *voltzowj2@scranton.edu*

Peeping through the keyhole: Endoscopy of a gastropod mantle cavity

The gastropod mantle cavity serves as the site of gas exchange, waste management, and gamete dispersal. The principle organs of the mantle cavity, the gills or ctenidia, drive the flow of water through the cavity and thus control these exchanges. Because the cavity is housed within the body whorl of the shell, it has been difficult to view the mantle cavity, and especially the gills, under normal functioning conditions. I used a mini boroscope (a type of endoscope) to peer inside the mantle cavities of living individuals of the keyhole limpet *Diodora aspera*. Video recordings indicate that the gills are inflated and fill the visible volume of the mantle cavity. When disturbed, individual leaflets can contract but quickly recover their original inflated positions. The restricted spacing between leaflets appears to correspond to the minimum space required for ciliary and water movements, maximizing the output of flow through the gill. Flow between the leaflets is extremely laminar; excurrent streams marked with dye maintain their integrity well beyond the apical opening of the shell and away from the mantle cavity.

6.7 VON BUSSE, J.R.S.*; SWARTZ, S.M.; BREUER, K.S.; HEDENSTRÖM, A.; WINTER, Y.; VOIGT, C.C.; Brown University, Providence, RI, Lund University, Sweden, Humoldt University, Berlin, Germany, Leibnitz Institute, Berlin, Germany; *rhea_vonbusse@brown.edu*

Energetics of Bat Flight

The goal of this study is to directly test the U-shaped flight velocity - power curve predicted by aerodynamic theory for the first time in bats. We carried out this test by measuring energy expenditure during flight in a wind tunnel over a broad range of flight speeds. We employed two experimental methods: we used open flow respirometry to measure oxygen consumption of *Leptonycteris yerbabuenae* flying from hovering to seven m/s, and used the sodium bicarbonate method, spectrometry of a labeled carbon isotope incorporated into expired carbon dioxide, for *Carollia perspicillata* flying from one to seven m/s. Both study species are nectar feeders that metabolize sugar almost exclusively, which allows for accurate conversion of oxygen consumption into metabolic energy. By comparing aerodynamic power output and metabolic power input, it is possible to estimate mechanical efficiency of flight. Because the power requirement for level forward flight equals speed times total drag, mechanical power output can be estimated from drag measurements. We made these assessments from aerodynamic measurements using stereo digital particle image velocimetry (SDPIV). We found that metabolic rate measured by open flow respirometry did not change significantly over the speed range. The sodium bicarbonate experiments demonstrate that most animals show strong velocity dependence in metabolic expenditure for flight. However, some individuals did not conform to this pattern, and employ different energetic strategies with changing flight speeds. Mechanical efficiency measured for *Leptonycteris yerbabuenae* follows a U-shaped curve, with values between 18 and 23%.

13.5 VON DASSOW, M*; DAVIDSON, LA; Univ. of Pittsburgh; *mvondass@gmail.com*

Does temperature dependence of morphogenesis require fine control of tissue mechanics?

Understanding morphogenesis requires deciphering how organisms withstand environmental perturbations. Environmental temperature strongly affects developmental rates but previous studies suggest that temperature does not affect the relative timing of developmental stages. Rates of morphogenetic movements should depend on both the viscoelastic properties of the embryo and the timing and magnitude of the driving forces. A simple model based on these conditions suggests tight constraints on how tissue mechanics should change with temperature to allow normal morphogenesis. We tested this model in gastrulating *Xenopus laevis* embryos, using micro-aspiration and electrically stimulated contractions. Tissue viscoelasticity was independent of temperature, consistent with our model when formulated for power-law time-dependence of compliance. Changes in contraction kinematics (~2.4-fold increase in speed from 16 to 26°C) appear similar to changes in whole embryo morphogenetic rates (2- to 3-fold increase). However, contraction magnitudes were ~40% smaller at high temperature than at low temperature, contrary to predictions. When investigated at a fine scale, temperature caused heterochronic shifts in morphogenesis. As temperature rose, the speed of blastopore closure increased more slowly than the speed of dorsal-to-ventral progression of involution. While there was only a ~25% shift from 16 to 26°C, this invalidates an assumption of our model. We conclude that the ability of morphogenetic rates to vary by more than three-fold with temperature depends on tolerance of variation in morphogenetic movements, rather than on fine control of tissue mechanics. The viscoelasticity of the tissue and the time-dependence of morphogenetic forces may account for the observed heterochronic shifts.

5.1 VON DASSOW, Y.J.; Duke University, NC; *yasmin.vondassow@duke.edu*

Benthic baby snatchers: predation on marine invertebrate embryos inside gelatinous egg masses

A common reproductive strategy for marine invertebrates involves the packaging of embryos into benthically-deposited egg structures. Some of these structures take the form of gelatinous masses with embryos embedded inside. The energetic costs of egg mass production suggest associated benefits, one of which may be protection of embryos from predation. Here, I examine two cases in which gelatinous masses fail to provide protection for embryos, and are in fact specifically targeted by predators. In one case, embryos of maldanid polychaetes are eaten directly out of the gel by the prosobranch gastropod *Nassarius vibex*. In the other case, the opisthobranch gastropod *Olea hansineensis* eats embryos of other sea slugs directly out of their masses. In both cases, individual embryos are consumed whole while the gel matrix is left largely intact, and the predators appear to prefer younger embryos. Surprisingly, neither predator eats embryos that have been removed from the egg mass. Thus, I hypothesize that chemical cues attracting the predators originate in both the gel and the embryos.

3.4 VORHEES, Ashley*; GRAY, Emilie; BRADLEY, Timothy; University of California, Irvine; *avorhees@uci.edu*

Comparison of upper thermal limits among geographically-distributed populations of the mosquito, Culex tarsalis

Thermal limits to activity play a central role in determining the abundance and geographic distribution of ecothermic animals. Therefore, understanding variation in thermal limits will be highly important for predicting species-level responses to climate change. While a variety of studies have examined large-scale patterns in thermal traits over geographic ranges, studies examining geographic variation in thermal tolerance limits within a single species are quite limited. To address this, we investigated the upper thermal limits of a widely distributed mosquito species, *Culex tarsalis*, across a climatic gradient. Our aim was to determine how the critical thermal maximum (CTMax) and metabolic rate vary with climate by comparing mosquitoes collected from several different sites. We captured and tested adult female *C. tarsalis* mosquitoes from three sites within California: 1) the northwest shore of the Salton Sea (Coachella, CA), 2) the San Joaquin Marsh Reserve (Irvine, CA), and the Sierra Nevada Aquatic Research Lab (Mammoth Lakes, CA). We determined the CTMax of individual mosquitoes using thermolimit respirometry, in which CO_2 release was measured from each animal as temperature increased, and CTMax was identified as the point of respiratory failure. Metabolic rate was measured using flow-through respirometry at 13, 23, and 33ºC. Our results showed that both CTMax and metabolic rate differed significantly among *C. tarsalis* from these different sites. Both variables appear to track environmental conditions, with CTMax being highest in mosquitoes from warm sites and metabolic rate being highest in mosquitoes from cold sites. These results contribute to our understanding of how certain traits can allow a widespread species such as *C. tarsalis* to inhabit such a wide variety of thermal environments.

S5-1.2 VORIS, Harold K.; Field Museum of Natural History, Chicago; *hvoris@fieldmuseum.org*

How a Dynamic Climate and Landscape in Southeast Asia During the Neogene Directed the Evolution and Diversification of Marine Snakes

The Sunda and Sahul continental shelves are the second and third largest on our planet and they are at the center of the present day geographic distribution of both the sea kraits and the true sea snakes. The biogeographic importance of sea-level fluctuations during and after the LGM has been cited by many authors, with an emphasis on the maximum land exposure. However, recent work has drawn attention to other less obvious consequences of sea-level changes. Terrestrial and marine ecosystems across these shelves were relentlessly reshaped throughout the Neogene. The biogeographic implications of retreating or inundating sea levels are far reaching as they simultaneously create and destroy terrestrial and marine habitat which in turn creates bridges and barriers to dispersal. Of primary importance are several interrelated physical factors including the extent or amplitude of sea-level change, the rate of sea-level change, the direction of change, grade or bathymetry of the bridge or seaway, the extent (area) of bridge or seaway produced, the duration of the bridge or seaway, the orientation of the bridge or seaway, and the regional climatic conditions resulting from the new configuration. The influence of these factors on the evolution and ecology of marine snakes are explored.

36.5 VRANA, P.B.; University of South Carolina;
VRANAP@mailbox.sc.edu

Disruption of Developmental & Epigenetic Programs in Peromyscus Hybrids

We use North American rodents of the genus Peromyscus (deer mice) to study the effects of natural genetic variation on epigenetic regulation and development. The P. maniculatus species complex is particularly widespread and varied, consisting of a series of partially reproductively isolated populations. For example, crosses between P. maniculatus (BW), and P. polionotus (PO), produce dramatic parent-of-origin effects on growth and development. BW females mated to PO males (bw x po) results in growth-retarded offspring but apparently healthy offspring. In contrast, PO females mated to BW males (PO x BW) produce overgrown but severely dysmorphic conceptuses. The rare PO x BW litters which reach parturition harbor fatal defects (e.g. hemorrhaging) and/or are unable to pass through the birth canal, resulting in maternal lethality. The placenta is particularly affected in both cases; ~ 10% of PO x BW conceptuses consist only of extra-embryonic tissues. BrdU and TUNEL studies show that both proliferation and cell death are altered. Expression of imprinted genes and DNA methylation at associated regulatory regions is perturbed in the PO x BW hybrids. Studies on the etiology of the placental phenotypes indicate lineage misallocation. For example, expression of Cdx2, a trophoblast stem cell marker, drops over time in PO x BW placentas (relative to parental strains and bw x po hybrids). At the same time, the PO x BW placentas re-express the pluripotency marker Oct4 at high levels. Thus both differentiation and stem cell numbers and/or maintenance appear compromised. Nascent analysis of comparative transcriptome data will also be discussed; among these are species differences in expression of apoptosis-related loci.

111.4 WADA, H; NEWMAN, AEM; HALL, Z; SOMA, KK; MACDOUGALL-SHACKLETON, SA*; Univ Western Ontario, Univ Guelph, Univ British Columbia; *smacdou2@uwo.ca*

Effects of corticosterone and dehydroepiandrosterone on adult neuroplasticity in songbirds

Chronically elevated glucocorticoids can impair brain development and reduce adult neurogenesis. In songbirds, the brain region HVC, which is critical for song learning and production, is particularly sensitive to glucocorticoids. For example, stressors during development impair HVC growth. In addition, in adult nonbreeding song sparrows,corticosterone (CORT) treatment reduces HVC size, the number of neurons in HVC, and the number of newly incorporated BrdU-labeled cells in HVC. Interestingly, these effects of CORT on HVC were prevented by co-administration of dehydroepiandrosterone (DHEA). CORT did not reduce BrdU-labeled cell number in the telencephalon outside of HVC, or along the mitotic subventricular zone. Here, we tested whether CORT reduced neuron migration to HVC by immunolabeling tissue for doublecortin (DCX), a microtubule-associated protein expressed in migrating neurons. CORT treatment significantly reduced the numbers of DCX-labeled cells and fibres in HVC. However, DHEA treatment did not significantly increase DCX-labeled cells or fibres in HVC. These data suggest that the neurodegenerative effects of CORT on HVC are mediated by disrupting neuron migration, but that the neuroprotective effects of DHEA occur through other processes such as reducing apoptosis and/or promoting neuron survival.

114.3 WADA, H*; ALLEN, N.R.; KRIENGWATANA, B; SCHMIDT, K.L.; SOMA, K.K.; MACDOUGALL-SHACKLETON, S.A.; Univ. Western Ontario, Univ. British Columbia;
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Long-term consequences of incubation temperature on offspring physiology and survival in zebra finches

The developmental environment plays an important role in shaping offspring phenotype. In birds, the developmental environment is strongly influenced by parental behavior. Because virtually all birds incubate their eggs, differences in incubation behavior affects incubation temperature, which may give rise to variation in offspring phenotype. Recent studies in songbirds and waterfowl showed that prenatal temperature manipulations influence corticosterone response and immune function in the hatchling/nestling stage. However, little is known about whether such temperature manipulations have long term effects into adulthood. Here we tested the effects of incubation temperature on survival, growth, body composition, immune function, and corticosterone response from nestling to adulthood in captive zebra finches. We artificially incubated eggs at control (37.4°C), low (36.2°C), or high (38.4°C) temperatures, and returned nestlings to the nest just after hatching. While the high temperature group had the lowest hatching success, the low temperature group had the lowest post-hatch survival. In addition, hatch weight was similar among treatment groups, but individuals in the high temperature group had delayed growth compared to individuals of other groups. Body fat content and lean mass were not affected by the temperature treatment. Finally, adrenocortical response to handling stress in females incubated at low temperatures tended to be higher than the rest, however this difference disappeared when they reached adulthood. These data suggest that small variations in incubation temperature not only affect offspring physiology but could also affect fitness of songbirds.

22.2 WAINWRIGHT, D/K*; KLEINTEICH, T; GORB, S/N; KLEINTEICH, A; SUMMERS, A/P; Duke University, University of Washington, Friday Harbor Marine Lab, University of Kiel, Germany; *dylan.wainwright@gmail.com*

These Dead Fish Really Suck: Adhesion performance of the Northern Clingfish

The Northern Clingfish, *Gobeisox maeandricus*, lives in the Pacific Northwest's rocky intertidal zone. Its pelvic fins and parts of the pectoral fins have been fused into a suction-cup-like structure that allows the fish to adhere to varied substrates. Our study compared the adhesive strengths of 22 clingfish and eight manufactured suction cups using eight surfaces of different roughness. All surfaces were made from the same material to control for variables besides roughness. Results show that freshly killed clingfish stuck to all surfaces, while manufactured suction cups were only able to adhere to the three smoothest surfaces. Furthermore, clingfish performance was lowest on the flat surface, with no other pattern observed in surfaces with any roughness. The fish adhered with an average of 39 kPa of adhesive stress or 180 times their body weight over all eight surfaces but suction cups adhered with ~70% more force than clingfish on the three smoothest surfaces. While these results make functional sense, they do not fit with what we know about suction adhesion's poor performance on rough surfaces. Scanning electron microscopy shows the presence of 0.3 micrometer diameter hair-like structures on the cling. These hairs, or microvilli, allow the generation of Van der Waals forces and enhance the fish's adhesion to rough surfaces. Van der Waals forces would increase friction of the cling, providing resistance to slipping and buckling, while microvilli would also increase the sealing ability of the suction disc by conforming to uneven substrates.

50.6 WAKELING, S.R.*; SANTANA, F.E.; CLARK, R.W.; Univ. of Nevada, Reno , San Diego State Univ. ;
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Tadpole Photo Mark-Recapture in critically endangered Rana Muscosa

Tadpole abundance and detection are important factors for wildlife professionals to consider when estimating population sizes and making management decisions. Tadpole detection by surveyors is often low which makes estimating abundance difficult. A photo mark-recapture survey was conducted on tadpoles of the critically endangered mountain yellow-legged frog (MYLF), *Rana muscosa*. This survey aimed to determine abundance and survival estimates of tadpoles within a healthy population. Spot pattern characteristics were assessed on captive tadpoles over several weeks. Each tadpole's pattern was found to be unique enough for re-identification, and patterns were retained over a time period similar to the duration of completion of the stream surveys. Over four sampling events there were 723 captures, 52 of those were recaptures, and a total of 671 individual tadpoles were captured. This work shows photo mark-recapture is possible in MYLF tadpoles, and it may prove to be an important tool in understanding the population dynamics of amphibians.

106.2 WALDROP, LD; Univ. of California, Berkeley;
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Fluid dynamics of antennule flicking of the terrestrial hermit crab, Coenobita rugosus (Decapoda: Anomura)

Many marine decapod crustaceans sense chemical signals (odors) in their surroundings to find food and mates using first antennae (antennules) which bear arrays of chemosensory hairs (aesthetascs). The fluid dynamics of discrete odor sampling are well studied in several marine species (spiny lobster, blue crab, Oregon shore crab), but odor-sampling fluid dynamics are unstudied in their air-dwelling relatives the coenobitid hermit crabs, which live their entire adult lives on land. Despite an evolutionary shift from sea to land which dramatically changes the fluid environment in which olfaction occurs, terrestrial hermit crabs retain many features of marine crabs including aesthetasc-bearing antennules. Compared to marine crabs, the antennules of terrestrial hermit crabs are heavily modified, having arrays of short, leaf-like aesthetascs that partially overlap. Terrestrial hermit crabs also move their antennules back and forth in a motion similar to the antennule movement of marine crabs. To investigate how this evolutionary transition affected the fluid dynamics of antennule flicking, I examined the kinematics of antennule flicking by filming hermit crabs (Coenobita rugosus) and the antennule morphometrics by collecting their antennules for scanning electron microscopy. Using these data, a dynamically scaled physical model of the antennule was constructed, and particle image velocimetry (PIV) was used to measure fluid flow around the model. PIV results indicate that although terrestrial hermit crabs have homologous antennule movements and morphological features with marine crabs, they do not discretely sample odors. Flicking by terrestrial hermit crabs could serve to increase the probability of encountering odors in turbulent air flow.

52.4 WALKER, SM*; TAYLOR, GK; University of Oxford, UK;
simon.walker@zoo.ox.ac.uk

The control of saccades in hoverflies

Saccades are fast turning manoeuvres, characteristic of dipteran flight. The wing kinematic parameters controlling these rapid turns have been investigated for several species, with changes in stroke amplitude and angle of attack being principal contributors to the generation of the required torques. However, the precise changes in wing kinematics that are used to control the duration and total angular displacement of saccades are not well known. We used high-speed digital video of free-flying hoverflies (*Eristalis tenax* and *Eristalis pertinax*) and automated tracking to reconstruct the body and wing kinematics of insects performing spontaneous saccades. We recorded more than 250 saccades, with angular displacements ranging from 10° to 115°. The total angular displacement is proportional to the maximum angular acceleration of the body, suggesting that *Eristalis* adjust the torque produced by asymmetries in the left and right wings to control turns rather than applying a constant torque and modulating its duration. We measured wing kinematic parameters, calculated separately on each downstroke and upstroke, and fitted them to an analytical model to test their association with the body’s angular accelerations. A range of kinematics parameters contribute to the control of saccades, with stroke amplitude and angle of attack being important, but also the timing of wing rotation and the stroke plane angle. During the second half of saccades, when the body decelerates, there is an asymmetry in the kinematics of the wings of opposite sign to that used in the first half of the turn. These reverse asymmetries are of similar magnitude to those used in the acceleration phase indicating that active production of a counter-torque is the main method used to terminate saccades, rather than a passive flapping counter-torque.

46.1 WALKER, SE*; MOON, HS; HOESE, WJ; BONSANGUE, MV; ZACHERL, DC; BURNAFORD, JL; READ, E; FILOWITZ, M; California State University, Fullerton; *swalker@fullerton.edu*

Supplemental Instruction and Student Success in an Introductory Biology Course

Improving student performance in introductory science and mathematics can lead to higher retention and graduation rates. We implemented a formal supplemental instruction (SI) program for the first course in the Biology major at California State University Fullerton starting in fall 2007. This course has the lowest pass rate of our introductory biology core classes, and even after successfully completing the course many students leave the major. Our SI program consists of one-hour sessions led by undergraduates who have done well in the course and apply to be in the program. The leaders undergo training and meet with the SI program coordinator weekly during the semester. Attendance is voluntary and students who come to a large percentage of SI sessions earn a small amount of extra credit (1 – 2 % of the total grade). We found that students attending SI scored higher on exams and were more likely to attain a C or greater in the course than non-attending students. To control for academic ability, High-School GPA or the student’s score on Lawson’s Classroom Test of Scientific Reasoning were used as covariates to analyze student performance. Taking these into account, there were still strong positive effects of SI attendance on performance. In addition, SI had strong positive effects on underrepresented minority students. Although we have not controlled for student engagement, our data suggest that SI is an effective way to improve student performance in introductory biology.

50.2 WALLING, KM; CARRERA, JV; CODY, JC; TAN, LT; CONNELLY, SJ*; Rochester Institute of Technology; *kmw9325@rit.edu*

The photoprotective properties of vitamin D in Daphnia spp.

Environmental variability significantly impacts the adaptations of natural populations. Increased levels of ultraviolet radiation (UVR) at earth's surface have been shown to have a wide range of effects on organisms, from no impact to lethality. Recent studies have shown benefits of vitamin D to individuals, primarily vertebrates, exposed to increased levels of solar radiation. *Daphnia* spp. are especially sensitive to environmental stressors, particularly UVR, and their rapid adaptation to these stressors is crucial. It is known that Vitamin D can increase the fitness (survival and reproduction) of *Daphnia* spp. This research focuses on the impact of UVR on freshwater microcrustacean, *Daphnia* spp., and the potential protective properties of vitamin D_3 in this genus. It is hypothesized that vitamin D_3, or its primary metabolite (25-hydroxyvitamin(OH)D_3,) will also have photoprotective properties in the *Daphnia*. Juvenile (pre-reproductive) *Daphnia* spp. were exposed to vitamin D_3 (0, 5, or 10mg / 100mL) and UV-A (320-400nm; 6.912 kJ/ m^2) for 72 hours, methanol extracted, and analyzed using High Performance Liquid Chromatography (HPLC) to quantify vitamin D_3 and 25(OH)D_3 in the *Daphnia*, the algae (*Selenastrum capricornutum*), and the freshwater synthetic growth media. The quantity of vitamin D_3 and 25(OH)D_3 in the *Daphnia* were then correlated to their overall fitness (survival and total reproduction) in a separate experiment. Increased concentrations of vitamin D_3 directly correlate with increased survival of *Daphnia* spp. with UV-A exposure, but not clearly with reproduction. Studies continue to determine if other vitamin D_3 metabolites may play a greater role in the fitness of the *Daphnia* spp. with changes in UVR. Further, food web studies of various algae and *Daphnia* spp. are being investigated to determine the photosensitivity and photoprotective properties of the vitamin D_3 in natural systems.

S7-2.1 WANG, Jane; Cornell University; *jane.wang@cornell.edu*

Stability and Control of Flapping Flight

I will report our recent results on stability and control of 3D flapping flight, derived both from computational studies of dynamic models of insects as well as the analyses of experimental data of fruit flies. I will further discuss the implication of the intrinsically unstable mode on the control strategies for steady flight and for maneuver.

73.3 WANG, D.L.*; PAPAJ, D.R.; University of Arizona; *wangd88@gmail.com*

Color as a visual cue in the pipevine swallowtail, Battus philenor: Is hue or brightness more important?

Color is a key cue used by visually oriented animals. In plant-insect interactions, insects use color to locate flowers for nectar foraging and plants for host selection. However, the methodology of many color studies confounds three distinct properties of color: hue, brightness, and chroma. For example, individuals may prefer yellow over blue because of differences in brightness between the two colors and not necessarily because of differences in hue. In this study, we use LED technology to tease apart the roles of hue and brightness in innate floral color preference, color learning, and host selection by the pipevine swallowtail, *Battus philenor*.

S10-1.3 WARES, J.P.*; EWERS, C.; University of Georgia; *jpwares@uga.edu*

Genetic variation: are barnacles so strange?

Environmental heterogeneity, both spatial and temporal, is likely to leave indicators in the patterns of nucleotide variation across genomes. These patterns are often assessed with statistical tests that rely on assumptions about the mechanisms of natural selection, and the demographic processes that have shaped contemporary populations. Recent work has suggested that, for some parts of the genome at least, it is so typical for a population to deviate from the assumptions of the null hypothesis that we should re-evaluate how these tests are employed. Here, we focus on such patterns in available data sets from barnacles, which represent a taxon that exhibits the most extreme empirical deviation from the null expectation. We evaluate whether specimen curation in this group, which is well known for morphological plasticity and high numbers of cryptic species, is responsible for this deviation. Our results suggest that this is not an artifact of sampling or curation, but is likely to have important basis in the interaction between species and their environment.

60.3 WARNER, S E*; PICKERING, P; PANAGIOTOPOULOU, O; PFAU, T; REN, L; HUTCHINSON, J R; Royal Veterinary College, University of Manchester; *swarner@rvc.ac.uk*

Size-related biomechanical constraints on foot impacts in ungulate mammals.

Understanding the mechanics of foot impact and its relationship with animal size may improve our ability to detect, prevent and treat foot disease. Newtonian mechanical principles suggest that heavier animals have a larger effective foot mass (*Meff*); this may contribute to greater impact forces that could initiate impact injury. So, for example, how can a 3000kg elephant safely control ~150kg of foot mass with every step? We hypothesised that *Meff* is modulated to ensure impact forces remain fairly constant in ungulates of increasing size. Using standard force-platform (1000Hz; Kistler, 200Hz; AMTI) and motion capture (250Hz; Qualisys or AOS high speed camera) methods we measured limb kinematics and kinetics in eleven species ranging from 18kg (blackbuck antelope) to 3157kg (Asian elephant). As ungulates get heavier, the forefoot *Meff* exhibits surprisingly strong negative allometry at slow running speeds; conversely, the hindfoot *Meff* has at least weak positive allometry at walking speeds. Impact force amplitude scales with isometry and peak GRF scales with negative allometry at dynamically similar speeds. Curiously, increased *Meff* is not reflected in the impact force amplitude, which remains a fraction of the GRF peak. These mechanisms show how ungulates keep impact amplitude from becoming a more prevalent cause of impact injury.

17.5 WEBSTER, D.R.*; DELAVAN, S.K.; Georgia Institute of Technology, University of Canterbury; *dwebster@ce.gatech.edu*

Unsteadiness of Bivalve Clam Jet Flow According to Environmental Conditions and Predator Presence

This study attempts to determine the patterns and/or randomness of the excurrent velocity of actively feeding clams, *Mercenaria mercenaria*. We hypothesize that clams alter their feeding current velocity patterns or randomness according to external cues in the environment such as hydrodynamic characteristics, density of the clam patch, and presence of predators in the upstream flow. A PIV system measured vector fields for two-dimensional planes that bisect the clam excurrent siphons, and time records were extracted at the siphon exit position. Spectral, fractal, and lacunarity analysis of the jet velocity time records revealed that clams alter their jet excurrent velocity unsteadiness according to the horizontal crossflow velocity. The results also reveal that the effect of clam patch density on the feeding activity was dependent on the size of the organism. This size/density dependent relationship suggests that predation by blue crabs dominates the system since larger clams are no longer susceptible to blue crab predation, whereas clams of all sizes are susceptible to whelk predation. Finally, clams increase the randomness of their excurrent jet velocity values when predator cues are located in the upstream flume flow. This suggests that the presence of predators elicits clam behavior that promotes the mixing and dilution of their chemical metabolites.

78.5 WEGENER PARFREY, Laura*; KNIGHT, Rob; University of Colorado, University of Colorado, Howard Hughes Medical Institute; *lwparfrey@gmail.com*

Broad patterns in the diversity of eukaryotic microbes

Microbial organisms make up the majority of organismal diversity on our planet and play a major role in biogeochemical cycling. Here we use high-throughput sequencing technology to assess broad patterns in the distribution of eukaryotic microbes across major habitat types, including soils and host-associated sites. We assess the environmental factors that drive diversity patterns across habitats. These data enable testing of the hypothesis that salinity and association with vertebrate hosts are the major drivers of diversity patterns in eukaryotic microbes as they are in bacteria and archaea. These data are also combined with community sequence data for bacteria to assess patterns of co-occurrence among taxa and gain an initial window into multilevel trophic dynamics in microbial communities.

23.2 WEHRLE, B.A.*; ESPINOZA, R.E.; CSU Northridge; *beck.wehrle.367@my.csun.edu*

Why do lizards lounge? The role of social aggregations in exchanging microbial communities among hatchling Green Iguanas

Why sociality evolves is poorly understood, but both biotic and abiotic factors have been implicated. Sociality may have evolved in some herbivorous reptiles to foster the transfer of gut microbes. These endosymbionts are needed to digest plant fiber and their fermentation products can contribute substantially to their host's energy budget, but this symbiosis is poorly understood. Green iguanas (*Iguana iguana*) are herbivorous throughout life, yet hatch with sterile guts. So how do they acquire their gut microbes? Although rare in lizards, social interactions are a hypothesized route of microbe transfer via direct contact and/or eating feces of conspecifics. Early attempts (>30 years ago) to characterize this microbial community in hatchling iguanas provided crude measures of microbial turnover. Our study is the first to characterize the spatial, temporal, and social variation of these vital microbial communities using modern genomic techniques. We hypothesize that there will be microbial community variation more consistent with social transfer than individual variation. We observed and individually marked juvenile iguanas in social lounges at eight sites on and around Barro Colorado Island, Panama over two reproductive seasons. Of the 540 focal observations of hatchlings, 38% were of social aggregations (mean = 2.9 lizards/ group). Hatchlings in groups averaged 1.2 m from their nearest neighbor (range = 0–6 m), although densities varied among sites. We collected microbe samples from iguanas and their environments over the first 60 days post-hatching. Microbe-specific DNA will be isolated from samples and pyrosequenced to characterize the gut microbe communities of iguanas over space, time, and with respect to observed social interactions. We predict that microbial communities will be most similar among proximate hatchlings and will increase in diversity over time.

15.4 WEIHRAUCH, D.*; FEHSENFELD, S.; MARINI, A.-M.; ZIEGLER, A.; EDWARDS, S.; MEYER, H.; SIEBERS, D.; TOWLE, D. W.; Univ. of Manitoba, Universite Libre de Bruxelles, Univ. of Ulm, Appalachian State University, Univ. of OsnabrÃ¼ck, Alfred-Wegener-Institut f. Polar und Meersforschung, Mount Desert Island Biological Laboratory; *weihrauc@cc.umanitoba.ca*

Ammonia excretion in the green shore crab Carcinus maenas

The passion for crabs and their capabilities for osmoregulation and ammonia excretion brought us, David Towle, me and a number of collaborators together to explore how toxic ammonia is excreted in the branchial epithelium of the green shore crab *Carcinus maenas*. Here we summarize our published and unpublished findings on ammonia excretion mechanisms in *C. maenas*. Studies were performed on animals acclimated to full strength seawater (32 ppt S.) and brackish water (10 ppt S.). Interestingly, in either environment active ammonia excretion rates were significantly lower in the osmoregulatory active, mitochondria-rich posterior gills. An Rh-like ammonia transporter cloned from *C. maenas* gills was highly expressed in the gill epithelium, here with corresponding expression levels with regard to their actual ammonia transport rates. In contrast, expression levels were found to be very low in other tissues such as the antennal gland, hypodermis, hepatopancreas and heart muscle. Long term exposure to high environmental ammonia (HEA, 1 mM NH_4Cl) caused in anterior and posterior gills of crabs acclimated to both, sea- and brackish water a significant decrease of the ammonia excretion rates. Moreover, while in seawater animals Rh-protein mRNA expression levels did not alter after short (6 hrs) and long term (14 d) HEA exposure, expression levels in the gills of brackish water acclimated crabs doubled after 14 d HEA exposure.

26.1 WEISBROD, Anat; CHIPMAN, Ariel*; The Hebrew University of Jerusalem; *ariel.chipman@huji.ac.il*

The origin of insect A/P axis determination pathways – insights from the holometabolous milkweed bug, Oncopeltus fasciatus

A key early process in development is the determination of the embryonic axes. The anterior-posterior axis in insects is determined by a series of signaling pathways and transcription factors. These are best known from the fruitfly *Drosophila melanogaster*, where the torso pathway activates a number of posterior transcription factors, while interacting diffusible factors define the anterior. We have cloned the homologues of most of the key players in axis determination from the milkweed bug *Oncopeltus fasciatus*, focusing on *huckebein, torsolike, hunchback, orthodenticle* and *tailless* We then studied their expression and function, and their interaction with other early developmental pathways. Our results show that many of the pathways known to be involved in *Drosophila* axis determination have different roles in *Oncopeltus* development. We suggest that their roles in *Drosophila* are derived from the more ancestral roles still preserved in *Oncopeltus*. We use our results to discuss a model for the evolution of the axis determination process in insects.

104.3 WEISSBURG, M.J.; Georgia Tech; *marc.weissburg@biology.gatech.edu*

Turbulent mixing diminishes discrimination of food and predator risk odor sources by altering small scale structure of signals impinging on blue crab antennules.

Animals frequently are challenged with the task of responding appropriately to chemical signals when they are intermingled or mixed with odors from multiple sources. The ability of animals to navigate to attractive cues typically is examined in isolation, despite the fact that animals experiencing multiple, conflicting messages, may not be able to easily distinguish attractive substances if they co-occur with aversive cues. To examine this process, blue crabs were challenged to locate a source of food odors in the presence of a second odor source emitting cues indicative of predation risk (injured blue crab metabolites). Blue crabs easily and reliably located the attractive source under low mixing conditions, even when it was within 10 cm of the aversive source. However, increased mixing extinguished this response. Crabs no longer foraged for the attractive source, and instead displayed behaviors consistent with responses to the aversive cue only, despite the fact that they could locate the attractive source when presented alone under the same conditions. Removing input from the antennules eliminated the suppressive effects of the aversive cue, whereas removing input from chemosensors on the legs and claws did not. Qualitative flow visualization shows intermingled attractive and aversive odor filaments in low mixing conditions, whereas turbulence caused filament homogenization. Thus-small scale discreteness of odor filaments arriving at antennules is key to preserving the ability of crustaceans to operate effectively in environments with multiple and conflicting chemical signals, and is substantially affected by fluid mixing at levels that do not substantially affect navigation *per se.*

58.2 WEN, Li*; LAUDER, G.; Harvard University; *liwen@oeb.harvard.edu*

Understanding undulatory locomotion in fishes using an inertia-compensated flapping foil robotic device

Recent advances in understanding fish locomotion with robotic devices have included the use of flapping foil robots that are self-propelled and in which the thrust forces during swimming average to zero when summed over an entire flapping cycle. But, instantaneous forces are not zero throughout the undulating cycle, and thus the center of mass of the flapping foil does not oscillate in a manner similar to that of freely-swimming live fishes. We have designed a new robotic system that can produce controlled upstream-downstream motion for swimming flexible foils. A linear motor oscillates the flapping robot which is mounted on a low-friction air bearings. We conducted experiments using a flexible foil with a length of 15 cm and a height of 6.8 cm (modulus=1.66 GPa), actuated in heave ±1.5cm at the leading edge at a frequency of 1.5Hz. The imposed linear motion profile is a sine wave function and the linear oscillating frequency was set to double the flapping frequency at 3Hz. We varied the linear amplitude from 0.1 mm to 1 mm, and varied the phase between the foil heave and linear motion. Three forces and three torques were measured simultaneously during self-propulsion. The results showed that a phase of 260-270° produced the minimum force fluctuations. Furthermore, the addition of a linear amplitude of 0.5mm added an inertial component that sums with the net axial force produced by the foil so that force fluctuation is minimal. The summation of forces induced by the added linear motion and forces generated by flapping produces the equivalent of a true freely-swimming foil with appropriate center of mass oscillation.

101.3 WERNING, S*; IRMIS, RB; NESBITT, SJ; SMITH, ND; TURNER, AH; PADIAN, K; Univ of California, Berkeley, Univ of Utah, Univ of Washington, The Field Museum, Stony Brook Univ; *swerning@berkeley.edu*

Early evolution of elevated growth and metabolic rates in archosaurs

Birds exhibit much higher growth and metabolic rates compared to other extant reptiles. Bone histology establishes that dinosaurs and pterosaurs also grew at elevated rates, but it remains uncertain when these features evolved, temporally or phylogenetically. We expand the histological database of archosaurs and their ancestors to include early archosauromorphs, pseudosuchians, and dinosauromorphs, tracking changes in growth rate and its underlying metabolism through deep time and in taxa whose character states are not represented among living animals. Our study differs from previous works in its approach, phylogenetic breadth, and level of taxonomic sampling, but also in that we used apomorphy-based identifications for all specimens and sampled at homologous locations from individuals of comparable ontogenetic stage. We mapped characters relevant to growth and metabolism (e.g., osteocyte density, collagen organization, osteonal development, vascularity) on a recent phylogeny of archosauromorph reptiles to assess where particular adaptations of growth dynamics first evolved, focusing on the lineages leading to Archosauria, Crocodylomorpha, Dinosauria, and Theropoda. Many histological features associated with high growth and metabolic rates evolved much earlier than the common ancestor of birds and pterosaurs, and several aspects of the accelerated growth syndrome did not evolve simultaneously. Most of these character changes accumulated in a short segment of the archosauriform tree before the end of the Early Triassic. Many physiological features related to the high growth and metabolic rates of living birds evolved before the most recent common ancestor of crocodiles and dinosaurs.

115.2 WESTERMAN, E.L.*; MONTEIRO, A.; Yale University; *erica.westerman@yale.edu*

Mating Status Drives Male-Female Interactions in a Polygynandrous Butterfly

Operational sex ratio (OSR) is one of the main factors driving mate selectivity and mating behavior. Though often considered stable for a given population, OSR may vary throughout the breeding season as mating statuses of individuals change. These changes in mating status may lead to shifts in mate selectivity, particularly in species that are polygynandrous (both sexes mate multiply). However, the effect of mating status on mate selectivity and mating behavior is largely unexplored. Here we test whether mating status influences mating behavior in a polygynandrous species, the butterfly *Bicyclus anynana*. We observed male-female interactions of pairs of butterflies of both seasonal forms with different mating status combinations (both virgins, male previously mated, female previously mated, both sexes previously mated) and documented rates of behavior, likelihood to copulate, latency to copulation, and copulation duration. Female, but not male, mating status influenced likelihood to copulate in both seasonal forms. Virgin females mated more frequently than previously mated females. However, male, but not female, mating status influenced duration of copulation in one of the two seasonal forms. Previously mated males copulated for a longer period than virgin males. These results demonstrate that both males and females are modifying their mating behavior based on their previous mating experience. This suggests that individual mating status may drive mate selectivity and consequent operational sex ratio in polygynadrous species such as *B. anynana*.

22.9 WESTNEAT, Mark W.; Field Museum of Natural History; *mwestneat@fieldmuseum.org*

New computational approaches to biomechanical modeling

Computational approaches to complex mechanisms of feeding and locomotion in vertebrates are often challenging due to the need to account for movement in three dimensions, the mobilities of joints, the properties of muscle, and the mechanisms of force transmission from muscular motors to the output and behavior. Custom software development may often be the best choice for biomechanical modeling, allowing maximal flexibility for model design and potential for interaction between data analysis and on-screen visualization. This lightning talk presents several recent advances in custom software development for biomechanical analysis, including three dimensional skull morphometrics and biomechanics, software tools for the web browser, and several examples of previous skull models ported to desktop and mobile apps. NSF DEB-0844745

35.4 WETHEY, DS*; WOODIN, SA; HILBISH, TJ; LIMA, FP; JONES, SJ; Univ South Carolina, Columbia, CIBIO, Univ Porto, Portugal, NOAA, Washington DC; *wethey@biol.sc.edu*

Extreme events and biogeography of range boundaries in the European intertidal

Against the background of several decades of gradual warming, the severely cold winter of 2009-10 in Europe caused interruption or rapid reversal of long term shifts in geographic distributions of some intertidal species. After decades of poleward retreat, the northern barnacle *Semibalanus balanoides* expanded its range in both France and Iberia at rates in excess of 25 km y-1 and reinvaded locations where it had not been seen for 40 to 60 years. The southern mussel *Mytilus galloprovincialis* and the southern barnacles *Chthamalus* had been expanding their northern ranges in France in response to several decades of warming winters, but suffered reproductive failure in 2009-10. The southern polychaete *Diopatra* which is sensitive to cold summers, had little to no change in distribution, as a result of the prior warm summer. The magnitude and duration of these biogeographic responses to extreme events depends upon a combination of metapopulation dynamics and demographic storage effects.

99.4 WETHINGTON, A R; Chowan University;
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Does predation by leeches inferred from chemical cues impose any appreciable costs on their snail prey?

Physa acuta, a prominent member of freshwater ecosystems, is known to have morphological, life history, and behavioral responses to both fish and crayfish predators. However, less is known about physid response to leech predators that are commonly found in close proximity to P. acuta and their egg masses. Leeches wrap around a snail, invade the snail's shell, and completely consume their prey, leaving the empty shell behind. Adult physids typically escape leech predation by violent shell swinging and sudden release of substrate to float away from danger. Physids can also crawl out of dangerous waters for short periods of time. Since juvenile physids are more vulnerable to leech predators than adults, effects that leech predation may have on a physid's life history and reproductive behavior was studied. Generally, snails that were reared with predatory leech cue (fed conspecific snails) experienced a delay in reproduction. Snails also delayed their reproduction in the presence of crushed snail cue. Snails did not exhibit any size or shape difference over time when exposed to leech cue, although snail growth was depressed over time in the crushed snail treatment. All treatments experienced a similar number of crawl outs during mating trials. Both the cue from crushed snails and predatory leech fed snails caused a depression in the number of noticeable behaviors the snails displayed during mating behavior trials. Unlike the cue from crushed snails, the cue from predatory leech fed snails did not seem to affect mating outcomes when compared to a control.

44.1 WHITCOME, K.K.*; O'CONNOR, J.P.; LOPEZ, J.; MILLER, E.E.; BURNS, J.L.; University of Cincinnati, Cincinnati, Harvard University, Cambridge; *katherine.whitcome@uc.edu*

Effect of Pelvic Rotation on Stride Length: Redefining the Human Obstetrical Dilemma

Human males and females differ in skeletal shape and size, notably within the pelvis. The correlates of this sexual dimorphism are known with respect to obstetric function but consequence in locomotor performance is less well understood. Given that a relatively wide pelvis generates more gravitational torque during swing phase than a narrow pelvis, we ask do pelvic determinants of gait differ by sex, and if so, do sexes achieve similar locomotor results in terms of gait economy? Here, we introduce a new pelvic rotation model to determine sex-specific effects of pelvic axial rotation on stride length. We examined locomotor kinematics in a group of 30 adults within which sexes differed anatomically in mean body mass (male 77.3 kg [1.8], female 60.8 kg [1.7]) and mean pelvic width (male 262.8 mm [3.4], female 258.9 mm [4.3]). Females have a greater dimensionless stride length at slower and higher speeds (1.57 [.07], 1.92 [.02]) than males (1.46 [.08], 1.82 [.01] and have larger excursion angles of the pelvis in the transverse plane (38.3 [13.1], 47.0 [12.2]) than males (47.7 [8.3], 53.6 [3.6]). Incorporating the kinematics into a biomechanical model combining limb and pelvic dynamics showed that females generate greater forward hip translation than males ($P<0.0006$). Further, the new model is a better predictor of stride length than a simple limb-based model and accurately predicted female stride length ($P=0.362$) but not male stride length ($P<0.0000$). These findings suggest that despite high hip torque emphasized by the Obstetrical Dilemma Hypothesis, females uniquely exploit the translational effects of the relatively wide pelves to increase stride length. Research supported by the University of Cincinnati.

5.5 WHITEHILL, E.A.G.*; MORAN, A.L.; Clemson University;
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The effects of temperature on the developmental energetics of a sea urchin with indirect larval development

The early life history stages of marine invertebrates are strongly affected by temperature, and these effects can carry over into juvenile and adult stages. Rearing temperature affects many physiological processes within the animal, which can lead to differences in growth and energetic efficiencies though the extent of this phenomenon - and the underlying mechanisms - are poorly understood. We assembled energy budgets for marine invertebrate larvae raised at different temperatures to determine if rearing temperature affects larval energetic efficiency and larval and juvenile quality. Larvae of the sea urchin *Lytechinus variegatus* were reared through metamorphosis at 23, 27, and 30°C (±1°C). Larvae grew faster when reared at higher temperatures but larvae reared at higher temperatures were smaller at comparable developmental stages. High-temperature larvae also contained less protein and lipid and had higher rates of oxygen consumption. Overall, when summed across development, larvae at high temperatures used more oxygen, excreted more ammonia, and consumed fewer algae during the larval phase than larvae at low temperatures. Juveniles resulting from larvae reared at higher temperatures were smaller and experienced greater mortality. The data suggest that higher rearing temperatures result in smaller larvae that contain fewer nutrient reserves and poorer-quality juveniles. These data also indicate that these larvae and juveniles may follow the temperature-size rule due to a combination of greater energy expenditures and lower energy intake at higher temperatures during the larval period.

20.1 WHITEMAN, John P.*; HARLOW, Henry J.; BEN-DAVID, Merav; DURNER, George M.; University of Wyoming, US Geological Survey; *jwhitema@uwyo.edu*

Polar bears may depress body temperature and metabolic rate during summer

In the Arctic summer, extent and duration of sea ice melt is increasing. This displaces Alaskan polar bears from ice in productive near-shore waters to deep-water ice or to land; both areas where seal prey is likely not as available. Also, extensive open water may increase long-distance swimming. Whether bears adjust metabolic rates and thermoregulation to accommodate these changes is unknown. We recorded body temperature (T_b) with loggers implanted adjacent to the abdominal peritoneum, ventral to the linea alba, in 4 bears on deep-water ice (May–Oct) and 5 bears on shore (Aug–Oct) in the Beaufort Sea. T_b of ice bears declined from a weekly mean of 37.2–37.5°C (May 23–Jun 03) to 34.7–36.6°C (Sep 21–Oct 09). We propose this reflects a gradual reduction in metabolic rate in response to limited seal availability. Shore bears did not show a decline over time in weekly mean T_b, perhaps reflecting a more constant metabolic rate enabled by human-provided food on shore. Bears also had unexpected, rapid bouts of T_b decline and recovery. In Aug–Oct, ice bears averaged 0.65 bouts per day (95% were ≤ 12 hours) that reached a mean minimum T_b of 33.6°C; shore bears averaged 1.06 bouts per day (94% were ≤ 12 hours) that reached a mean minimum T_b of 28.6°C. The cause of these bouts and why they were more frequent and reached a lower T_b for bears on shore is not clear. We propose bouts do not reflect reduced whole-animal metabolic rate and temperature, but regional heterothermy similar to diving penguins. Data on location, ambient conditions, and blood and muscle chemistry may clarify causes and advantages of these bouts in both groups, as well as the gradual T_b decline in ice bears.

114.5 WIEDEBACK, B D*; OSWALD, M E; ROBISON, B D; University of Idaho, University of Notre Dame; *bwiedeback@vandals.uidaho.edu*

The link between stress and behavior in zebrafish: is embryonic perturbation a factor?

It is well known that embryonic exposure to stress hormones can affect adult behavior in mammals. However, the effect of embryonic stress exposure in determining the adult behavior of fish is not as well understood. In this presentation we describe results from two experiments that test for linkages between stress and anxiety related behaviors in the zebrafish. First, we show that in lines of zebrafish selected for shy and bold behavior, production of cortisol is higher in male zebrafish relative to females. In addition, while cortisol does not appear to vary between shy and bold lines, the expression of key stress related genes in the brain is significantly different between them. Most notable is the increase in expression of two splice variants of the glucorticoid receptor in shy fish. In the second and ongoing experiment, we sought to determine if the differences we observed among the sexes and among selected lines could be explained by changes in the early embryonic environment experienced by the fish. We therefore administered five different cortisol treatments (a control, an ethanol carrier treatment, and three cortisol treatments of 1mg/L, 10mg/L and 100mg/L) to 150 fish from the Scientific Hatcheries strain. Dosing occurred for the first 48 hours of development. This experiment will help us determine whether exposure to cortisol, a glucocorticoid related to the long term stress response, during early development has a dose dependent effect on the behavior, gene expression, and stress responsiveness of adult (3 month old) zebrafish.

56.3 WIGTON, R/A*; KRUEGER, P/S; BARTOL, I/K; Old Dominion University, Norfolk, VA, Southern Methodist University, Dallas, TX; *rwigt001@odu.edu*

Maneuverability and Agility in Cuttlefish Sepia pharaonis and Sepia bandensis

Cuttlefish live in complex coral reef habitats that require them to make frequent turns to navigate, hunt for prey and evade predators. Cuttlefish turn using a dual mode system involving fins that extend along the mantle and a pulsed jet directed through a funnel that can be rotated within a hemisphere below the body. Turning performance has been quantified for many fishes and marine mammals, but there are currently no extensive studies on turning performance in a cephalopod. The objective of this study is to quantify turning performance in two cuttlefishes, *Sepia pharaonis* and *Sepia bandensis*. The cuttlefishes were induced to turn within a 50 x 50 cm Plexiglas viewing chamber using a food cue. Each turn was filmed from lateral and ventral perspectives using two high-speed DALSA cameras triggered at 100 frames per second and a custom video capturing system (IO Industries).. Several landmarks on the cuttlefish mantle, funnel, arms, and fins were tracked, and parameters such as minimum radius of the turning path (a measure of maneuverability) and angular velocity of turns (a measure of agility) were determined using Matlab routines. Cuttlefishes employed a wide repertoire of behaviors to improve turning performance, including adjusting mantle and arm angles, using asymmetric fin motions, and augmenting fin movements with a directed jet. Current data on length specific turning radius and maximum angular velocity during turns in *S. pharaonis* and *S. bandensis* indicate that they are comparable to angelfish and boxfish in terms of maneuverability and agility, respectively.

109.1 WILCOXEN, Travis E*; HORN, David J; CERNY, Jared; HOGAN, Brianna; HUBBLE, Cody; HUBER, Sarah; KNOTT, Madeline; ROBERTSON, Abigail; SALIK, Faaria; Millikin University; *twilcoxen@millikin.edu*

The buzz about food: songbird physiology in response to increased availability of a natural food source.

The emergence of periodical cicadas serves as a substantial resource pulse for avian insectivores large enough to consume the cicadas. The true value of such a sudden increase in food availability to free-living birds remains unknown, and in previous studies, some species that consume periodical cicadas actually show population declines in subsequent years at sites where cicadas had emerged in the previous year. We examined body condition, nutritional condition and measures of immune, reproductive, and stress physiology in songbird species before and after simultaneous emergence of 13-year and 17-year periodical cicadas. We also compared individuals from these sites to a site with no cicadas 15 km from the nearest study site with cicadas. Our results demonstrate that there are a number of physiological processes that appear to be influenced by this resource pulse, however, certain changes in response to this increase in food availability appear to be species-specific.

91.2 WILKINSON, Kit C.*; NISHIKAWA, Kiisa C.; UYENO, Theodore A.; LEE, David; Northern Arizona University, Valdosta State University, University of Nevada Las Vegas; *kcw53@nau.edu*

Propulsive force calculations of a frog jumping from the water's surface

The juvenile North American bullfrog or Lithobates catesbeianus has a remarkable ability to generate enough thrust necessary to jump while floating in water, to distances up to several body lengths. This jump mode is used for aerial prey capture, escape from water-filled depressions, and possibly for aquatic predator avoidance and may contribute to the bullfrog's success at invading new environments. The adult bullfrog is one of the best terrestrial jumpers in the world, jumping over 180cm in a single jump. However, few studies have attempted to analyze thrust production of jumping from an aquatic medium. Here we compare both terrestrial and aquatic jumping of juvenile bullfrogs. We jumped the frogs off a force plate (ATI, Nano 17) to measure ground-reaction forces to calculate terrestrial thrust. We are currently studying the unique aquatic jump using a custom DPIV (Digital Particle Image Velocimetry) system to analyze the flow generated by the jumping frog. Frogs are tested during aerial prey strike and escape response in an aquarium. The aquarium water is seeded with neutrally buoyant particles, illuminated with a green (532nm) laser light sheet. A high speed camera at 125frames/sec. records the flow of particles during the aquatic jump. The video file is converted to single image files. The images are analyzed with software that tracks the flow of particles. The DPIV system software measures vortex ring velocity and is used to calculate thrust. A comparison of the terrestrial and aquatic thrusts will allow a test of our hypothesis that a correlation exists between the thrusts produced in the two jumping modes.

46.3 WILKINSON, Kit C.*; UYENO, Theodore A.; NELSON, Rusell; Northern Arizona University; *kcw53@nau.edu*
An economical and open-source particle image velocimetry instrument for use in a secondary and higher education setting
A particle image velocimetry (PIV) instrument measures fluid flow velocity. This is performed by seeding the fluid with an isobuoyant particle and illuminating the particles with a laser light source in one to three dimensions. The movement of the particles is recorded by a high-speed camera. A synchronizer coordinates by pulsing the laser light from the camera TTL signal. The video file is then converted to single image files. The software tracks the particles by marking their relative locations in each frame. A PIV instrument can be used to research and demonstrate fluid dynamics, aerodynamics, and flows relating to biological systems. Measurement of fluid velocity flows has traditionally required expensive high powered lasers, high-speed cameras and software that were beyond the budget of most teachers. Usually, grants and donations had to be made to assemble a PIV instrument that produced data of useable resolution. Classes in high school and the college level that teach oceanography, physical engineering, fluid dynamics and biology can now build an economical PIV instrument from laser pointers, inexpensive microcontrollers, open-source software, used computers and used high-speed cameras.

6.4 WILLIAMS, C.D.*; SALCEDO, M. K.; REGNIER, M.; IRVING, T. C.; DANIEL, T. L.; Univ. of Washington, Seattle, Ill. Inst. of Technology, Chicago; *cdave@uw.edu*
Pulling apart lattice spacing: interfilament distance regulates force
As muscle contracts it both shortens and grows thicker. Under isovolumetric conditions the increase in thickness spreads the contractile lattice of the muscle cell. This spread changes the orientation of muscle's molecular motors relative to the sites where they may bind and produce force. Our previous models show that lattice spacing strongly modulates the maximum isometric force muscle can generate. Lattice spacing's influence is on the same order of magnitude as that exerted by the change in the overlap between the contractile filaments that occurs during shortening. Here we use measurements of force in muscle whose lattice spacing we osmotically control and monitor through x-ray diffraction imaging to examine the interaction between lattice spacing and force in skinned muscle fibers. D_{10} lattice spacing varies between 40 and 60 nm and has a significant ($p=0.006$) 0.4 correlation with maximum force. Initial lattice spacing prior to a given contraction is offset by the introduction of a high molecular weight sugar into the relaxing and activating solutions, Force and lattice spacing data were collected simultaneously by means of an automated apparatus developed for the task. Our x-ray diffraction derived measurements support the results of our prior models, showing a non-sarcomere-length dependence to the maximum isometric force generated. Combined with new modeling results, these data suggest that much of the increased force seen in the ascending limb of the sarcomere length-tension relationship is due to changes in lattice spacing, rather than changes in filament overlap.

3.8 WILLIAMS, C.M.*; CHICK, W.D.; SINCLAIR, B.J.; University of Western Ontario; *cwilli67@uwo.ca*
Multiple trade-offs among life-history and metabolic traits mitigate the impacts of overwintering microclimate on the fitness of Fall Webworm across its native range.
The impact of the environment on distinct physiological and ecological traits, and across life-stages, can result in trade-offs that combine to determine the fitness of individuals and thus population dynamics. We examined the role of local adaptation and plasticity in modifying the life-history and physiological characteristics of a widespread, generalist pest species *Hyphantria cunea*, Lepidoptera: Arctiidae) from the centre (Columbus, OH [CO]) or northern periphery (Ottawa, ON [OT]) of their range, in response to overwintering microclimate conditions approximating the collection sites (northern or southern treatments), in a reciprocal common garden design. Populations differed in the majority of life-history and metabolic traits, but this differentiation did not appear to be adaptive. Diapause entry was advanced in CO compared to OT populations, which had negative effects on adult size, but larger pupal size in CO pupae compensated for this effect. Pupae facultatively suppressed their metabolism at warm, energetically demanding southern temperatures, which more than compensated for the increased energetic demands of warmer winters, as pupae from the warm southern treatment actually had more energy reserves remaining at the end of winter than did the cooler northern treatment. This species thus has a large repertoire of genotypic and plastic changes to life-history and metabolic traits that render them relatively insensitive to changes in their overwintering thermal environment.

27.1 WILLIAMS, T.M.*; WOLFE, L.L.; DAVIS, T.R.; KENDALL, T.; RICHTER, B.; ELKAIM, G.; WILMERS, C.; Univ. of California, Santa Cruz, Colorado Parks and Wildlife, Fort Collins; *williams@biology.ucsc.edu*
Energetics and Mechanics of Mountain Lions: A step by step analysis for carnivore conservation
As one of North America’s largest terrestrial carnivores, the mountain lion (*Puma concolor*) places extraordinary demands on habitats and prey resources. As a result, conflicts with human activities can occur but have been difficult to predict. We developed a new “smart” collar incorporating physiological attributes of the animal, GPS and accelerometers to monitor movements, behavior and energetics of free-ranging lions in the Santa Cruz Mountains. Collars were calibrated on three adult lions (mass = 65.7 kg) trained to wear the collar in a natural enclosure and while walking on a treadmill. Oxygen consumption (VO_2) was determined by open-flow respirometry from rest to 7 $km.hr^{-1}$ and correlated to gait. The data were then used to assign behavioral and energetic signatures to collar signals. VO_2 ($mlO_2.kg^{-1}.min^{-1}$) increased linearly with walking speed ($m.s^{-1}$) according to $VO_2 = 8.71 + 10.12$speed ($r^2=0.96$). Net transport costs and gait transition speeds of mountain lions were as predicted for quadrupeds. Conversely, total energetic costs for both rest and activity were 71% higher than predicted for domestic mammals, following the trend for elevated metabolism in large carnivores. Tests with collared, free-ranging lions demonstrated peak energy expenditure during dawn and dusk for lone females while those with kittens maintained constant hunting/energetic demands throughout the day. This integrative wildlife monitoring approach provides new insights regarding optimal foraging by a large carnivore, and demonstrates the importance of species-specific physiological traits when developing conservation plans.

103.2 WILLIAMS IV, R.*; NEUBARTH, N. L.; HALE, M. E.; Univ. of Chicago; *rwilliams@uchicago.edu*
Characterizing sensory nerve fiber responses to pectoral fin ray bending
While the roles of fins in actinopterygian locomotion have been studied in depth, little is known of how they receive sensory feedback from interactions with the physical environment. We selected the bluegill (*Lepomis macrochirus*), a species that uses its pectoral fins extensively during swimming, as a model organism for the exploration of pectoral fin somatosensation. Previously we demonstrated that the sensory nerves innervating the pectoral fins of bluegills are capable of conveying mechanosensory feedback in response to fin bending, using extracellular physiological recordings in a fictive fin preparation. In this study we examine the responses of these nerves to sinusoidal and step-and-hold bending of the fin rays. Activity recorded in response to these stimuli show that sensory nerve fibers respond to the magnitude and the velocity of the bending movement. Additionally, we used spike-sorting analyses to examine the responses of individual afferents to aspects of fin ray bending. These data suggest that there are multiple types of mechanosensory neurons responsive to fin ray bending and that these populations of neurons may communicate different properties of the bending stimulus. The feedback provided by these neurons may allow the pectoral fins to act as mechanical sensors as well as propulsors.

19.1 WILSHIN, Simon; HAYNES, G. Clark; REEVE, Michelle; REVZEN, Shai; SPENCE, Andrew J.*; Royal Veterinary College, University of Pennsylvania; *aspence@rvc.ac.uk*
How is dog gait affected by natural rough terrain?
In nature legged animals depend on locomotion over uneven terrain for survival and reproduction. One way in which animals may optimize their locomotor behaviour for this task is by adjusting the relative timing of their leg recirculation, or gait. Therefore, we asked how the relative leg timing of quadrupeds changes during locomotion over natural, uneven terrain, and compared this to our idealised notions of the walk, trot and gallop. Five male dogs of shoulder height 522.0 ± 62.6 mm (mean ± s.d.) and body mass 20.0 ± 2.5 kg (mean ± s.d.) were trialled at nominal walk, trot, and gallop speeds over flat and uneven terrain. Mean perturbation size on uneven terrain was 54.8 ± 44.6 mm versus 4.2 ± 3.1 mm on flat. Dogs were fitted with a wirelessly synchronized suite of five sensors, comprised of Global Position System and inertial measurement units. One device was attached to the proximal-most segment of each leg, and a fifth on the midline of the back at the front legs. Raw sensor data were used to compute animal speed, position, and a continuous estimate of leg phases. The centroids of relative leg phase (averaged across time within each stride), describing the gait used by the dog on each terrain at each nominal gait speed, were significantly different on the rough terrain (linear mixed-model; $n=5$ dogs, $p<0.05$). At walking speeds on the rough terrain, dog gait moves towards the trot. Averages and distances between gaits in relative leg phase space do not account for the dynamical and geometric structure of these phase variables, however. Theoretical developments required to handle these data will be discussed. To explain why we observe these changes in dog gait, we propose experiments in a physical model, the robot XRL.

49.5 WILSHIN, S.D.*; HAYNES, G.C.; PORTEOUS, J.; SPENCE, A. J.; Royal Veterinary College, University of Pennsylvannia; *swilshin@rvc.ac.uk*
Describing gait transitions and the role of symmetry in control
Gait transitions represent a natural perturbation away from steady state behaviour. As such they provide insight into how control emerges during a complex locomotor task. Here we explore the form of gait transitions and investigate the structure of the controller necessary to achieve them. We tracked the motion of five dogs (average body mass 23.5 kg, range 10.5 kg to 32 kg, average age 5.4 years, range 2 to 7.5 years, various breeds) moving on a treadmill. The dogs were ramped up through speed inducing transitions from walk to trot and trot to walk. Limb and body positions were used to compute limb phases prior to, during, and after the transition. Transition times (walk-trot: 0.17 ± 0.11 s; trot-walk 0.21 ± 0.20 s; mean ± s.d.), were estimated by fitting a logistic function and the transitions were found to be highly stereotyped (variation in relative limb phasing at mid transition walk-trot: 0.74 ± 0.27 rad; trot-walk: 0.87 ± 0.34 rad). The stereotyped nature of the transition suggests there may be an underlying mechanical or neural mechanism or constraint which locks relative phase during the transition. The underlying symmetry of the system will be used to infer the minimal control architecture sufficient achieve this transition and compared to more complex control systems. This work has a natural extension incorporating duty factor with applications in bipedal locomotion.

91.5 WILSON, AM*; LOWE, J; HUDSON, PE; ROSKILLY, K; MCNUTT, JW; The Royal Veterinary College, Botswana Predator Conservation Trust; *awilson@rvc.ac.uk*
Dynamics of hunting in free ranging cheetah
Studies of maximum performance are limited by subject motivation and attempts by ourselves and others to measure domestic cheetah performance show limited straight line and manoeuvring performance. We set out to describe the speed, acceleration and manoeuvring of wild cheetahs when hunting. We developed a collar powered by a combination of rechargeable, non rechargeable batteries and solar panels. Sensors comprise a 5Hz L1 raw pseudorange Doppler data GPS receiver, 3-axis MEMS accelerometer, 3 axis MEMS gyroscope, and a 3 axis magnetometer. Data were off loaded via a wireless link to an aircraft or vehicle. The sensors provide, at 300 Hz, acceleration (force) and with integration velocity and position, angular velocity and with integration heading and orientation of the collar and (approximately) the cheetah. GPS pseudorange and Doppler velocity vector to each individual satellite are post processed along with data from a local ground station (tightly coupled mode) using our own Kalman filtering optimised for sensor characteristics and animal dynamics to provide the data we require. Accuracy is 0.2 m position, 0.1 ms^{-1} speed and 2 degree heading and track (all sd). The collar adapts its operation (and hence power consumption) across six states depending on the time of day, the animal's activity level and battery voltage. This allows collection of fine grained behaviour and movement data. Collars were attached to three cheetahs in the Okavango Delta area of Botswana. To date we have collected data for 22 hunts from these three cheetah and data collection is ongoing. Successful hunts involve rapid acceleration, relatively high speed galloping (up to 22 ms^{-1}) with a stride frequency of up to 4 Hz and a period of manoeuvring with lateral accelerations of close to 2g.

38.2 WILSON, R S; The University of Queensland; *r.wilson@uq.edu.au*

Bigger is Better in all environments: temperature-induced variation in phallus size is a reliable indicator of male physical performance and gamete quality

Males of many organisms possess elaborated structures that are used to engage in fights with other males and/or to attract females during courtship. The size and elaboration of these secondary sexual traits can be affected by the environment via its influence on the condition of an individual male. This link between male condition and the elaboration of male sexual signals is one of the most important mechanisms maintaining the reliability of these traits as signals of male quality. The role temperature plays in mediating the condition of individual males and the size and elaboration of their sexually selected traits is currently unknown. Males of the eastern mosquitofish (*Gambusia holbrooki*) possess a modified anal-fin phallus (gonopodium) that is used as both a signal of dominance and a stabbing weapon during male-male competitive bouts. I examined the effect of temperature on the size of this putative sexual signal (phallus size) by chronically exposing males to either 20° or 30°C for four weeks. I also tested the influence of these thermal environments on various measures of male quality; including male territorial performance, swim speed and gamete function. Males chronically exposed to 30°C possessed longer phalluses greater ejaculate sizes, larger testes and faster sperm swimming speeds than those exposed to 20°C. This is the first study to show that environmental variation in phallus size can be a reliable indicator of male physical performance and gamete quality.

52.3 WINDSOR, S.P.*; BOMPHREY, R.J.; TAYLOR, G.K.; Univ. of Oxford; *shane.windsor@zoo.ox.ac.uk*

Flight control sensorimotor response in the hawk moth Hyles lineata

The functional properties of the flight control system of an insect can be explored experimentally by measuring how the insect responds to a range of sensory perturbations. Using a custom built virtual reality flight simulator we measured the flight forces and moments produced by tethered white-lined sphinx hawk moths (*Hyles lineata*) in response to moving wide field visual stimuli. Each moth's response to a sinusoidal grating oscillating over a range of frequencies around three axes was recorded. When perturbed in roll the moths responded so as to stabilize the position of the stimuli; whereas in pitch and yaw the moths stabilized a combination of the position and velocity of the stimulus. These responses could be explained by the relative flight stability of the moth in different axes and suggest possible structures and limitations for the architecture of the moth's sensorimotor flight control system.

13.2 WINSLOW, B. B.*; LEARY, B.; KAVANAGH, K.; University of Massachusetts Dartmouth; *bwinslow@umassd.edu*

Developmental evidence that the metatarsals and phalanges are distinct modules

Historically metatarsals and phalanges have been considered as evolutionarily independent skeletal units in the autopod because of their functional and variational differences. However, during ontogeny these bones appear to develop from identical morphogenetic processes, using the same gene networks. This project aims to test the hypothesis that the metatarsals exist as a different developmental module than the phalanges. Specifically, each region should respond independently to experimental perturbations. Our data show that manipulations performed on the developing phalanges, such as the implantation of a foil barrier, can alter phalangeal patterns, indicating the presence of a proximal patterning signal. However, when the identical manipulations are applied to the metatarsal the phalanges develop normally, despite morphological changes to the metatarsal, suggesting the metatarsal-phalangeal joint separates two modules in the developing digit. To test the hypothesis that the metatarsal-phalangeal joint initiates the phalanges module, we experimentally manipulated the identity of the metatarsal-phalangeal joint via transplantation, manipulated proximal or distal signaling centers chemically, and assayed for patterning shifts in the phalanges. Phalangeal pattern is only altered by manipulations performed distal to the metatarsal-phalangeal joint, and not by manipulations proximal to the joint or to the identity of the joint itself. These data suggest that the metatarsal-phalangeal joint interzone itself does not provide signals specifying the sequential patterning of the digit (the "identity"), while metatarsal-phalangeal joint formation is clearly a critical stage creating a boundary in separating the metatarsal and phalanges modules.

S4-1.1 WINSTON, Judith E.; Virginia Museum of Natural History; *judith.winston@vmnh.virginia.gov*

Dispersal in Marine Organisms without a Pelagic Phase

In contrast to marine organisms whose offspring go through an extended planktonic stage, the young of others develop directly into benthic juveniles or have non-feeding larvae which spend only a few hours in the plankton before settling. Yet, paradoxically, many such species have geographic distributions that are comparable to those of species with a pelagic dispersal stage. This paper reviews some of the ways in which these organisms can expand their distributions: drifting, rafting, hitchhiking, creeping, and hopping. Drifting applies to species in which larvae may be short-lived, but adults can detach or be detached from their benthic substratum and be passively carried to new areas. Many encrusting species can spread by rafting, larvae settling on natural or artificial floating substrata which are propelled by wind and currents to new regions. Hitchhiking applies to those attaching to vessels or being carried in ballast water to a distant region in which their offspring can survive. Other species can extend their distributions by hopping from one island of hard substratum or favorable sedimentary microhabitat to another, while creeping species extend their distributions along shores or shelves where habitats remain similar for long distances.

3.5 WOLF, BO*; MCKECHNIE, AE; Univ. of New Mexico, University of Pretoria, SA; *wolf@unm.edu*

Heat waves - challenges for desert bird communities

For the avifaunas of hot subtropical deserts, among the most important, but understudied, direct effects of climate change may involve catastrophic mortality events associated with extreme heat waves and droughts. A number of large-scale die-offs during extremely hot weather have been documented in the past, and general circulation models predict increases in the intensity, frequency and duration of heat waves. Here, we identify the physiological mechanisms underlying avian mortality associated with heat stress and the lack of water, and develop a model that predicts rates of evaporative water loss and survival times during very hot weather as functions of body mass and dehydration tolerance. Applying our model to current and projected maximum air temperatures for two localities in hot subtropical deserts, we find that the increase in maximum air temperatures predicted for the 2080s will increase rates of evaporative water loss by more than 50-80% in very small birds, reducing survival times by 30-40%. For birds weighing < 100g (more than 80% of species in most desert bird communities), rates of evaporative water loss will increase by 30-50% and survival times will be reduced by at least 25%. The existing literature suggests that many species will simply be unable to up-regulate EWL to maintain body temperatures below critical lethal limits given the predicted increases in heat stress. Current and historical accounts already document catastrophic mortality caused by hyperthermia or through dehydration. Increasing global temperatures, combined with more intense and frequent heat waves, will result in more frequent die-offs among desert birds, potentially depopulating regional communities.

97.3 WOLF, Marta*; ORTEGA-JIMENEZ, Victor M.; KIM, Erica; DUDLEY, Robert; Univ. of California, Berkeley; *marta.wolf@berkeley.edu*

Flow visualization, kinematics, and metabolic rates of Anna's Hummingbird hovering in ground effect

Animals in flight potentially benefit from an aerodynamic ground effect when moving above continuous surfaces. Three different methods were used to evaluate possible consequences of the ground effect for hovering flight performance of Anna's hummingbirds (*Calypte anna). We used Particle Imaging Velocimetry to study the vortex wake of birds hovering at five different distances above a smooth plate, and simultaneously measured their wingbeat kinematics and metabolic rates. Induced velocities were significantly reduced by 10 - 25% for hovering at vertical distances of 0.3 - 0.5 wing span. Flapping frequency was unchanged but stroke amplitude as well as the rate of oxygen consumption decreased with diminishing height of the bird above the plate. Hummingbirds thus benefit from a ground effect, albeit at relatively low distances from a surface. Boundary effects may be particularly relevant for small animals flying near flowers and within vegetational canopies.*

21.4 WOODIN, S.A.*; HEWITT, J.E.; PILDITCH, C.A.; POLERECKY, L.; THRUSH, S.F.; VOLKENBORN, N.; WETHEY, D.S.; Univ South Carolina, Columbia, NIWA, Hamilton, NZ, Univ Waikato, Hamilton, NZ, Max Planck Inst Marine Micro, Bremen, DE; *woodin@biol.sc.edu*

Bivalves as Infaunal Hydraulic Ecosystem Engineers vs Wimps of the Class

In 2010 we proposed that organisms living in sediments could be categorized according to the frequency, direction and strength of their hydraulic activities within the sediments and that this axis was likely to be as significant in driving community dynamics as sediment turnover or organism mobility. Data on the impact of bioadvection on the availability of transport of both nutrients and heat were presented to support our claim (Woodin et al. 2010). We further proposed that infauna could be characterized by the complexity and magnitude of their hydraulic activities. Specifically, tellinid bivalves, arenicolid polychaetes and thalassinid crustaceans were suggested to be enormously important in terms of porewater movement and those hydraulic activities might be more important than sediment turnover, the typical focus of research on infauna. In contrast, we proposed that suspension feeding bivalves in general were at the opposite end of the bioadvective gradient, having simple hydraulic signals of low magnitude. Planar optode plus pressure sensor data from common bivalves of intertidal flats of New Zealand, Germany, and the Pacific northwest of the United States are used here to illustrate that our original proposal appears to be correct. Activities of tellinid bivalves result in strong pressure changes within the sediment that are uniquely associated with a range of behaviors and are bidirectional. In contrast, excluding initial burrowing, the activities of a suspension-feeding venerid bivalve do not result in strong pressure changes though brief pressure pulses are seen during feeding.

114.1 WOODLEY, S.K.*; RICCIARDELLA, L.F.; Duquesne University; *woodleys@duq.edu*

Is plasma corticosterone a useful biomarker of environmental degradation?

Amphibians are declining throughout the world due to many factors. One source of environmental degradation impacting amphibian populations in Pennsylvania is stream acidification. We asked whether sublethal exposure to acidified environments was associated with elevated plasma corticosterone (CORT), an important mediator of the vertebrate stress response. We sampled baseline and handling-induced increases in plasma CORT in male stream-side salamanders (*Desmognathus ochrophaeus*) from 13 populations representing an acid-alkaline gradient from pH of 4.1 to 8.1. A previous study had found decreased abundance and diversity of salamanders in acidified sites. We found no effect of acidification on plasma CORT levels. Likewise, a study in the laboratory found similar plasma CORT in subjects exposed to acid versus acid-neutral conditions. However, captive subjects previously exposed to an acidified environment had decreased activity compared to subjects previously exposed to an acid-neutral environment. Together, these results indicate that environmental acidification resulted in behavioral changes that were not associated with endocrine changes. Thus, measurement of plasma and stress-induced CORT is not a useful biomarker of environmental acidification in stream-side salamanders.

5.6 WOODS, HA; Univ. of Montana; *art.woods@mso.umt.edu*
A caterpillar grows up: thermal consequences of growing larger on a leaf
Leaf-associated insects live partially or entirely within leaf boundary layers. Because leaves transpire, boundary layers can be cooler and more humid than ambient air. I examined the thermal consequences of living within versus protruding from leaf boundary layers, using larval *Manduca sexta* on their primary host plant in Arizona, *Datura wrightii*. A newly-hatched larva projects about 1 mm from the leaf surface. In the subsequent 2 – 3 weeks, the larva increases in mass by 10,000-fold, at which time it projects > 15 mm from the leaf surface. For comparison, leaf boundary layers are generally 1 – 4 mm thick, depending on leaf size and wind speed. These observations indicate that temperatures of eggs and early-instar larvae should be strongly coupled to leaf temperature, whereas those of larger larvae should increasingly match air temperatures, or perhaps exceed air temperatures when larvae are directly illuminated by the sun. I tested this prediction using an infrared video camera to record, during midday, the temperatures of leaves and their associated eggs and larvae (all five instars). Leaf temperatures were usually cooler than ambient air, on average by 4°C and occasionally up to 8°C. Egg and larval temperatures depended strongly on body size. Eggs and first-instar larvae were always within 1°C of leaf temperature, regardless of ambient temperatures. By contrast, fifth-instar larvae were always close to air temperature, regardless of leaf temperature. The middle instars transitioned between these extremes. These results show that the thermal experience of larvae changes dramatically over ontogeny. A consequence is that larger larvae reach maximum temperatures 2 – 6°C higher than those of small larvae, and these natural changes in thermal stress may be mirrored by changes in larval stress physiologies over ontogeny.

6.8 WOODS, W. A.*; SCHULER, F. R. ; YEE, A. L. ; TRIMMER, B. A. ; Tufts University; *william.woods@tufts.edu*
Optimizing work and power production of a Manduca sextalarval locomotory muscle
Because caterpillar locomotory muscle develops relatively high stress over a large strain range, and because larval muscle cultured from primary myocytes shows better longevity and environmental tolerance than vertebrate muscle, it is a promising candidate for cultured bioactuators. Since such constructs lack motor neurons, we optimized muscle work and power production of native larval ventral interior longitudinal muscle under direct stimulation. In anticipation of powering devices producing rotary motion, we used sinusoidal strain cycling, which is unlike strain cycling during *in vivo* crawling. We varied stimulus train timing, duration and frequency, as well as pulse duration and voltage. In physiological saline mimicking hemolymph, no combination of parameters yielded positive work during any portion of the strain cycle; the very slow relaxation of the muscle at termination of stimulus caused prohibitively high stress during relengthening. Because of the potential channel blocking properties of the physiological saline Mg^{2+}, we carried out subsequent experiments using saline optimized for desheathed nerves; this reduced the muscle relaxation time constant sixfold. During cycling at 0.25 Hz (approximating *in vivo* crawl cycle frequency), muscles produced up to 1.7 x 10^{-5} J per cycle, yielding 2.59 W kg^{-1} power output; peak stress during shortening was 90 kPa. Higher cycling frequencies reduced work without increasing power, while lower frequencies reduced power. Optimal performance was achieved when 40 Hz trains of 0.1 ms 40 v pulses were applied for 0.6 s beginning 0.1 s after shortening from 1.14 to 0.86 lengths commenced. Both work and power production values were over an order of magnitude higher that those for simulated *in vivo* crawling conditions.

66.10 WOZNICA, A; HAUSLER, M; JEMMET, J; STAROBINSKA, E; LI, Y; DAVIDSON, B*; UC Berkeley, UC Santa Cruz, University of Arizona, University of Arizona; *bjd18@email.arizona.edu*
Resetting the clock: Temporal dynamics in gene network evolution
Spatial shifts in gene expression domains have well documented roles in evolution. In contrast, the precise evolutionary contribution of temporal expression dynamics remains poorly characterized. We are studying the gene regulatory network underlying heart lineage specification in the invertebrate chordate, Ciona intestinalis. Microarray analysis has delineated distinct temporal clusters of heart genes that are up-regulated within the first two hours of specification. Through both in-silico and wet bench analysis, we have begun to unravel the regulatory logic mediating discrete temporal gene expression. Our findings suggest that both early and late heart genes are regulated by the same primary transcription factor, Ets1/2. However, Ets1/2 pairs with distinct co-factors to generate differential temporal outputs. We are currently exploring how this "paired input" regulatory logic may influence the robustness of temporal gene regulation and thus constrain or potentiate adaptation.

S2-2.1 WRIGHT, Patricia A; University of Guelph, Guelph, ON Canada; *patwrigh@uoguelph.ca*
Environmental Physiology
Mangrove rivulus (*Kryptolebias marmoratus*) are hardy amphibious fish, unique for their reproductive behaviour, as well as their ability to survive > 1 month out of water relying solely on the cutaneous surface for respiration. As water quality deteriorates (eg. hypoxia), neuroepithelial cells in the gills and skin respond to low oxygen levels and trigger a ventilatory response, while more severe or prolonged hypoxia induces emersion. Over the first week of air exposure, metabolic rate increases, cutaneous angiogenesis occurs and effective gill surface area is reduced as a consequence of gill remodeling. The skin is a key site of nitrogenous waste excretion and iono/osmoregulation in air-exposed *K. marmoratus*. Mangrove rivulus are ammoniotelic and volatilize a significant amount of ammonia as the gas NH_3 across the cutaneous surface when out of water. Ion transporting cells (ionocytes) are present in both gills and skin, but in air-exposed *K. marmoratus* skin ionocytes enlarge when fish are in contact with a moist hypersaline solution. These findings indicate that reversible cellular and morphological changes to the skin and gills during air exposure probably enhance the cutaneous contribution to ion, nitrogen and water balance.

100.4 WRIGHT, C.W.*; MOELLER, K.M; DENARDO, D.F.; Arizona State Univ., Tempe; *cwright729@hotmail.com*

Do low energy systems practice state-dependent foraging strategies?

Much of the existing literature on the influence of physiological state on foraging decisions (e.g., state-dependent foraging) examines high energy systems (i.e., birds and mammals). Assessing such interactions in low energy systems (i.e., vertebrate ectotherms) that feed infrequently and thus are typically in negative energy balance can provide insight into the broad applicability of current theories on the mechanisms that drive foraging behavior, thus furthering our understanding of state-dependent foraging strategies. We conducted a supplemental feeding experiment to investigate how meal consumption alters acute behavioral responses as well as chronic (seasonal) physiological and behavioral responses of Gila monsters, *Heloderma suspectum*. Radiotelemetered, free-ranging Gila monsters were supplementally fed or sham-manipulated throughout their active season, and we serially assessed physiological stores (body mass, energy stores via tail volume, and hydration state via plasma osmolality), field metabolic rate (FMR) using doubly labeled water, and behavioral responses (proportion of time spent surface active). We present the results of the impact of meal consumption on short-term behavioral responses as well as seasonal variations in physiological stores, FMR, and activity levels, discussing these results within the context of state-dependent foraging strategies and mechanisms driving foraging decisions in organisms across taxa.

S8-1.1 WUND, Matthew/A; The College of New Jersey; *wundm@tcnj.edu*

Introduction to the Symposium: Assessing the Role of Developmental Plasticity in Evolutionary Innovation and Diversification

Conventional thinking proposes that the environment has a single function in adaptive evolution: to supply the selective pressures that shape phenotypic and genetic variation across generations. In addition to this role, however, the environment also impacts the phenotypic variation upon which those selective pressures act because of individual phenotypic plasticity. Recent conceptual and theoretical models support the hypothesis that the form of, and variation among, plastic responses in a population can substantially impact both the rate and outcome of adaptive evolution. However, empirical tests of this hypothesis remain elusive because any impacts of phenotypic plasticity on the early stages of adaptive evolution will likely be transient, and thus difficult to document. The focus of this talk will be to highlight recent advances in overcoming this challenge, with particular emphasis on using the threespine stickleback fish as a model system. I will also discuss future research avenues that apply to a number of potentially informative systems, such as invasive species and natural populations impacted by anthropogenic activity, in an effort to help empirical evidence keep pace with theory.

S10-2.4 YAMAGUCHI, S.*; SAWADA, K.; YUSA, Y.; Kyushu Univ., Fukuoka, Japan, JSPS, Grad. Univ. Adv. Stud. (SOKENDAI), Kanagawa, Japan, Nara Women's Univ., Japan; *syamaguchi@bio-math10.biology.kyushu-u.ac.jp*

Life history and sexuality patterns in barnacles: A theoretical perspective

Darwin (1851) found that barnacles have three sexuality patterns: hermaphroditism, androdioecy (coexistence of hermaphrodites and males) and dioecy (females and males). Males are always very small and associated with larger females or hermaphrodites, and are called "dwarf males". In this presentation, we review our theoretical studies on the evolution of sexuality patterns and male dwarfing in barnacles. The extent of male dwarfing (male body size relative to size of females or hermaphrodites) varies among barnacle species. In the first model (Yamaguchi et al. 2007), we studied optimal life history strategy to explain the variation in male body size. We concluded that poor food availability and reduced sperm competition due to dioecy (as compared with androdioecy) lead to extensive degree of male dwarfing. We (Yamaguchi et al. 2008) then expanded Charnov's (1987) model on the evolution of barnacle sexuality to incorporate the settlement pattern of larvae and food availability. In our model, the three patterns of sexuality evolve depending on these parameters. In these models, size distribution is given in advance. However, size distribution, as well as sexuality patterns, is a result of life history evolution. Therefore, our next model (Yamaguchi et al. in prep.) integrated both life history theory and sex allocation theory. We investigated the effects of mortality and food availability on sexuality. Our model showed that rich food and low mortality lead to hermaphroditism, poor food and high mortality to dioecy, and intermediate conditions to androdioecy. We compare our results with information on various barnacle species, and aim to unify theoretical and empirical evidence.

29.5 YAMAGUCHI, Emi*; SEAVER, Elaine C; University of Hawaii at Manoa, Kewalo Marine Lab; *emiy@hawaii.edu*

Developmental potential of embryonic cells to generate larval and juvenile eyes in the polychaete Capitella teleta

In spiralian animals, a common stereotypic cleavage program gives rise to adult animals with diverse body plans, such as polychaete annelids and bivalve mollusks. The spiral cleavage program allows for the unique identification of cells in the early embryo, which in many cases give rise to similar body regions across a broad range of taxa. In this study, we address the developmental potential of cells to generate eyes, a complex sensory organ, in the polychaete annelid *Capitella teleta*. In *C. teleta* and many other spiralians, the larval eyes are generated by the 1a and 1c lineages. We used single-cell laser ablation techniques to experimentally delete the 1a or 1c lineage, which resulted in larvae missing the left or right eye, respectively. Our results suggest that the eyes are specified by 1a and 1c as early as the 8-cell stage in *C. teleta*, and other cells are unable to regulate for the loss of these cells. Double ablation of both the 1a and 1c cells results in animals with no eyes and a reduced head. Ablations for the daughter cells of 1a and 1c that generate the eyes, $1a^1$ and $1c^1$, resulted in larvae missing the left or right eye, respectively. In addition, we addressed the question of larval eye regeneration and the origin of the adult eyes through direct ablation of the larval eyes. When the left eye is ablated in a larval stage animal, the eye does not regenerate, even after several days. The left eye is also missing in post-metamorphic juveniles, suggesting that the cells of the larval eyes contribute to the juvenile/adult eyes. These results suggest that the potential for eye development is strictly confined very early in the embryo to the lineages that eventually generate the eye, and it is likely that no other cells have the potential to develop eyes.

S7-1.4 YEN, J.*; WEBSTER, D.; MURPHY, D.; CATTON, K. ; MITTAL, R.; ZHENG, L.; Georgia Tech, Colorado State University, Johns Hopkins University; *jeannette.yen@biology.gatech.edu*

Wake signatures formed at intermediate Re regimes: signals of prey, predators, mates or schoolmates.

What happens when an aquatic biologist works together with fluid dynamics engineers? Do we lose a bit of our identity or are we enhanced and entranced? For me (JY), it's been the latter. We've been working with planktonic organisms that operate at intermediate Re, some residing mostly in the viscous regime, others mostly in the inertial regime and then those that dip into both. The adaptations to each regime and the dynamics of the behavior when in transition are fascinating. I'd like to share what we've learned about jetting copepods, paddling krill and flapping pteropods from investigations of their propulsion kinematics, flow field dynamics and computational fluid dynamic models. While the analyses focus on propulsion, the objective is to understand the wake signatures left by the swimming plankton and their importance as signals sensed by prey, predators, mates or schoolmates. Plankton generate watery signals that can be attenuated by viscosity and confused with small-scale turbulence. Yet messages are created, transmitted, perceived and recognized. These messages guide essential survival tasks of aquatic organisms. At the small-scale where biologically-generated behavior differs from physically-derived flow, we find plankton self-propel themselves, are aware of each other, and evolve in response to the fluid environment in surprising ways.

S4-1.4 YOUNG, C.M.*; HE, R.; EMLET, R.B.; LI, Y.; QIAN, H.; ARELLANO, S.M. ; VAN GAEST, A.L.; BENNETT, K.; SMART, T.I. ; WOLF, M.; RICE, M.E.; University of Oregon, North Carolina State University, North Carolina State University, Smithsonian Marine Station, Ft. Pierce; *cmyoung@uoregon.edu*

Larval life and dispersal potential of deep-sea animals from the Intra-American Seas

Using ocean circulation data, we modeled the potential dispersal distances for 7 species of bathyal invertebrates whose durations of larval life have been estimated from laboratory rearing, MOCNESS plankton sampling, spawning times and recruitment. Methane seep species from the Gulf of Mexico included the gastropod *Bathynerita naticoidea*, the bivalve *Bathymodiolus childressi* and the siboglinid polychaete *Lamellibrachia luymesi*. Non-seep species included the asteroid *Sclerasterias tanneri* from the Gulf of Mexico, the echinoids *Cidaris blakei* and *Stylocidaris lineata* from the Bahamas, and the sipunculan *Phascolosoma turnerae*, which is found in Barbados, the Bahamas and the Gulf of Mexico. Pelagic larval durations ranged from 3 weeks in lecithotrophic tubeworm larvae to 2 years in planktotrophic starfish larvae. Larval trajectories were modeled with the LTRANS Lagrangian larval transport model (Schlag et al., 2008) using ocean circulation hindcasts produced by either the South Atlantic Bight and Gulf of Mexico (SABGOM) ocean model or the Global HyCOM ocean model. The model predicted significant monthly variation in transport directions and distances for species that reproduce continuously, and significant inter-annual variation in species with seasonal breeding. For example, planktotrophic sipunculan larvae from the Northern Gulf of Mexico were capable of reaching the mid-Atlantic off Newfoundland, a distance of more than 3000 km during a 7-month drifting period, but the proportion retained in the Gulf of Mexico varied significantly among years. Larvae drifting in the upper water column had much longer trajectories than larvae drifting for the same amount of time at bathyal depths. Model results are in strong agreement with genetic information on seep species in the Gulf of Mexico.

71.7 YUND, P.O.*; TILBURG, C.E.; MCCARTNEY, M.A.; University of New England, University of North Carolina - Wilmington; *pyund@une.edu*

Is the southern range boundary of the northern blue mussel, Mytilus trossulus, determined by constraints on larval dispersal?

Constraints on larval dispersal can theoretically limit the range of marine invertebrates, but there are few concrete examples. The northern blue mussel, *Mytilus trossulus*, co-occurs with its congener, *M. edulis*, throughout the Canadian maritime provinces but abruptly decreases in abundance just south of the Bay of Fundy. The prevailing current in this area, the Eastern Maine Coastal Current (EMCC), flows from northeast to southwest, so upstream source populations should be plentiful and larval abundance high. However, the EMCC diverges from shore where *M. trossulus* abundance decreases, suggesting that limited mixing between the EMCC and nearshore waters may prevent larvae from returning to the coast. We tested this hypothesis by regularly collecting hydrographic and larval density data along a series of three transects, each of which extended from the nearshore waters out into the EMCC. Data from temperature loggers and an oceanographic buoy provided continuous time series to supplement the snapshot data from our cruises. Analysis of the hydrographic data indicates limited wind-driven across-shelf mixing in the northeast portion of our study region, but virtually no mixing to the southwest. Mussel larval densities were largely consistent with predictions from the hydrographic study, suggesting that a diverging coastal current can limit across-shelf larval dispersal. However, because these water masses differ in temperature, we are also considering the alternative hypothesis that the range boundary is set by thermal tolerance. We are currently testing this hypothesis via transplant experiments with juveniles and in the future will be conducting laboratory temperature experiments with larvae.

43.4 ZABALA, F.A.*; DICKINSON, M.H.; Univ. of Washington; *zabala@caltech.edu*

Vision-based altitude control in freely flying Drosophila

Insects are thought to achieve robust flight stability through the implementation of rapid sensory-motor reflexes. Specialized interneurons within their visual system detect unintended rotations and translations during flight and convey that information to motor circuits that generate compensatory changes in wing motion. Until recently, most investigations of sensory motor reflexes in Drosophila have utilized tethered animals, but such conditions are known to generate artifacts. Measuring the subtle changes in wing motion that are elicited by visual input in free flight requires both very high spatial and temporal resolution, and the ability to track a flying animal within a suitably large region of space. To this end, we have developed an arena in which we can present arbitrary visual stimuli to freely flying fruit flies, and record with high definition their behavioral responses using 3D high speed videography. As the insects traverse a small volume in the arena, a laser-based detector circuit triggers a moving visual pattern displayed on a cylindrical panorama of LEDs. By analyzing the open-loop responses of the animals to the visual motion, we are able to characterize with high accuracy the changes in wing and body motion that are elicited during visually-mediated compensatory flight reflexes. The high-throughput in our analysis is facilitated by implementation of automated tracking software that incorporates 3D kinematic measurements from an image-based visual hull, a parameterized generative model of the fly, and a Sigma-Point Kalman Filter for parameter estimation. In a preliminary study, we investigated the altitude control response, which we elicited by vertically displacing a horizontal grating on the walls of the flight chamber. When presented with this stimulus, flies adjust their wing motion to generate a syndirectional flight response, which can be interpreted as an attempt to minimize the slip of the pattern on their retina.

S3-2.2 ZAKAS, Christina*; WARES, John P; University of Georgia; *christinazakas@gmail.com*

The consequences of a poecilogonous life history for dispersal ability, genetic structure and gene flow in coastal populations of the polychaete Streblospio benedicti

In many species, alternative developmental pathways lead to the production of two distinct phenotypes, promoting the evolution of morphological novelty and diversification. One such species, the poecilogonous marine annelid *Streblospio benedicti*, is an ideal system to study the evolutionary consequences of larval life history mode because adults either produce many small planktotrophic larvae that spend weeks feeding in the water column, or fewer, larger lecithotrophic larvae that complete development more rapidly. Larval type influences transport time by ocean currents, which dictates dispersal potential and gene flow, and thus has sweeping evolutionary effects on the potential for local adaptation and on rates of speciation, extinction, and molecular evolution. Here we further develop *S. benedicti* as a model system for studies of life history evolution by using next-generation sequencing to characterize the transcriptome for a pooled set of embryos, larvae, and juveniles. We developed and validated 84 novel single nucleotide polymorphism (SNPs) markers for this species that we use to distinguish populations on the U.S. East and West Coast. Using these markers we found that in their native East Coast, populations of *S. benedicti* have high population genetic structure, but that this structure is dictated predominately by geography rather then developmental type. Interestingly, very little genetic differentiation is recovered between individuals of different development types when they occur in the same or nearby populations, further supporting that this is a true case of poecilogony. In addition, we were able to demonstrate that the recently introduced West Coast populations (~100ya) likely originated from a lecithotrophic population in Delaware.

51.5 ZATTARA, E.E.*; BELY, A.E.; University of Maryland, College Park; *ezattara@umd.edu*

A modern view of annelid "neoblasts": live 4D imaging reveals widespread cell migration during annelid regeneration

The ability of some cell types to retain wide differentiation potential beyond embryogenesis is a crucial element of adult regenerative biology. One of the most well-known examples of totipotent adult stem cells are cells referred to as neoblasts, migratory cells with a large nucleus/cytoplasm ratios that have been described in both annelid and planarian regeneration. In annelids, neoblasts are thought to migrate along the ventral nerve cord to the wound site and proliferate to form a significant fraction of the regenerated tissues. This model has been widely accepted despite the fact that actual evidence for neoblast migration is only indirect, there has been an evident bias towards the study of large and histologically conspicuous cells, and there are no hard data on neoblast function or fate. While the neoblast model of regeneration has been well supported in planarians, the role of neoblasts in annelid regeneration is still unclear. We developed a novel 4D live imaging technique to obtain high-resolution time-lapse recordings of naidid annelids over many days, allowing us to capture the complete regeneration process. Using this technique, we have obtained the first direct evidence of cell migration towards wound sites, and characterized migration speeds, migration routes, and migrating cell types during regeneration. We find that the cell migration response to injury is much more widespread than what the current neoblast model suggests, involving diverse cell types and diverse migration routes. This study lays the groundwork for planned cell tracing and gene expression studies intended to test the role of neoblasts and other migratory cells in annelid regeneration.

98.6 ZENG, Yu*; DUDLEY, Robert; Univ. of California, Berkeley; *dreavoniz@berkeley.edu*

Wing Reduction and Flight Biomechanic in Stick Insects (Insecta: Phasmatodea)

Many unresolved questions in insect flight evolution relate to the transition between flightless and flying insects. Functional analysis of transitional forms using anatomical intermediates may help to explain how complex morphology and biomechanical features evolved. The stick insects exhibit a wide spectrum of wing size variation, and our recent study revealed diverse flight performances associated with these wings. The venation and membrane morphology were quantitatively studied in wings of different sizes, and the results showed a continuous structural reduction and simplification along the size gradient. Assisted with high-speed filming and motion analysis, we examined the biomechanics of flight performed with different wings, from full flapping capacity to parachuting with winglets. In wings of reduced sizes, we found rudimentary wing kinematics, specialized behavior and distinctive aerodynamic features different from typical flapping wings. Comparison among different flight modes suggested a transitional pattern in the aerodynamic functions coupled with relative wing size. Our results demonstrated a connection between intermediate wing morphology and various forms of gliding flight in an arboreal context. The adaptive significance of these wing designs may help to understand the evolutionary transitions between flightless and volant forms.

108.4 ZIMMERMAN, L. M.*; CLAIRARDIN, S. G.; PAITZ, R. T.; HICKE, J. W.; VOGEL, L. A.; BOWDEN, R. M.; Il. St. Univ.; *lmzimme@ilstu.edu*

Humoral immunity to lipopolysaccharide in a long-lived ectotherm

Immunosenescence, a decrease in immune function with age, does not affect all immune responses in the same manner. In humans, specific antibody responses decrease with age while non-specific antibodies increase. This reduction in specific antibody responses has been viewed as a contributor to the increase of mortality and morbidity with increasing age. Like humans, reptiles show an age-specific increase in non-specific antibodies, but unlike humans, reptiles of all ages have a less robust specific antibody response. Thus, the increase in non-specific antibodies may constitute an improvement in immune defense. However, the characteristics of the humoral response beyond quantity have not been determined. This study examined humoral immune responses in the red-eared slider turtle, *Trachemys scripta*, to lipopolysaccharide (LPS), a component of Gram negative bacteria. LPS is a T-independent antigen, meaning B cells can respond to it without help from T cells. Adult turtles were trapped and blood samples were taken at three points during the active season. Because red-eared sliders grow throughout their lifetime, plastron length was measured as a proxy for age. Leukocytes were isolated and their ability to produce antibodies in response to LPS stimulation was measured using an ELISpot assay. An ELISA was used to measure total immunoglobulin levels (Ig) and LPS-specific antibodies (Abs) in plasma. LPS Abs significantly increased with age, while antibody response to stimulation did not vary with age. Our results show no evidence of immunosenescence in humoral immunity to LPS. Therefore, in reptiles, unlike in humans, changes in humoral responses may not cause impairment in immune defense with age.

50.3 ZOHDY, S*; KEMP, A.D.; DURDEN, L.A.; WRIGHT, P.C.; JERNVALL, J; University of Helsinki, University of Texas, Austin, Georgia Southern University, Statesboro, Stony Brook University, Long Island; *sarah.zohdy@helsinki.fi*
Mapping the Social Network: Tracking lice in a wild primate population (Microcebus rufus) to infer social contacts and vector potential
The brown mouse lemurs (*Microcebus rufus*) of Madagascar's southeastern rainforests are small (40g), arboreal, nocturnal and cryptic solitary foragers for which data on population-wide interactions are difficult to obtain despite advances in relevant technology. We developed a simple method of inferring mouse lemur interactions by tracking the transfer of sucking lice (*Lemurpediculus verruculosus*) to compare with ranging estimates based on trapping data. We hypothesized the frequency of louse transfers, and thus interactions, will decrease with increasing distance between the trap locations of individuals. Lice were marked with a host specific color code and tracked as they moved throughout the population. As sucking lice are known pathogen vectors this method simultaneously provided insight on the population's parasite ecology. We predicted individuals would play varying roles in the population's overall disease transmission ecology: specifically, lemurs whose ranges overlap with more individuals have higher vector potentials. Despite limited and stereotypic trap locales per individual, the parasite transfer data indicate that the probability of contact between any two individuals (and hence louse transferal) does not vary with increasing distance. These results indicate wider ranging behavior of mouse lemurs and a higher chance for rapid population-wide pathogen transmission than based on trapping data alone. Our approach demonstrates the potential to make available otherwise inaccessible social interaction data on any trappable species parasitized by host-specific sucking lice.

117.6 ZYSLING, DA*; PARK, S-U; MCMILLAN, EL; PLACE, NJ; Cornell Univ, Ithaca NY; *daz32@cornell.edu*
Gonadotropin suppression alone does not induce the short-day ovarian phenotype in Siberian hamsters
Many seasonal breeders time their reproductive effort to the spring and summer months to insure adequate resource availability for the production and care of young. Females born before the summer solstice (long days, LD) reach maturity quickly and often breed that same year. In contrast, females born after the summer solstice (short days, SD) may delay reproductive development to the following spring when conditions are favorable. In Siberian hamsters, development in SD is associated with significant structural and functional differences in the ovary as compared to females held in LD. These SD-induced differences include a greater number of primordial follicles and an abundance of hypertrophied granulosa cells (HGCs), which are immunoreactive for anti-Müllerian hormone (AMH). Ovarian developmental differences in SD are thought to result from suppression of gonadotropins, but this hypothesis has not been adequately tested. Therefore, the goal of this study was to determine whether gonadotropin suppression explains the SD ovarian phenotype. Specifically, we treated LD females with the GnRH antagonist acyline every other day, beginning at weaning (postnatal day 18) and continuing until 10 wk of age. Control LD and SD females were similarly treated with vehicle. We found that acyline induced SD-like decreases in ovarian and uterine horn mass and serum FSH and AMH. Conversely, primordial follicle numbers and ovarian *Amh* mRNA levels were not significantly different than in controls, and HGCs were not observed. Our data suggest that gonadotropin suppression alone does not completely account for the SD ovarian phenotype and other factors may be involved, including SD-induced changes in other hormones, such as melatonin and prolactin. This possibility will be the subject of future studies.

82.2 ZYLBERBERG, M*; LEE, KA; KLASING, KC; HAHN, TP; WIKELSKI, M; UC Davis, Max Planck Institute for Ornithology; *mzylberberg@ucdavis.edu*
Change in Avian Pox prevalence varies by species and land use type in Galápagos finches
Introduced disease has been implicated as an important factor in recent extinctions and population declines. Avian pox (AP), a pathogen implicated as a major factor in avian declines and extinctions in Hawaii was introduced to the Galápagos in the last century. While AP is thought to have increased in prevalence in recent years, no study has carefully evaluated the threat this disease poses to the Galápagos avifauna. In this paper, we examine the course of the AP epidemic in seven species of Galápagos finch on Santa Cruz Island, Galápagos. We describe temporal change in infection and recovery rates from 2000-2009. Then, we test two hypotheses regarding geographic variation and temporal patterns in disease prevalence: specifically, that AP prevalence and recovery trends vary 1) by altitude, or 2) according to human land use patterns. We show that AP prevalence has increased dramatically from 2000-2009. However, we find that this increase in prevalence varies by species and by geographic location. Specifically, while small ground finches, small tree finches, warbler finches, and cactus finches appear to suffer high mortality rates from the disease, medium ground finches appear much less susceptible. In addition, populations in agricultural areas appear to be much harder hit than those in either urban or undeveloped areas. In both cases, variation in innate immune function at least partially explains apparent variation in susceptibility to AP. We conclude that AP poses a threat to the integrity of the Galápagos avifauna, and that more work is needed to understand why certain species and populations appear to be particularly affected by this disease.

Poster Abstracts

P3.90 ABDELHADY, A; CORTES, R*; MUSUMECI, S; SRINIVASAN, D; SHIGENOBU, S.; STERN, D; KOBAYASHI, S; Rowan University,NJ, NIBB,Japan, Howard Hughes Medical Institute,MD; *cortes48@students.rowan.edu*

Investigation of the role of Aubergine RNA-binding proteins in the reproductive plasticity of the pea aphid, Acyrthosiphon pisum

Environmental changes can elicit alterations in the form, behavior and/or physiology of all species, and this developmental response to environment is known as phenotypic plasticity. Despite its ubiquity, the molecular basis for phenotypic plasticity is not fully understood. The pea aphid, *Acyrthosiphon pisum*, serves as a model for an extreme form of phenotypic plasticity, known as polyphenism. Changes in photoperiod stimulate a switch in female aphid reproductive mode from asexual to sexual reproduction over the course of one generation without changes in genotype. This reproductive polyphenism results in female aphids with ovaries of one of two types: sexual ovaries (producing haploid oocytes via meiosis), or asexual ovaries (producing identical diploid aphid clones via parthenogenesis). To better understand how aphid ovaries could produce different outputs, we surveyed the transcriptomes of sexual and asexual ovaries using RNA-seq. Among genes that exhibited greater than two-fold differences in gene expression between sexual and asexual ovaries, we identified several *aubergine* paralogs, which encode for germline-specific members of the Argonaute small RNA-binding protein family. The *A. pisum* genome contains eight *aubergine* paralogs and at least two *piwi* paralogs. We are currently comparing the expression patterns of these aphid *aubergine* paralogs between asexual and sexual aphid ovaries. Aubergine proteins in other species are thought to help suppress the activity of transposable elements, which are found in high quantities throughout the *A. pisum* genome. Together, these experiments will help elucidate a potential relationship between *aubergine* paralogs and aphid reproductive plasticity.

P1.62 ABUHAGR , A. M.*; CHANG, E. S.; MYKLES, D. L.; Colorado State Univ., UC Davis Bodega Marine Lab; *aliabuhagr@gmail.com*

Role of mTOR and TGFβ in Y-organ activation during the crustacean molting cycle

Molting in decapod crustaceans is controlled by molt-inhibiting hormone (MIH), an eyestalk neuropeptide that suppresses production of ecdysteroids by a pair of molting glands (Y-organs or YOs). In the blackback land crab, *Gecarcinus lateralis*, molting is induced by eyestalk ablation (ESA) or autotomy of 5 or more walking legs. The YO transitions through four physiological states during the molting cycle: "basal" state at postmolt and intermolt; "activated" state at early premolt (D0); "committed" state at mid premolt (D1,2); and "repressed" state at late premolt (D3,4). The basal to activated state transition is triggered by a transient reduction in MIH; the YOs hypertrophy, but remain sensitive to MIH, as premolt is suspended by MIH injection or by limb bud autotomy (LBA). Metazoan Target of Rapamycin (mTOR), which controls global translation of mRNA into protein, appears to be involved in YO activation in early premolt. Rapamycin (1 µM) inhibited YO ecdysteroidogenesis in vitro. Injection of rapamycin (10 µM final) lowered hemolymph ecdysteroid titer in 1, 3, 7, and 14 day post-ESA animals. At the activated to committed state transition, the animal becomes committed to molt, as the YO is less sensitive to MIH and premolt is not suspended by LBA. YO commitment involves a putative transforming growth factor-beta (TGFβ)-like factor. Injection of SB431542 (10 µM final), a TGFβ receptor antagonist, lowered hemolymph ecdysteroid titers in 7 and 14 day post-ESA animals, but had no effect on ecdysteroid titers at 1 and 3 days post-ESA. The goal now is to determine the effects of molting, rapamycin, and SB431542 on the expression of mTOR signaling components (mTOR, Rheb, Akt, and S6K) using quantitative PCR. Supported by NSF (IOS-0745224).

P2.32 ACKERLY, K. L.*; WARD, A. B.; Adelphi University; *kerriackerly@yahoo.com*

More of a good thing: The positive relationship between vertebral number and performance

Environmental conditions significantly affect the development, morphology, and performance of aquatic vertebrates, as shown by previous research in diverse groups of aquatic vertebrates, including fishes and amphibians. Studies have shown that temperature during development affects vertebral morphology, such that individuals reared at higher temperatures tend to develop a lower number of vertebrae than individuals reared at lower temperatures. Studies have also displayed the impact of vertebral morphology on performance. In order to demonstrate the relationship between environmental conditions and performance through morphology, we investigated the relationship between the effect of temperature on vertebral development, and the subsequent effect of any discrepancy on burst swimming performance in two model aquatic vertebrates, zebrafish (*Danio rerio*) and axolotls (*Ambystoma mexicanum*). Embryos of both species were collected and evenly distributed among a range of species appropriate temperatures prior to the onset of somitogenesis. Following development, startle responses were recorded and individuals were analyzed for either vertebral number or muscle fiber composition. Our results indicate that small fluctuations in temperature can significantly influence an individual's vertebral development, which can then subsequently impact survival. We found that individuals reared in higher temperatures develop a lower number of total vertebrae and a less favorable ratio of pre-caudal to caudal vertebrae for maximum performance. As a result of these morphological discrepancies, these individuals were found to have decreased burst swimming performance, as they achieved significantly less velocity and a slower overall response time. Placing these results in the context of a changing climate, these results indicate the significant impacts of rising temperatures on aquatic vertebrates.

P2.29 ADAMS, D.K.*; NOWAKOWSKI, N.M.; ANGERER, L.A.; National Institutes of Health, Bethesda, MD, American University, Washington, DC; *adamsdi@mail.nih.gov*

Evolution of food-induced developmental plasticity in echinoids

Recent work in the model echinoid, *Stronglyocentrotus purpuratus*, has shown that phenotypic plasticity during the pre-feeding larval stage is mediated by a food-induced dopamine signal that alters the developmental program. Elucidation of part of the mechanism allows us to probe Echinoidea to determine when developmental phenotypic plasticity arose in larval urchins, with the long-term goal of uncovering the evolutionary and mechanistic steps by which an environmental signal becomes integrated into the developmental program. Within the regular urchins, a derived and basal species showed a developmental response to food mediated by dopamine. Another regular urchin, *Lytechinus variegatus*, did not demonstrate a phenotypic response to food, but did alter arm length in response to dopamine signaling and developed putative dopaminergic neurons in an appropriate temporal and spatial pattern. Thus, while the developmental response to food may have been lost in some regular urchins, the underlying molecular mechanism remained intact supporting the conservation of developmental plasticity within this clade. In a sister clade, larvae of multiple sand dollars lacked both the developmental response to food as well as a response to dopamine and delayed development of dopaminergic neurons until after the prefeeding period. Initial examination of the pencil urchin, which is basal to both the regular urchins and the sand dollars, also revealed no response to food and dopamine, but putative dopaminergic neurons did develop in a temporal and spatial pattern similar to that of the regular urchins. Thus, our preliminary results suggest that the developmental response to algae was an innovation of the regular urchins (Echinacea) that built upon neurobiology already present in basal echinoids.

P1.81 ADDIS, E.A.*; BOURY, N.M; POWELL-COFFMAN, J.A.; Iowa State University; *addis@iastate.edu*
Scientific Reasoning Skills in Introductory Biology
At Iowa State University, over 1500 students take introductory biology each year, representing 40 different majors. Historically, introductory biology courses have emphasized the memorization of material, and this has left little time to devote to developing scientific skills. The large number of students taking these courses and the diversity of student backgrounds creates unique challenges; it also presents important opportunities to inspire student interest, teach important concepts, and develop scientific reasoning skills. In Fall 2010, Iowa State University initiated a program to transform first and second year science courses to increase student success in scientific disciplines. Working with this program, ISU faculty have initiated a multi-step program, including the organization of a Biology Faculty Learning Community (BioFLC). The goals of the BioFLC include clarifying and communicating course learning objectives, particularly those focused on scientific reasoning skills learning objectives, and developing strategies for student-centered active learning in high enrollment courses. To achieve these goals, we have developed POGIL activities that combine active and problem-based learning to teach scientific reasoning skills for the two-semester introductory biology sequence. These activities will challenge students to solve authentic problems that require scientific reasoning skills. Beginning in Fall 2011, we have given a scientific reasoning skills assessment as pre- and post-tests to measure learning gains in both courses that implement the active learning exercises and those that do not. Not only will this assessment provide us with feedback regarding the efficacy of the approach, but it will also provide information regarding specific skills on which future activities should focus.

P1.153 ADKINS, ZE*; DE BURON, I; ROUMILLAT, WA; MCELROY, EJ; College of Charleston, South Carolina Department of Natural Resources; *zeadkins@g.cofc.edu*
The effect of a myxosporean parasite, Kudoa inornata, on the flesh quality of spotted seatrout, Cynoscion nebulosus
Spotted seatrout, *Cynoscion nebulosus*, is an important game fish in SC estuarine waters. Unofficial reports from fishermen say that the flesh of spotted seatrout is often ‘mushy’ during warm months and thus unappealing. Concurrently, the presence of a myxosporean parasite, *Kudoa inornata*, has been observed in SC populations of the fish. One closely related *Kudoa* species is known to induce post-mortem myoliquefaction (‘mushiness’) in other species of fish by secreting enzymes. We investigated the effects of this parasitic infection on the flesh quality (‘mushiness’) of spotted seatrout. We expected that greater parasite intensity and greater time post-mortem would reduce the maximum strain that a muscle sample could withstand. Results suggest that higher parasite loads, but not time post-mortem, result in a fillet that has a more ‘mushy’ quality. Thus, infection by this myxosporean parasite may explain reports from fishermen.

P2.187 AGUILAR, J.J.*; LESOV, Alex; WIESENFELD, Kurt; GOLDMAN, D.I.; Georgia Tech, Atlanta GA; *gth657s@mail.gatech.edu*
Lift-off in a hopping robot
Jumping from rest has been studied for different initial movement strategies. For example, Bobbert et. al, 1996 found that among the countermovement jump and three different variations of the squat jump, the countermovement achieved maximum jump height. To systematically determine how actuation strategy affects movement amplitude needed to achieve lift-off, we studied an actuated robotic instantiation of the 1-D spring-loaded inverted pendulum (SLIP) model, commonly used to study hopping and running in humans and animals. The 1 kg robot consisted of a prismatic actuator (a tubular linear motor) connected in series to a linear spring (2.8 to 12.2 kN/m) which can make contact with the ground. A continuity sensor recording at 1000Hz on the bottom of the spring determines if the robot is in contact with the ground. The motor is forced to move starting from rest in a sinusoidal trajectory at a specific frequency and amplitude, and phase, and the number of oscillations required before lift-off is recorded. We measured number of cycles to lift-off, N, as a function of forcing amplitude, frequency, and initial phase. Since resonance in a linear spring-mass system occurs at the natural frequency, we expected that the optimal forcing frequency required for lift-off, defined as the frequency f0 at which forcing amplitude is a minimum, would be the natural frequency. We found that this is true when $N>\sim 2$, but not necessarily the case for $N<\sim 2$. For $N<1$, f0 is sensitive to the initial phase of the driving. A theoretical model of the robot captured these observed phenomena.

P3.52 AHRENS, J. B.*; BORDA, E.; CAMPBELL, A. M.; SCHULZE, A.; Texas A&M University at Galveston; *jba462@neo.tamu.edu*
High degree of connectivity among amphi-Atlantic populations of Hermodice carunculata (Amphinomidae, Annelida)
Polychaete annelids in the genus *Hermodice* exhibit an amphi-Atlantic distribution extending into the Gulf of Mexico as well as the Caribbean and Mediterranean Seas. Currently, this genus contains two nominal species; *H. carunculata*, which inhabits the Grand Carribbean, and *H. nigrolineata* which is found in the Mediterranean and along the African Atlantic coast. In this study, we analyzed DNA sequence data from specimens in the Gulf of Mexico (GoM), the Mediterranean and Caribbean Seas to estimate population structure and phylogeographic patterns for *Hermodice*. Analysis of mitochondrial cytochrome oxidase subunit I (COI) and 16s rDNA indicates very low levels of divergence between Grand Caribbean and Mediterranean specimens. Preliminary analyses using the nuclear internal transcribed spacer (ITS) and 28s rDNA also reveal low genetic distance between these two groups, suggesting that the results observed for COI and 16s rDNA are not merely attributable to mitochondrial recapture. Additionally, at least three outliers from Mediterranean populations share haplotypes with Grand Caribbean specimens. Our results provide no support for the distinction between *H. carunculata* and *H. nigrolineata* and stress the importance of including molecular data as a criterion for delimiting species. Whereas other genetic studies of marine taxa often reveal the presence of cryptic species complexes, our study indicates high population connectivity across a wide geographic range for *H. carunculata*.

P2.121 AKANDE, P.*; BANDAOGO, Z.; CARROLL, M.A.; CATAPANE, E.J.; Medgar Evers College, Brooklyn, NY; *patrickbkaka@yahoo.com*

Sensory Motor Integration of Gill Lateral Cilia in the Bivalve Mollusc, Crassostrea virginica

Gill lateral cilia of *Crassostrea virginica* are controlled by serotonergic-dopaminergic innervation from their ganglia. Most bivalves that have been studied also have lateral cilia which respond to serotonin and dopamine indicating a neuro or endocrine mechanism. While the motor aspects of this control have been studied over the years, the sensory side has not and there is limited information available about sensory inputs beyond that of temperature and salinity changes. We examined effects of sensory cues on beating rates of lateral cilia of gill of *C. virginica*. Cilia beating rates were measured in whole animal preparations. Irritating the mantle rim by brushing with a metal probe caused a 70% drop in beating rates lasting at least 15 min. Shining a light on mantle rim decreased beating by 50%. Applying crab extract reduced beating rates to zero. When the branchial nerve, was cut the crab extract did not have any effect on the cilia. When the cerebrovisceral connective was cut the basal cilia rate was lower than controls and the crab extract was effective in slowing beating rate. Since the mantle rim is a major site of sensory cells in the animal, we excised the rim from the animals and applied crab extract. The absence of the mantle rim prevented the crab extract from affecting beating rates. The study shows a sensory-motor integration of the beating of the lateral cilia which involves the sensory rim of the mantle, and the visceral and cerebral ganglia. It appears the animals may be interpreting the sensory cues as hostile. In their natural environment, they would then close their shells and reduce water pumping rates with a corresponding drop in cilia beating rates.

P2.64 ALLARD, CA*; GRIM, JG; HU, M; PARKER, SK; POSTLETHWAIT, JH; DETRICH III, HW; Northeastern University, University of Oregon; *allard.co@neu.edu*

Exploring the role of hemgn in blood and bone formation using the zebrafish and Antarctic fish models.

The Antarctic marine fauna has been isolated in the cold (-2°C), stable, and oxygen-rich Southern Ocean for 25 million years, and consequently these animals are extremely cold-adapted. One family within the Antarctic notothenioid fishes, the icefish, has lost the capacity to produce erythrocytes and the oxygen transport protein hemoglobin. Their profound anemia makes them an evolutionary mutant model of human anemias. Using a comparative-genomic approach, we have isolated 10 novel genes that are differentially expressed by the red-blooded species *Notothenia coriiceps* and the "white-blooded" icefish, *Chaenocephalus aceratus*, and may be novel genes involved in erythropoiesis. We have identified one of these genes (*hemogen - hemgn*) as a putative ortholog of mammalian *EDAG* and *RP59*. In mammals, these genes are involved in the proliferation of blood and bone cells, however, whether the putative ortholog hemgn functions similarly in fishes has not be reported. In the current study, we use a reverse-genetic approach in a zebrafish model system to explore the functions of *hemgn* in fishes. We show that morpholino knockdown of *hemogen* mRNA in early zebrafish embryos eliminates erythrocyte production and influences the skeletal phenotype possibly by altering the expression of genes associated with hematopoiesis (e.g., *GATA1*, *SCL*, and *Globin*) and skeletal development (e.g., *Col1a1*, *Col2a1*, and *ColXa1*). These phenotypic changes can be reversed if treated embryos are co-injected with wild type *hemogen*. Together, these experiments demonstrate that *hemogen*, like *EDAG* and *RP59* in mammals, plays a role in blood and bone development, and may be a model for future translational studies into the treatment of human anemias.

P1.116 ALUCK, R/J*; WARD, A/B; Adelphi University; *robertaluck@mail.adelphi.edu*

Fish out of water: Evaluating the use of substrate during terrestrial excursions

Vertebrate body shapes are extremely diverse ranging from spheroidal to highly elongate. In fishes, body elongation is due primarily to changes in the axial skeleton. Most frequently, elongate fish species have more vertebrae than non-elongate relatives. Increases in vertebral number tend to occur region-specifically with most groups of elongate ray-finned fishes having an increased caudal vertebral number. When comparing habitats of elongate and non-elongate fishes, elongate species are often found in habitats with a great deal of vertical structure. Many elongate species are also known to move onto land for short excursions either to feed or to move between bodies of water. Previous studies have demonstrated that individuals may use "push-points" in their environment to generate forward momentum. In this study, we examined the use of substrate during terrestrial excursions by two elongate fish species that differed in their type of axial elongation (*Polypterus senegalus* and *Gymnallabes typus*) to determine whether relative body proportion affected how successfully a fish could locomote terrestrially. Individuals moved through an array of pegs with one of the pegs instrumented with two uniaxial strain gages to measure force of pushing. We found that contact times and pushing force differed in the two species. These results provide a greater understanding of how extreme changes in body shape may affect locomotion.

P3.40 ANDERSON, R A*; MCBRAYER, L D; FABRY, C J; DUGGER, P J; Western Washington Univ., Georgia Southern Univ., Western Washington Univ. ; *Roger.Anderson@wwu.edu*

Production in a desert lizard as a consequence of prey availability and annual variation in climate

In water-limited systems such as desert scrub, among year variation in precipitation and temperature should cause commensurate annual variation in the trophic cascade, with strong, dynamic linkage in energy flow up to tertiary and quaternary consumers. The long-nosed leopard lizard *Gambelia wislizenii* is a prominent diurnal mesopredator of desert scrub ecosystems of western North America. This mesopredator eats primary consumers such as grasshoppers, and secondary and tertiary consumers such as robber flies and lizards. Assuming food is limiting, then food abundance in desert scrub will directly affect this mesopredator's body condition (mass per unit body length) its ability to grow and reproduce. Hence, it is predicted that marked among-year differences in weather will have similarly marked effects on the abundance of arthropod and lizard prey of *G. wislizenii*, and will have commensurate effects on individual *G. wislizenii* and on resulting *G. wislizenii* population dynamics. For much of the past decade, arthropod and lizard prey abundances have been measured at a single field site in the northern Great Basin desert scrub in mid-summer. These data have been concomitant with focal observations, body measures, and population densities of *G. wislizenii*. Correlative analyses provide strong inferential support for linkage between climate and productivity among trophic levels in this desert ecosystem.

P3.57 ANDRYKOVICH, K.R.*; LOWE, E; SWALLA, B.J.; BROWN, C.T.; Carleton College, Michigan State University, University of Washington; *andrykok@carleton.edu*
Investigating the molecular basis of notochord loss in Molgula occulta via transcriptome sequencing
Of 3,000 total ascidian tunicate species, only approximately 20 are anural. Almost all of these anural ascidians are within the Molgulidae, a clade containing three groups of geographically differentiated species found primarily in the Northern Hemisphere. As there are closely related anural and urodele species in the Molgulidae, this clade offers an opportunity to identify pathways present only in the urodele species and effectively characterize elements necessary for notochord development. During this study, *prickle*, a gene involved in the convergence and extension of ascidian notochordal cells, was isolated by PCR from cDNA and used for *in situ* hybridization. We were especially interested in *in situ* hybridizations of the isolated genes in *M. occulta*, *M. oculata* and *M. occulta* x *M. oculata* hybrid embryos. Future studies will use the same transcriptome-guided molecular methods to isolate and perform *in-situs* for other prospective “notochordal genes.”

P1.18 ANSORGE, Kirsten*; CRANE, Daniel; CUNNINGHAM, Charles; JENNY, Matthew J; University of Alabama, University of New Mexico; *mjjenny@bama.ua.edu*
Identification of Key Members of the Aryl Hydrocarbon Receptor (AHR) Pathway and Related Oxidative Stress Genes from the American Oyster, Crassostrea virginica
Oysters (*Crassostrea virginica*) were one of the major estuarine species to be impacted by the Deepwater Horizon oil spill which released ~5 million barrels of crude oil into the Gulf of Mexico in the Spring-Summer of 2010. Although oysters are routinely used as model estuarine organisms for environmental monitoring, we know very little about their molecular response to hydrocarbon exposure. To identify potential biomarker genes, we exposed oysters to crude oil (100 ppm) or crude oil and dispersant (1 ppm) for four days. Digestive gland and gill tissues were dissected for RNA isolation. Total RNA from control and oil-exposed oysters were pooled and each tissue RNA sample was sequenced using a 454 Genome Sequencer. ~700,000 sequences reads were generated from each tissue sample. The sequences were assembled and blasted against the NCBI nonredundant database using the blastx algorithm. From these results several candidate genes were selected for characterization, including putative clones for the aryl hydrocarbon receptor (AHR), aryl hydrocarbon receptor nuclear translocator (ARNT), and three candidate cytochrome P450 1A (CYP1A) transcripts. Although CYP1A genes are classic molecular biomarkers of hydrocarbon exposure in vertebrates, very little is known regarding invertebrate CYP1A genes and their response to environmental pollutants. In addition to the AHR pathway genes several classic oxidative stress genes were identified, including superoxide dismutase, catalase, and glutathione reductase. Gene expression studies with both controlled oil exposures (0.1 to 100 ppm) and oysters collected from oil-impacted reefs are currently being used to assess the feasibility of these genes serving as biomarkers of crude oil exposure.

P2.74 ARELLANO, Shawn M.*; ZHANG, Yu; WANG, Hao; CHEN, Zhangfan; QIAN, Pei-Yuan; Woods Hole Oceanographic Institution, Hong Kong University of Science and Technology; *sarellano@whoi.edu*
Proteome and transcriptome changes associated with competency and metamorphosis in the marine gastropod Crepidula onyx
Metamorphosis of marine gastropods is generally unspectacular, with few more morphological changes than the loss of a few transient larval characters. In fact, much of the gastropod larva is already fated to be juvenile tissues by gastrulation. Nevertheless, a recent microarray study has shown widespread transcriptional changes associated with larval development and metamorphic competence of lecithotorphic abalone larvae. But whether and how these changes are translated is unclear and genomic studies through larval development are rare in lophotrochozoans. Here we provide results from a study that examines variations in transcriptome, proteome, and phosphoproteome in newly-hatched veligers, 4-day old veligers, competent veligers, and juveniles of the gastropod *Crepidula onyx*. We generated transcriptome data from each stage using titanium 454 sequencing and proteomic data using 2D gel electrophoresis followed by multiplexed staining with both a total protein stain and phosphoprotein-specific stain. Differentially expressed proteins were identified using MALDI-TOF/TOF tandem mass spectrometry and querying both existing databases and the annotated transcriptome as a reference. Key differentially regulated proteins were confirmed with western blotting and their spatial and temporal expression patterns were confirmed with in situ hybridization and real time PCR.

P2.46 ASHLEY-ROSS, MA*; PERLMAN, BM; CARPENTER-CARTER, S; GIBB, AC; EARLEY, RL; Wake Forest University, Northern Arizona University, University of Alabama; *rossma@wfu.edu*
Heads or tails? Two different ways for fish to jump
Multiple species of small littoral fish have been described to move on land by executing a “tail-flip” behavior in which the fish forcefully pushes the tail against the substrate and launches into the air. We hypothesized that possibly all teleost fish below a threshold mass, and with a fusiform body shape, would be capable of tail-flipping. We tested this idea by comparing terrestrial movements of a species known for coordinated tail-flipping, *Kryptolebias marmoratus,* with those of largemouth bass *(Micropterus salmoides),* which as adults are known to flop ineffectually on land, and are only distantly related to *K. marmoratus.* We recorded movements of juvenile largemouth bass that were sized similarly to adult *K. marmoratus* using high-speed video (500 fps) and compared movement patterns of the two species. *K. marmoratus* always jumps via the tail-flip mechanism, in which the animal lifts its head from the substrate and curls it up and over the caudal peduncle, then straightens its body, pushing the tail against the ground to spring into a ballistic trajectory that moves the animal several body lengths from its starting point. We expected that juvenile bass would use tail-flipping as well, but surprisingly found that while bass can jump, it was most often accomplished by a completely different movement pattern, in which the fish would rapidly bend its entire body toward the substrate, bringing head and tail toward one another, and launching into the air by the forceful displacement of the center of mass. Kinematics of the *M. salmoides* jumps suggest that the animal is attempting to execute stage 1 of a C-start on land, which results in minimally directed, uncoordinated terrestrial movement.

P2.28 ASKINS, M.; LONATI, G.*; GUTTENPLAN, K.; FAHEY, A.; JOHNSON, A.; ELLERS, O.; Bowdoin College, Maine; *ajohnson@bowdoin.edu*

Externally visible polyfluorochrome marking of urchins: growth comparisons between lab-reared and tidepool urchins

We marked 2200 *Strongylocentrotus droebachiensis* urchins (5-35 mm in diameter) with six unique combinations of the fluorochromes tetracycline and calcein. These urchins were outplanted into six individual tidepools at Cedar Beach, Bailey Island, Maine. The tidepools were at a variety of tidal heights and all contained urchins prior to the outplant. The outplanted urchins were obtained from a hatchery at University of Maine's Center for Cooperative Aquaculture. Tidepool oxygen, temperature, pH and salinity were monitored periodically. After one month, 64 urchins were recaptured from the tidepools; of the recovered urchins, 26 were marked, giving a 1.2% recovery rate. Concurrently, 23 urchins from each marking treatment and an additional unmarked control group were grown for a month in lab aquaria at ambient temperatures and ad libitum food. Gonad index was 8 times higher in lab-reared well-fed urchins than in tidepool urchins. Also, 50 urchins from each treatment were assayed for marking success; the results demonstrated >95% externally visible fluorescent marks and <5% false positives. In addition, a size range of urchins are being grown in the lab at a six different temperatures and we will present the results of the effects of temperature on growth at the meeting. We expect to determine an optimal size-dependent temperature for growth rate and gonad accumulation and to detect an effect of temperature on maximum size. The growth rates are expected to size specific and will be analyzed using Tanaka, von Bertalanffy and Gamma functions.

P3.71 ASPIRAS, A.C.*; ANGELINI, D.R.; American University; *aaspiras42@gmail.com*

Sex-specific gene interactions in the patterning of insect genitalia

Genitalia play an important role in the life histories of insects, as in other animals. These structures are a unique developmental system to explore as they are rapidly evolving sexually dimorphic structures derived from multiple segment primordia. Despite the importance of insect genitalia, descriptions of their genetic patterning has been limited to fruit flies. In this study, we report the functions, interactions and regulation of appendage patterning genes (e.g. *homothorax, dachshund*, and *Distal-less*) in the milkweed bug *Oncopeltus fasciatus*. Female *O. fasciatus* have a multi-jointed ovipositor while male *O. fasciatus* have a genital capsule consisting of large gonocoxopodites and claspers. *O. fasciatus* required appendage-patterning genes for development of the male claspers, but not the proximal gonocoxopodite, suggesting a non-appendicular origin for this structure. The posterior Hox genes (*abdominal-A* and *Abdominal-B*) were required for proper genital development in *O. fasciatus*, and regulated *Distal-less* and *homothorax* similarly in both sexes. Appendage patterning regulation of *Distal-less* and *dachshund* was different between males and females. Knockdown of *intersex* produced a partial female-to-male transformation of abdominal and genital anatomy, and also resulted in abrogation of female-specific regulation of these genes. These results provide developmental genetic support for specific anatomical hypotheses of serial homology. Importantly, these gene functions and interactions describe the developmental patterning of sexually dimorphic structures that have been critical to the diversification of this species-rich insect group.

P3.72 ASPIRAS, A.C.*; PRASAD, R; FONG, D.W.; CARLINI, D.B; ANGLINI, D.R.; American University, Washington,D.C.; *aaspiras42@gmail.com*

Evolution in the dark: Exploring the Genetic Basis of Cave Adaptation in Amphipod Populations

Caves and their fauna provide excellent natural experiments with which examine evolutionary questions. Karst environments are characterized by low nutrient availability, low predation, low and constant temperatures, and little or no light and thus cave species like the amphipod *Gammarus minus*, tend to share characteristics such as low pigmentation, elongated limbs, and reduced or absent eyes. The evolutionary and developmental mechanisms of troglodytism has been worked out in some vertebrate models; however, to date, relatively little has be done in invertebrate models. In this study, we compare population level expression of eye development genes (*hedgehog, pax6, sine oculis*, and *dachshund*) of three population pairs of *G. minus* found in Greenbrier County, West Virginia. We observed significant differences in hedgehog expression between cave and surface populations, which suggests *hedgehog* may be a consistent target of evolution among observed population pairs. Interestingly, no differences were observed in *pax6, sine oculis*, and *dachshund* expression, despite their integral role in eye development in insects. These results provide developmental genetic support for the "hotspot" of evolution hypothesis and provide for an important comparison of adaptive mechanisms for animals in Karst environments.

P3.133 BADGER, M.A.*; JONES, M.A.; University of California, Berkeley, Florida State University, Tallahassee; *mbadger@berkeley.edu*

Falling faster: Size and folding behavior decrease descent time in a brittle star (Ophiocoma aethiops)

Fluid living organisms often undergo shape changes in order to move more effectively through the environment. Brittle stars (Ophiuroidea) living in high-energy intertidal and shallow subtidal zones may occasionally be dislodged and carried into the water column by wave energy. This open environment likely increases predation pressure and puts the individual at risk for drifting into an unsuitable habitat. In response, a brittle star folds its arms, which decreases its descent time to the relative safety of the bottom substrate. We measured falling speeds in *Ophiocoma aethiops* for both open and folded arm configurations. Body mass ranged by more than a factor of 100, and large individuals were geometrically similar to small individuals. Small brittle stars may have a greater need to avoid gape-limited predation by fishes. Therefore, we hypothesized that (i) large brittle stars would be less likely to fold during a descent than small individuals. Because larger bodies generally have higher terminal velocities, we hypothesized that (ii) large brittle stars would fall faster than small individuals regardless of the folding behavior. We also hypothesized that (iii) folding behavior would increase falling speed within individuals. Folding frequency was not dependent on disk size. Folded brittle stars fell faster on average than they did when in the open position. Falling speed increased significantly with size for stars in the open configuration. For stars in the folded configuration, however, falling speed was not related to size. These results indicate that the folding behavior may be more beneficial for small brittle stars than for large brittle stars. A potential source of this difference is the smaller stars' greater need to avoid gape-limited predators.

P3.141 BAHLMAN, Joseph Wm*; SWARTZ, Sharon M; BREUER, Kenny S; Brown University; *joseph_bahlman@brown.edu*

Measuring cost of flight associated with varying kinematics in a robotic bat wing

Bats inhabit a variety of realized ecological niches that require diverse aspects of flight performance. Depending on its niche, a bat may be required to perform complex maneuvers, commute or migrate long distances, carry heavy loads, fly very fast, hover, or various combinations of these. These behaviors arise from distinct wing kinematics that produce distinct patterns of aerodynamic forces while incurring a mechanical cost. The mechanical cost to flap results, in part, because bats possess relatively heavy wings, ~12% of body mass, and their motion incurs inertial and aerodynamic costs as they move the wings through a fluid medium. To understand the mechanical cost associated with different flapping kinematics we constructed a robotic bat wing, with seven joints actuated by three servo motors. This flapper design allows the shoulder to move dorsoventrally and anterioposteriorally, and the elbow and wrist to flex and extend simultaneously, which retracts and extends the entire wing. These degrees of freedom allow us to test a variety of kinematic parameters including: wing beat frequency and amplitude, stroke plane, downstroke ratio, and retraction/extension, all across a realistic range for our model species, *Cynopterus brachyotis*. The robotic wing was mounted in a windtunnel on a two-axis force transducer that measures aerodynamic force; torque and power were measured from the servo motors. For each kinematic parameter we quantified the lift and drag/thrust generated per wingbeat, mechanical work per wingbeat, and average flapping power. Our model showed how aerodynamic force generated, and work and power cost change with different kinematic parameters.

P2.21 BAKKEN, G.S.; Indiana State Univ.; *george.bakken@indstate.edu*

Stress, Strain, Thermal Environment, and Thermoregulation

Stress is an applied force, while strain is the response of the object to the stress. For example, the weight of a diver (stress) causes a springboard to bend (strain). Stress and strain are related by a filter function, in this case springboard stiffness. In thermoregulatory physiology, the thermal environment determines the stress, while physiological strain is the resulting rate of change of body temperature or the metabolic heat production and evaporative cooling needed to stabilize body temperature. A small armadillo exposed to an arctic winter day is incorrectly described as "cold stressed." An arctic fox of similar size is equally cold stressed, but is not strained because its filter function (fur) is radically different. Stress vs. strain confusion is evident in some studies using temperature-sensing reptile models to characterize a complex thermal environment. A model with heat storage capacity(filter function) similar to that of the animal estimates strain (body temperature), while a model with minimal heat capacity estimates thermal stress (operative temperature). Strain (body temperature) can easily be computed, even for active animals, given the spatial distribution of stress (operative temperature. In contrast, measured strain applies only to an animal rooted to a particular point. I will describe the construction of free-standing, temperature sensing, low mass reptile models, present data illustrating the effects of model properties on measured operative temperature, and present simple example computation procedures for estimating body temperature given the spatial distribution of operative temperature, movement patterns, and the animal filter function.

P1.45 BALDO, S.; GUINDRE-PARKER, S.*; GILCHRIST, H.G; DOUCET, S.M.; MENNILL, D.J.; LOVE, O.L.; Department of Biological Sciences, University of Windsor, National Wildlife Research Centre, Environment Canada; *guindre@uwindsor.ca*

Does physiology mediate the link between acoustic and visual signals and reproductive success in an Arctic passerine?

Sexual ornaments are often used to signal quality and through sexual selection can cause intra-specific variation in reproductive success. While this relationship has been established in many taxa, the role of physiology in driving this relationship is less often studied. This could be due to the need for an integrative approach, and/or because most organisms have more than one ornament that can act to signal individual quality, adding complexity to this topic. We acknowledge that organisms have more than one potential signal of quality and use an integrative approach to examine how these signals drive reproductive success in free-living Snow Buntings. Males of this Arctic passerine have two potential sexual ornaments: song and plumage. We study how testosterone, oxidative stress and immunoglobulins may link male song or plumage quality to reproductive success by undertaking the following: 1-Assessing song quality by measuring performance- and complexity-related characteristics. 2-Quantifying plumage traits using feather reflectance, growth rate and pattern of colouration on wing and tail 3-Measuring plasma testosterone and stress-mediated traits 4-Determining the reproductive success of each male. Selected results will be presented on (1) song, plumage and reproductive success, (2) physiological mechanisms that link signals and reproduction, and (3) trade-offs in breeding effort and immune function.

P2.30 BARNETT, A.A.*; THOMAS, R.H.; Southern Illinois University, Carbondale; *abarnett@siu.edu*

Exploring the Loss of the Hox Gene abdominal-A in the Mite Archegozetes longisetosus

Hox gene products have a highly conserved role throughout Metazoa in patterning the anterior-posterior axis. This high degree of functional conservation makes observations of their losses rare. Sequencing the Hox cluster of the chelicerate mite *Archegozetes longisetosus* revealed the loss of the posterior patterning Hox gene *abdominal-A (abd-A)*. *abd-A* has been shown to be necessary in determining the identity of posterior segments in a number of arthropod species, and is often co-expressed with the Hox gene *Ultrabithorax (Ubx)*. In order to explore the potential causes and consequences of the loss of *abd-A*, we followed the expression of the mite orthologues of *Ubx*, the segmentation gene *engrailed (en)*, and the Hox co-factor *homothorax (hth)* in the posterior chelicerate tagma, the opisthosoma. The expression of *en* in the opisthosoma is absent in early stages, followed by the simultaneous appearance of two stripes. This simultaneous appearance of two segments was confirmed by SEM and by time-lapse photography. No further *en* expression was observed, indicating a reduction in the segmental nature of the mite opisthosoma. *Ubx* is expressed in a stable group of cells in the posterior opisthosoma in two groups of cells straddling the proctodael invagination. However, unlike other studied chelicerates, *Ubx* was not expressed in the genital region. *hth* expression is dynamic in the opisthosoma, and is initially expressed in the anterior opisthosoma and into the fourth limb buds of the anterior prosoma. However, *hth* is restricted to the posterior opisthosoma in later developmental stages where it is also expressed in the mesodermal midgut rudiment. These data are preliminary observations that are aiding in our understanding of the evolutionary pressures leading to Hox gene loss.

P3.200 BARRILE, G.M.; BOWER, C.D.; DOWNS, L.K.*; EVANCHO, B.J.; GERARD, N.R.; KLINGER, T.S.; HRANITZ, J.M.; Bloomsburg University of Pennsylvania; *lkd30583@huskies.bloomu.edu*

Comparative Studies of Island Dwarfism in Fowlers Toads on Several Atlantic Coast Barrier Islands.

Studies conducted in 1988-1989 and 2010 documented island dwarfism in Fowler's Toad, *Anaxyrus fowleri*, that persisted on Assateague Island for 22 years. In 2010 we found that *A. fowleri* on two other barrier islands were also dwarf in body size compared to mainland populations. The scarcity of freshwater habitats on Atlantic Coast barrier islands supports a nested subset of the mainland amphibian communities. Life history traits are important adaptations to local conditions within the range of the species. In 2011, we conducted pilot studies of several life history traits of female toads (clutch size and egg diameter), and toadlets (post-metamorphic growth rate). Amplexed females laid their eggs in the laboratory, which we counted for clutch size and measured for egg diameter. Clutch size differed between island and mainland samples but egg diameter did not. In July and August of 2010 and 2011, we captured, measured snout-vent length (SVL), and released toadlets in natural habitats. Island toadlets were smaller than mainland toadlets in both July and August samples. To determine if island dwarfism in one species can be generalized to other species, we compared SVL of mature Green Treefrogs (*Hyla cinera*) on two barrier islands to those at a mainland site. Our pilot study revealed no differences in body size at maturity for *H. cinera* breeding at these sites. Although small sample sizes temper our conclusions, we suggest life history shifts in growth rate and reproductive effort of *A. fowleri* on barrier islands, but no shift in body of size the competitor *H. cinera*.

P3.39 BARTHELL, J. F.*; HRANITZ, J. M.; ALBRITTON-FORD, A. C.; BARNETT, A.; BUTLER, M. E.; COWO, C. L.; KURTZ, R. M.; SANCHEZ, M. L.; WARREN, J. J.; PETANIDOU, T.; WELLS, H.; University of Central Oklahoma, Bloomsburg University of Pennsylvania , Valdosta State University, State University of New York, Siena Heights University, Commack High School, University of North Texas, Oklahoma State University, University of the Aegean, University of Tulsa; *jbarthell@uco.edu*

Competition Between Two Eurasian Plant Species for Pollinators: A Perturbation Experiment

We studied competition for pollinators by two sympatric species of flowering plants on the island of Lesvos, Greece. One of these plant species, *Centaurea solstitialis* L., or yellow star-thistle, is a widespread, invasive species in the western USA. In the non-native environment, the species is highly attractive to pollinators, especially the non-native honey bee, *Apis mellifera*, L. However, at our (native) study site in Greece, far more large-bodied pollinators (including the honey bee) appeared to be attracted to nearby populations of chasteberry, *Vitex agnus-castus* L. We investigated whether pollinators would show an immediate preference for *V. agnus-castus* if it were suddenly made available to them foraging at *C. solstitialis*, as a perturbation effect. Accordingly, two transects of *C. solstitialis* were established with thirty inflorescences (kept alive in flower stem tubes) inserted into each transect at regular intervals. In one transect, hymenopteran pollinators (bees and wasps) were observed to visit the sprigs of *V. agnus-castus* in higher frequency than the *C. solstitialis* plants paired with them. However, in a higher density transect of *C. solstitialis*, we observed no such effect. These results suggest pollinators are guided by available nectar levels (standing crop) but that high densities of lower nectar standing crop species (e.g., *C. sosltitialis*) may draw them away from lower densities of a higher standing crop species (e.g., *V. agnus-castus*). A more nuanced perspective on foraging constancy by bees is therefore in order, with several factors (including genetic ones) determining how pollinators make foraging decisions.

P2.175 BAUER, C.M.*; KOPLIK, L.; ROMERO, L.M.; Tufts University, Universidad de Puerto Rico; *carolyn.bauer@tufts.edu*

Effects of chronic stress on ketone and uric acid levels in juvenile Passer domesticus

The stress response is partially mediated by increased levels of circulating glucocorticoids. While the stress response may be adaptive in the short term, chronically elevated levels of glucocorticoids can be pathological. Chronic stress is caused by homeostatic overload; meaning the mediators (glucocorticoids) start to cause the problems themselves. Some of these problems include immunosuppression, diabetes, and muscle breakdown. We aimed to verify that chronic stress is caused by homeostatic overload by monitoring ketone (evidence of fat breakdown) and uric acid (evidence of protein breakdown) concentrations in chronically stressed juvenile house sparrows (HOSPs). HOSPs were chronically stressed for three weeks by applying a series of rotating mild psychological stressors. One group of birds received injections of a glucocorticoid blocker (mitotane) halfway through the chronic stress period to test whether glucocorticoid levels are responsible for protein and fat metabolic product levels. We found that both baseline and stress-induced corticosterone (CORT) levels decreased in all birds after the onset of the chronic stress period. Mitotane birds further decreased their CORT levels after receiving mitotane injections. Towards the end of the chronic stress period, control birds decreased in weight compared to mitotane birds. Contrary to our expectations, we saw no differences in ketone or uric acid levels between control and mitotane birds. In conclusion, corticosterone does appear to mediate the stress-induced decrease in weight, but the mechanism does not appear to involve increased protein or lipid metabolism.

P2.203 BAUM, J.T.*; JAYNE, B.C.; Univ. of Cincinnati, Cincinnati; *baumjn@mail.uc.edu*

Kinematics and Performance of Arboreal Limbless Locomotion in Boiga irregularis

In arboreal habitats branch orientation and spacing vary considerably. Branches and objects such as pegs provide discrete locations for snakes to generate propulsive forces when they use lateral undulation. However, the consequences of branch spacing for locomotor performance of snakes and nearly all animals are poorly understood. Hence, we determined maximal speeds and kinematics of an arboreal snake (*Boiga irregularis*) crawling on cylindrical perches (diameter = 1.6 cm) with horizontal and vertical orientations and five different peg spacings (10, 20, 30, 40, and 80 cm). All of the snakes used lateral undulation on all of the surfaces, and peg spacing, perch orientation, and their two-way interaction all had significant effects on all measures of performance and kinematics. For the horizontal perches, the mean speeds at the smallest and largest peg spacing were approximately 10% snout-vent length/sec, and the greatest mean speed was for the 40 cm spacing (16% SVL/sec). Unlike snakes on the horizontal surfaces, the mean speeds for the vertical surface varied little with peg spacing and were uniformly slow (range 5-6% SVL/sec). For both perch orientations the number of pegs touched by the snake decreased as peg spacing increased, and while touching only one peg the snakes crawled with apparent ease and steady speed. In addition, the snakes crawled vertically using one peg as quickly and easily as they did using 2-10 pegs. Pegs on a horizontal cylinder are probably important for both balance and propulsion of snakes, whereas pegs protruding from vertical cylinders probably resemble those protruding from horizontal planar surfaces by being used almost exclusively for propulsion.

P3.49 BEAM, M*; ZUZOW, M; TOMANEK, L; California Polytechnic State Uni., San Luis Obispo; *mbeam@berkeley.edu*
Sirtuin-induced protein deacetylation affects the heat shock response in blue mussel congeners (Mytilus)
The warm-adapted Mediterranean blue mussel species *Mytilus galloprovincialis* invaded southern California during the last century and has since replaced the cold-adapted native *M. trossulus* from its southern range, possibly due to climate change. Based on previous proteomic analyses, we hypothesized that the more heat-sensitive *M. trossulus* switches from NADH-producing metabolic pathways that may generate reactive oxygen species (ROS) to NADPH-producing pathways that are able to scavenge ROS during severe heat stress (32°C). We further linked these changes to the activity of the mitochondrial NAD-dependent deacetylase, sirtuin-5, which has been shown to regulate many metabolic pathways. To test the latter hypothesis, we repeated the experiment for both species by exposing gill tissues to 37°C, 28°C, 32°C and 35°C (heating rate of 6°C/h) seawater for 1 h with a subsequent 24 h recovery at 13°C under constant aeration. In a parallel set of incubations we added suramin, a potent sirtuin inhibitor, to characterize the effect of sirtuins on the stress response. Applying a gel-based proteomic analysis and mass spectrometry, we found that sirtuin inhibition affected 19% and 25% of all protein changes during heat stress in the warm-adapted *M. galloprovincialis* and the cold-adapted *M. trossulus* (excluding 35°C), respectively. Identified proteins function as molecular chaperones, in proteolysis, signaling, ROS scavenging, energy metabolism, and cytoskeletal dynamics. The number of proteins that were affected by sirtuins doubled in *M. trossulus* at 35°C, suggesting possible thermal damage of proteins or a role of internal lysine-acetylation in protein degradation as has been shown for N-end lysine-acetylation.

P2.37 BECHLER, D.L.*; ELDER, J.F.; Valdosta State Univereisty, Valdosta, Georgia; *dbechler@valdosta.edu*
Inter-strain Differences in Personality and Learning in the Self-Fertilizing Mangrove Killifish, Kryptolebias marmoratus Poey 1880
This study identifies inter-strain differences in shy and bold personality traits and learning in the self-fertilizing hermaphroditic mangrove killifish, *Kryptolebias marmoratus*. Taking into account behavioral plasticity, data show that significant inter-strain differences are consistent not only in fertile egg laying adults, but also in newly hatched juveniles 7-10 days old. Analyses showed that the most bold strains spent significantly less time in a sheltered area (Lag Time or latency) and more time in the open (time in open or exploration) regardless of whether or not a stimulus was present or not while shyer strains showed more or less time in shelters or in the open respectively. Principle Components Analyses identified Lag Time as the single best correlate of shyness verses boldness in both adults and juveniles. The applicability of using *K. marmoratus* for both mechanistic and functional behavioral studies based on genetic structure and behavioral plasticity is discussed.

P2.38 BECHLER, D.L*; LUKE, K.; FLAHERTY, F.; Valdosta State University, South Georgia College; *dbechler@valdosta.edu*
Activity Patterns of the Mangrove Killifish, Kryptolebias marmoratus, in an Artificial Crab Burrow
The mangrove killifish uses burrows of the land crab, Cardisoma guanhumi as shelters. Using a detection system consisting of three sets of infrared sensors fed to a PIC 168F4 microprocessor linked to a PC, we studied the movement patterns of three strains of *Kryptolebias marmoratus* in an artificial PVC pipe crab burrow. The burrow was U-shaped with an open pool at each end and small chambers in each burrow arm. Sensors were located at the openings of the burrow and its nadir. Distance moved and time spent resting at each sensor was computed using Excel Logic statements. Strains moved significantly greater distances through the burrow during the day than at night, but no interstrain differences were found. All strains spent more time at sensors at the mouths of the burrow, but less time at any one sensor during the night. Intraclonal analyses revealed that strains Hon 7 and Hon 11 were more active at night moving from one end of the burrow to the other than was strain 50.91, which spent more time at the burrow mouths. Interstrain analyses of time spent at sensors showed no differences. From these analyses we conclude that *K. marmoratus* spent more time at night in the open pools and that in general complex behaviors involving movement and resting in the artificial burrow masks potential differences due to the high variability exhibited by the strains. A more flexible, upgraded version of the detection system capable of use in the field is also presented.

P2.87 BELANICH, Jonathan R.*; SHILLINGTON, Cara; SECOR, Stephen M.; University of Alabama, Eastern Michigan University; *jrbelanich@crimson.ua.edu*
Determinants of the postprandial metabolic response and specific dynamic action of the tarantula Grammostola rosea
A mandatory physiological response to meal digestion and assimilation is an increase in metabolic rate; the accumulative cost of which is referred to as specific dynamic action (SDA). While SDA has been examined for a wide spectrum of invertebrate and vertebrate groups, there has been relatively little attention on the postprandial metabolic responses of arachnids. In this study, we characterize the postprandial metabolic profile of the Chilean rosehair tarantula, *Grammostola rosea*, following the consumption of crickets (*Acheta domesticus*), hornworms (*Manduca sexta*), and neonatal rats. Meal size of each prey type averaged 6.4%, 19.5%, and 28.9% of tarantula body mass, respectively. Because tarantulas do not completely consume their prey, individuals were weighed immediately prior to and after feeding to obtain an accurate measure of meal size. Tarantulas responded to all three meals with a characteristic rapid increase in metabolic rate that peaked at six hours after feeding. For each meal type, metabolic rates peaked at 4, 6, and 12-fold of standard metabolic rates and returned to resting levels within 24, 36, and 72 h after feeding, respectively. SDA for each meal averaged 0.16, 0.42, and 1.56 kJ, respectively, equivalent to 2.2%, 5.5%, and 5.3% of the meal's energy. Effects of meal size for a common meal type were examined with cricket meals ranging from 1.2-7.0% of body mass. A four-fold increase in meal size generated an 80% in peak VO_2, a 50% increase in duration, and a 110% increase in SDA. Over a 270-fold range in body mass, SDA generated from cricket meals of ~5% of body mass scaled (log-log) with a mass exponent of 0.94. Tarantulas exhibit the characteristic SDA response, the magnitude of which is influenced by meal type and size.

P3.35 BELL, C.B.*; DILLON, M.E.; University of Wyoming, Laramie; *cbell@uwyo.edu*

Seasonal variation in body size of native bees: thermal constraint or resource limitation?

Body size has profound implications for the physiology and ecology of insect pollinators, and strongly affects their role within pollinator networks. Several considerations suggest that size distributions of insect pollinators may change seasonally, with potential impacts on pollination services. However, with few exceptions, we have little data on seasonal changes in size distributions of pollinator species or communities. We measured body sizes of native bees sampled weekly throughout the growing season at sites in southeastern Wyoming. Given the scaling of metabolic rates and heat loss with body size, larger bees should be able to warm up more quickly and therefore have larger activity windows in the cooler conditions of early spring. Thermoregulatory considerations therefore predict larger bees earlier in the season. Alternatively, body size may be driven by resource partitioning within the nest which depends in part on seasonal availability of floral resources. We found that bees were small in early spring when temperatures were low and flowers were scarce and largest in mid-summer when temperatures increased and flowers were most abundant. These results suggest that floral resources rather than thermal constraints may drive seasonal changes in body size in these communities.

P1.8 BELTON, Sheena/M*; CHARLES, Curtisha; SANFORD, Jillian/L.; SHIELDS, Vonnie/D.C.; Baltimore City Community College, Towson University; *vshields@towson.edu*

Can Gypsy Moth Larvae (Lymantria dispar) Adapt Its Aversive Behavioral Response to Alkaloids?

Deterrent substances, such as alkaloids, are important in influencing the food selection of many insects. Some of these compounds are potentially toxic and insects benefit from having an ability to discriminate between them. We tested the hypothesis that pre-exposure (24 and 48 hours) to a diet containing an unpalatable compound (e.g., an alkaloid) will result in adaptation of the taste-mediated aversive response of gypsy moth larvae, *Lymantria dispar* (L.). We tested several alkaloids, namely aristolochic acid, caffeine, nicotine, berberine, and salicin to determine if each alkaloid acted in a similar manner. Our results indicated that the larvae consumed less when fed on some of these alkaloids at both 24 and 48 hour exposure periods, as indicated by only marginal growth rate and relatively little frass production. We concluded that when insects repeatedly sample a noxious food over a period of a few days, this may reduce their aversive response to that food's unpleasant taste or toxic effects and allow them to adapt physiologically to it. In addition, we also carried out a three-part brief feeding test regime to determine if the deterrent response was mainly a sensory response or whether post-ingestive effects also played a role. This study was supported by NIH grants (1R15DC007609-01 and 3R15DC0076409-0151) to V.D.C.S., FCSM and Towson University undergraduate research grants to J.L.S., and NIH grant 5R25GM058264-08 to G. Gasparich.

P2.110 BENNETT, M.M.*; PETERSEN, K; YOCUM, G; RINEHART, J; GREENLEE, K; North Dakota State University, Concordia College, United States Dept of Agriculture, United States Dept of Agriculture; *meghan.bennett@ndsu.edu*

The effects of extended diapause duration on the metabolic rate and critical PO_2 of the alfalfa leafcutting bee, Megachilee rotundata

The alfalfa leafcutting bee, *Megachile rotundata* F. (Hymenoptera: Megachilidae), is a solitary, cavity-nesting bee. Most individuals enter diapause at the end of summer and overwinter as prepupae. However, some individuals avoid diapause and complete their life cycle in the summer. Furthermore, some bees can survive artificially imposed diapause periods of varying length. Previous studies have shown that high temperature pulses during the overwintering period improved survival of adult bees. To determine whether lengthening the diapause period has an observable effect on the bees' adult physiological phenotype, we measured resting and flight metabolic rates. We compared bees that had been maintained at 6C for 12 months (simulating normal diapauses) to bees that had been kept at 6°C for 24 months. We used flow-through respirometry to measure resting and tethered flight metabolic rates. There was no significant difference in flight metabolic rate between the two groups, and flight metabolic rates were 20-fold higher than resting CO_2 emission rate. To determine the critical $PO_2(P_c)$ bees were exposed to decreasing levels of O_2 for ten minutes each, and CO_2 emission was recorded. P_c was similar between bees that had been stored for 12 or 24 months. Both groups of bees were very tolerant of hypoxia with a P_c between 3 and 5%. Increasing the diapause period by 12 months resulted in no significant difference in the bees' P_c. Together these data suggest that diapause length has no affect on adult metabolism. Whether increasing diapause duration affects other parameters of adult physiology, such as foraging capacity or reproductive fitness remains unclear.

P1.36 BERGAN, H.E.; SHERIDAN, M.A.*; North Dakota St. Univ., Fargo; *mark.sheridan@ndsu.edu*

Mechanisms that Underlie Fasting-Associated Growth Cessation and Lipid Catabolism in Rainbow Trout (Oncorhynchus mykiss)

In this study, we used rainbow trout (*Oncorhynchus mykiss*) to identify the cellular mechanisms involved with growth cessation and lipid catabolism during periods of fasting. Fish were placed on one of five dietary regimes—fed continuously for 2 or 4 weeks, fasted continuously for 2 or 4 weeks, or fasted 2 weeks then refed 2 weeks—and the effects on organismal growth and lipid catabolism and activation state of signaling elements (e.g., Akt, ERK, JAK-STAT, PKC) in selected tissues were measured. Fasting for either 2 or 4 weeks significantly retarded growth in terms of body weight and body length; refeeding restored growth to near levels seen in continuously fed fish. Fasting activated lipid catabolism by stimulating the catalytic activity and mRNA expression of hormone-sensitive lipase (HSL). In adipose tissue, liver, and white muscle, HSL activity was significantly elevated in 2- and 4-week fasted fish compared to fed animals, whereas in red muscle, HSL activity was significantly elevated compared to fed fish after 4 weeks. Two HSL-encoding mRNAs have been characterized, and the expression of both forms of mRNA in 2- and 4-week fasted fish were significantly elevated over levels in fed fish in all tissues. Refeeding reversed both fasting-associated elevations of HSL activity and HSL mRNA expression. Fasting resulted in the deactivation of Akt, JAK2, and STAT5 in adipose tissue, liver, and red and white muscle. By contrast, fasting activated ERK and PKC in all tissues measured. Refeeding reversed fasting-associated alterations in the activation state of all signal elements. These findings suggest that deactivation of Akt and JAK-STAT in conjunction with the activation of ERK and PKC underlie fasting-associated growth retardation and lipolysis. (Supported by NSF IOS0920116 to M.A.S.)

P2.53 BERGOU, AJ*; SWARTZ, S; BREUER, K; TAUBIN, G; Brown University; *attila_bergou@brown.edu*
3D Reconstruction and Analysis of Bat Flight Maneuvers from Sparse Multiple View Video
We present a novel framework for the 3D reconstruction and analysis of complex flight maneuvers performed by bats. By incorporating biomechanical and geometric knowledge about bats into an articulated model, we are able to recover the time varying posture of freely flying bats from sparse multiple view high speed video. Our method scales easily to multiple views, elegantly handles missing and occluded markers, and has a versatility in the type and complexity of the tracking model. We apply this tracking method, in conjunction with a simulation framework we developed, to analyze how bats perform complex aerial rotations during landing and takeoff.

P3.201 BERTIN, A*; SAMPERTEGUI, S; RUIZ, V; FIGUEROA, R; GOUIN, N; Universidad de La Serena, Chile, Universidad de Concepcion, Chile, Centro EULA, Concepcion, Chile, CEAZA, La Serena, Chile; *abertin@userena.cl*
Between-population variation in fluctuating asymmetry: testing the relative importance of spatial processes and ecological traits in the water-strider Aquarius chilensis
Fluctuating asymmetry (FA), a measure of small non-directional departures from perfect symmetry in bilateral traits, is thought to reflect the level of genetic and environmental stress experienced by individuals or populations during development. While FA has been widely used as a bioindicator tool for environmental monitoring and conservation biology, our knowledge of the factors underlying its expression remains limited. In this study, we analyze the spatial structure of body shape asymmetry in the water-strider *Aquarius chilensis* across populations belonging to the same river basin and evaluate the importance of spatial processes and environmental characteristics (i.e. habitat and water characteristics, aquatic predators and parasitism) in producing between-population variation in FA. In both sexes, environmental and spatial processes explain more than 80% of the between population variation in FA. In females, a large fraction of this variation (i.e. 63%) is spatially structured with populations living near each other having more similar levels of FA than populations living further apart. According to variation partitioning analyses, both spatially-structured environmental factors and genetic relationships between populations may explain this phenomenon. In contrast, we did not evidence non-random spatial structure in males but found instead a predominant role of non-spatially structured environmental factors on FA levels. In sum both environmental and genetic factors may affect body shape FA in populations of *A. chilensis* but gender differences may occur, possibly due to alternative dispersion behaviors.

P1.143 BEZAULT, Etienne*; MACHADO, Heather; HUNTER, Jeff; JOYCE, Domino; LUNT, David; RENN, Suzy CP; Reed College, Stanford , University of Hull; *renns@reed.edu*
Genomics of adaptive radiation: Gene duplication in African cichlid lineages
Among African cichlids, the repeated and independent origin of adaptive radiations, in combination with closely related lineages that have not undergone dramatic radiation, offers an excellent model in which to study the genetic basis of adaptation and diversification. Structural variation has recently been shown to be a major source of evolutionary novelty. We investigate the relationship between gene duplication and the potential for adaptive radiation using Array-based Comparative Genomic Hybridization (aCGH). We quantify gene duplications among three divergent species for each of two independent radiations (Lake Malawi and Lake Victoria) relative to their closely related non-radiating riverine species. We find an increased number of gene duplications among the radiating lineages compared to the non-radiating relatives. While the majority of these gene duplications are specific to the different radiations, we also identify repeated instances of duplicated genes across the lake-radiations. These candidate duplicates represent Gene Ontology categories that are discussed in terms of potentially adaptive phenotypes. Our results support the hypothesized association between gene duplication and adaptive radiation. With the recent completion of genome sequence for 4 African Cichlids, we can address the genomic architecture of duplication events. Currently, genome wide sequence comparison for duplicated genes against the genome draft assemblies (CGC & Broad Institute, unpublished) does not recover these recent paralogs. Therefore, to quantitatively investigate the relationship between dynamics of gene-duplication, we are developing novel high throughput technologies by designing a multi-species whole genome CGH-array platform. This approach can be applied on a population level as well on broader phylogenetic context.

P1.6 BIANCHI, K.M.*; JACOBS, M.W.; ATEMA, J.; BAYER, S.; Falmouth Academy, McDaniel College, Boston University, Darling Marine Laboratories; *kbianchi14@aol.com*
The Effect of Experience on Shelter-Seeking Behavior of Early Juvenile Homarus americanus
Previous research shows that juvenile lobsters (*Homarus americanus*) are strongly dependent on shelter, and avoid predator odor. There is additional evidence that year-old juveniles find shelter faster with experience. We hypothesized that very young (week-old) juveniles *H. americanus* would settle in shelter as quickly as possible, and would find the shelter faster with experience. We also hypothesized that predator odor (juvenile dogfish *Mustelus canis*) would decrease time to locate or relocate the shelter. We constructed a simple maze with a rock shelter at one end of the tank, with flow towards the shelter. Naïve lobsters were released into the maze and allowed to find the shelter, then removed and immediately re-released. Juveniles found the shelter significantly faster during the second trial. This result suggests that the lobsters learned the location of the shelter. We characterized flow in the chamber using a dye test and found evidence of a countercurrent, suggesting that the lobsters could have used olfactory cues to relocate the shelter. Once the lobsters made visual contact with the shelter, there was no difference between trials in the time it took to reach the shelter. Overall, the lobsters often found the shelter but then chose to leave, or occasionally found the shelter during the 1st trial but did not return to it during the 2nd trial, suggesting that juveniles may be more exploratory than previous literature suggested. Juvenile lobsters *H. americanus* show the ability to learn the location of shelter even at a very young age, and visual or olfactory cues may be involved.

P1.144 BIARDI, James; Fairfield University; *jbiardi@fairfield.edu*
Comparative proteomic analysis of blood sera of venom-resistant and non-resistant ground squirrels under rattlesnake predation
Rattlesnake venoms produce a suite of effects, including hemorrhage, myotoxicity, hypovolemic shock, clotting disorders, edema, and paralysis. These arise from a complex mix of enzymatic and non-enzymatic toxins. Our work on California ground squirrels and others' work on other mammals shows some prey are resistant to rattlesnake venoms. Most work has focused on snake venom metalloproteases (SVMP) and their inhibitors since this toxin class produces extensive hemorrhage and expose a larger volume of prey tissue to other venom components. However, we have little insight into the molecular basis of resistance to non-SVMP venom toxin classes. We have applied a biomarker discovery approach to identify aspects of prey sera proteomes correlated with resistance via 2DiGE analysis of California ground squirrel (*Otospermophilus beecheyi*) sera samples from one site with has a high density of snakes where squirrels show high resistance, and one site where rattlesnakes are rare and squirrels have low resistance. Eleven spots (78%) have been identified based on homology to proteins in the NCBI nr database. Four of five spots with 1.9 to 19.8–fold increased expression levels in resistant animals are isoforms of α 1-antitrypsin. The other nine identified to date represent serum proteins (albumin, transferrin, transthyretin) involved in osmotic regulation and transport. Protein spots not yet anaylzed span the range of 24.9 to -13.8–fold difference in volume. We predict that some, but not all, will reflect SVMPI based on the highlighted differences in regions of low pI and intermediate MW (upper left). To our knowledge, this is the first application of comparative proteomics to evaluate vertebrate responses to predation, and the first application of 2DiGE technology to ecological or evolutionary studies in non-human animals.

P2.152 BIERMAN, H.S.*; YOUNG, B.A.; THORTON, J.L.; JONES, H.G.; KOKA, K.; CARR, C.E.; TOLLIN, D.J.; University of Maryland, College Park, University of Massachusetts, Lowell, University of Colorado Medical School, Aurora, University of Colorado Medical School, Aurora; *hilaryb@umd.edu*
Evidence for a pressure difference receiver system in alligator sound localization.
Physiological and anatomical studies have suggested that alligators have unique adaptations for spatial hearing. It has been hypothesized that directionality may be enhanced via the acoustic coupling of middle ear cavities, resulting in a pressure difference receiver (PDR) mechanism. We have therefore measured the acoustic cues available to the animal, and re-examined the skull anatomy of the juvenile American alligator. Directional transfer functions, the directional component of the head-related transfer function, were measured for 4 specimens. Interaural differences in time and level, as well as monaural spectral shape cues, calculated from these measurements, showed no evidence for enhanced cues generated by the animal's morphology. Behaving similarly to a spherical model, results refute the null hypothesis that physiological results are accounted for by cues generated by the passive transformation of sound pressures about the animal's head and body. The PDR hypothesis is instead supported by anatomical data verifying the presence of continuous dorsal and ventral pathways that connect the middle ear cavities. A muscular flap separating the Eustachian tube from the pharynx further suggests that these animals may have some control over transmission through the ventral pathway.

P1.5 BIRK, M.A.*; ULMER, K.M.; CHIAO, C.-C.; CHUBB, C.; SIEMANN, L.; HANLON, R.T.; Univ. of North Carolina Wilmington, Marine Biological Laboratory, Woods Hole, MA, National Tsing Hua Univ., Hsinchu, Taiwan, Univ. of California, Irvine; *matthewabirk@gmail.com*
Cuttlefish camouflage: using visual psychophysics approach with grayscale disk patterns to examine disruptive body patterning
Cuttlefish can change their color, intensity, and pattern to camouflage in any natural environment. This study sought to determine an "activation function" for the 11 skin components that make up disruptive body patterns, and whether their activations could be predicted based on different proportions of grayscale disks in the visual background. Ten cuttlefish (*Sepia officinalis*) were used in a behavioral assay to determine these "activation functions". Four complementary pairs of visual patterns were designed with proportions of five grayscale disks varying in mean intensity, contrast, skewness, and kurtosis. All four pairs of disk patterns were tested on white, 50% gray, and black backgrounds. The patterns potentially provide the ability to determine the sensitivity of the cuttlefish to each of the five grayscale disks. Preliminary analyses indicate that cuttlefish were not differentially sensitive to the disk patterns on a gray or black background. Cuttlefish showed stronger disruptive body pattern on a white background with disk patterns that were low mean intensity, high-contrast, or all-black. These three disk patterns each have a large proportion of black disks, thus suggesting that cuttlefish are more sensitive to black objects than white or gray objects when the objects are placed on a light background. Further analyses suggest that activation functions of a few disruptive components can be derived from these data, although predicting body patterns of cuttlefish on any given background still remains elusive.

P3.14 BJELDE, B.E.*; TODGHAM, A.E.; San Francisco State University; *bbjelde@mail.sfsu.edu*
Cardiac performance and metabolism of an intertidal limpet under conditions of emersion and immersion
Species distribution and abundance are changing in the face of increasing temperature; however the physiological mechanisms underlying these shifts are not clear. Intertidal animals provide an excellent study group to examine how organisms respond to environmental stressors under different habitat conditions as their environment fluctuates between terrestrial and aquatic conditions with each tidal cycle. We investigated the physiological response of the finger limpet, *Lottia digitalis*, to thermal stress when exposed to elevated temperatures in water (immersed) or in air (emersed). Using measurements of heart rate and metabolic rate, we were able to examine both sensitivity to increases in temperature as well as thermal tolerance thresholds of limpets in air and water. Thermal limits of heart function were determined by calculating the temperature which caused a drastic drop in heart rate (break temperature) while heating at a rate comparable to a low tide period. Heart rate and metabolic rate, estimated through measurements of O_2 consumption, were also measured in both environments under acute plunging experiments from 15-40°C at 5°C intervals. Final break temperatures were significantly higher (3-5ºC) in emersed limpets than immersed. Oxygen consumption was higher and more variable under conditions of emersion compared to immersion where limpets decreased O_2 consumption with increasing temperature. Comparisons of heart rate differences between ramping and plunging experiments suggest that thermal tolerance thresholds depend on heat shock protocol. Temperature logger data suggests that *L. digitalis* are currently living close to their tolerance limits and may not have the capacity to keep up with increasing climate change or increased frequency of extreme heat waves.

P2.10 BLACK, C.E.*; GIRAUDEAU, M.; MCGRAW, K.J.; NOLAN, P.M.; The College of Charleston, Arizona State University, The Citadel; *ceb51490@gmail.com*

Bird song behavior along an urban-to-rural gradient

Urban environments pose a variety of challenges to wildlife, containing more stressors than are found in rural areas. One of these challenges is the interference faced by singing birds when confronted with urban noise. Birds may be forced to change the frequency of their song, delay the start of a song, have a song cut short, or stop singing altogether. Each of these effects mimics behaviors shown to be important in the sexual selection of a number of avian species. Our study analyzes characteristics of house finch song recorded at sites along an urban to rural gradient. We recorded 20 songs from each of 10 males at each of 6 field sites in the Phoenix, AZ area, in May 2011. Songs were analyzed to determine frequency range, upper and lower frequencies, song length, and complexity (% of unique notes per song). Our results showed significant differences in song characteristics between the extreme ends of the urban to rural gradient with mixed results in between. In particular, the birds responded differently to continuous noise than they did to periodic noise. We conclude that urban noise does impact the birds' singing behavior but that the birds have sufficient behavioral flexibility to adapt to this interference.

P3.187 BLAIR, PB*; FREEMAN, CJ; THACKER, RW; Univ. of Alabama at Birmingham; *pbblair@uab.edu*

Genotyping symbionts through high-resolution melting analysis: Distinguishing clades of the sponge-specific cyanobacterial symbiont Synechococcus spongiarum

Approximately one-third of Caribbean coral reef sponges host photosynthetic cyanobacterial symbionts classified as *Synechococcus spongiarum*. The diverse *S. spongiarum* group consists of multiple, distinct clades that are distinguished using DNA sequences of the 16S-23S ribosomal RNA internal transcribed spacer (ITS) region. Since this task requires labor-intensive PCR-based amplification, cloning and DNA sequencing, we developed a high-throughput method to rapidly screen sponge hosts for the presence of particular *S. spongiarum* genotypes. We generated a series of standard clones for each major clade based on previously identified and sequenced specimens. We conducted high-resolution melting (HRM) analysis by using specifically designed primers to amplify a variable portion of the ITS region from these clade standards. We normalized the melting curves for each clone, and then calculated fluorescence difference plots between each normalized melting curve, standardized to a single clone. These plots differentiated clones from clades A, B, and C, which are all commonly reported in previous studies from Bocas del Toro, Panama. We are currently determining the ability of HRM analysis to discriminate mixtures of symbionts within a single host. This rapid, high-throughput method of genotyping *S. spongiarum* will facilitate future work with these symbionts. This approach has been successfully used to genotype coral-*Symbiodinium* associations and can be applied to a broad range of other ecological interactions.

P3.171 BOISETTE, B.*; DIALEY, F.; DORCE, K.; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College, Brooklyn, Kingsborough Community College, Brooklyn; *catapane@mec.cuny.edu*

The Effects of Manganese and Copper on Mitochondrial Membrane Potential in the Gill of Crassostrea virginica

Accumulations of manganese (Mn) or copper (Cu) is characteristic of the neurodegenerative disorders Manganism and Wilson's Disease, respectively. The mitochondrion is a source and target of oxidative stress. Previously we found gill mitochondria from the oyster *Crassostrea virginica*, treated with Mn or Cu, had impaired oxygen utilization. Oxidative damage causes a loss of mitochondrial membrane potential (MMP) with associated mitochondrial dysfunction. Here we used two fluorescent dyes, TMRM and JC-1, to determine effects of Mn and Cu treatments on MMP. Mitochondria from gill of C. virginica were isolated and treated. For JC-1 we compared fluorescence intensities at 525 nm ex and 590 nm em of Mn treated (50 - 150 mM) mitochondria to that of control. Mn treated showed dose dependant decreases in fluorescence of up to 70%. For TMRM we compared slopes of the 573/564 nm ex, 590 nm em fluorescence intensity ratio. Decreasing slope indicates loss of MMP. Treating isolated mitochondria with Cu resulted in a dose dependant reversal in the slopes from 20 to -20 and from 15 to -3, respectively. Cu was significantly more toxic than Mn and both fluorescent dyes were equally effective in demonstrating that short-term treatments with either Mn or Cu could de-energize gill MMP. This information correlates well with our previous findings on the toxic effects of both Mn and Cu on mitochondrial respiration. Identifying the molecular and cellular mechanisms of metal-induced oxidative stress will provide a better understanding of the pathophysiological features of neurodegenerative disorders associated with metal toxicity.

P2.118 BOLES, S.E.*; HETTINGER, A.; GAYLORD, B.; SANFORD, E.; TODGHAM, A.E.; San Francisco State University, Bodega Marine Laboratory and University of California, Davis; *ponettie@mail.sfsu.edu*

Metabolic costs of ocean acidification on growth and development of the native Olympia oyster, Ostrea lurida.

Since the Industrial Revolution, roughly 48% of anthropogenic CO_2 has been absorbed by the oceans, causing a reduction in pH of 0.1 units, and a further decrease of 0.3-0.4 pH units is expected by the end of this century. A great deal of research has been done to predict the future impacts of ocean acidification (OA) on calcifying organisms; however, studies examining the synergistic effects of OA and global warming on the physiological and biochemical processes during early development of calcifying animals are in their infancy and require further analysis. We reared larvae of the Olympia oyster, *Ostrea lurida*, under a factorial combination of CO_2 (control, 385 ppm vs. elevated, 1000ppm) and water temperature (control, 20°C vs elevated, 24°C). To evaluate the energetic costs associated with growth and development under these treatments, we assessed enzyme activity of the Krebs cycle, a proxy for aerobic metabolism. If more metabolic energy is being allocated to biomineralization and development, larvae reared under conditions of elevated CO_2 could face higher energetic demands. This in turn could leave less energy available for coping with thermal stress (e.g. ocean warming as well as highly variable thermal habitat of the intertidal zone), possibly impeding survival and settlement of *O. lurida*. With global climate change, a plethora of environmental factors are predicted to undergo relatively rapid changes; therefore it is pertinent to understand the impacts of climate change from a multi-stressor perspective.

P2.85 BONE, N. B.*; KRAJNIAK, K. G.; Southen IL Univ. Edwardsville, Southern IL Univ. Edwardsville; *nbone@siue.edu*

THE RESPONSE OF THE EARTHWORM CROP/GIZZARD TO MEMBERS OF THE OXYTOCIN/VASOPRESSIN FAMILY OF PEPTIDES

Members of the Oxytocin/Vasopressin family of peptides are present in both vertebrates and invertebrates. While oxytocin and vasopressin are found in vertebrates, annetocin is found exclusively in annelids. Many of these peptides modulate the motility of smooth muscle. Several experiments have been performed on several species of Annelids regarding the effects of annetocin, oxytocin, and vasopressin. However, the effects of these peptides have yet to be determined in the earthworm *Lumbricus terrestris*. In this study we used isolated the crop-gizzard of *L. terrestris* to measure the effects of oxytocin. The crop-gizzard was removed from the animal, placed in a tissue bath, and connected to a force transducer. The responses to increasing concentrations of peptide were recording using a computer with an Iworx converter and Labscribe 2. Preliminary findings show that the oxytocin increased contraction rate with a threshold of 10^{-8} M, and amplitude with a threshold between 10^{-8} and 10^{-7} M. Other peptides in the oxytocin/vasopressin family are also being investigated for their effects on the crop/gizzard of the earthworm.

P1.124 BONIN, J.A.*; HOMBERGER, D.G.; Louisiana State Univ., Baton Rouge; *jbonin1@tigers.lsu.edu*

Optical properties of yellow psittacofulvin colors in the tail feathers of cockatoos (Cacatuidae) and parrots (Psittacidae)

The yellow feather colors of Psittaciformes are produced by unique pigments (psittacofulvins). They may also fluoresce, but do so in different color ranges in cockatoos and parrots (Voelker 1937). To test the hypothesis that these colors evolved independently in cockatoos and parrots, yellow contour feathers were analyzed spectrometrically in four Australasian cockatoos (*Calyptorhynchus banksii*, *C. funereus*, *Cacatua galerita*, and *Nymphicus hollandicus*) and two parrots (the Australian *Melopsittacus undulatus* and the Caribbean *Amazona ventralis*). The yellow patches in the tail feathers of the three cockatoos and the yellow facial feathers of *Nymphicus* varied in the intensity of reflectance, but displayed similar reflectance spectra with a slight peak in the UV range (325-350nm), a slight dip in the near UV-violet-blue range (375-425nm), and a sharp increase in the blue-greenish range (425-475nm) followed by a constant intensity to 700nm. The yellow patches in the tail feathers of the parrots differed in the relative intensity of reflected UV and visible light, but displayed similar reflectance spectra with a pronounced peak in the UV range (325-350nm), a pronounced dip in the blue range (400-475nm), and a sharp increase in the green range (475-525nm) followed by a constant intensity to 700nm. Only the yellow feathers of the *Calyptorhynchus* and *Nymphicus* species fluoresced. Hence, cockatoos are characterized not only by several functional-anatomical features, but also by similar reflectance spectra of their yellow contour feathers. Our data further support the hypothesis that cockatoos may have evolved their psittaciform morphotype independently from parrots (see Homberger 2003).

P2.188 BOOSTER, N.; SU, F.Y.*; ADOLPH, S.C.; AHN, A.N.; Pitzer College, Harvey Mudd College; *fsu@hmc.edu*

The effect of temperature on running in the tarantula, Aphonopelma hentzi

Tarantulas lack extensor muscles in some of their leg joints but still need to extend their limbs. Instead of muscles, extension in the leg joints is mediated by a hydraulic mechanism, where hemolymph is pumped from the prosoma (or thorax) into the legs. Our study examined tarantulas sprinting in a temperature-controlled environmental chamber at four temperatures: 15, 24, 32, and 40°C. Using a high-speed video camera (Allied Vision Technologies; Pike model), we quantified the three-dimensional joint angle changes of the femur-patella (proximal) and tibia-metatarsus (distal) on the first (front) and fourth (hind) legs in four animals. Since muscle activity increases with temperature, we examined the hydraulic mechanism using extension fraction, or the fraction of the stride devoted to extension. Stride frequency, as expected, increased from 3.7 to 9.4 Hz at 15 and 40°C, respectively. Stride length, however, did not change with temperature at 1.3 ± 0.1 body lengths (7.1 ± 1.6 cm). Extension fraction remained constant with temperature at 0.48 ± 0.003. Additionally, the joint angle range for each of the four joints remained constant with temperature. Interestingly, the joint angle ranges of the proximal joints exceeded that of the distal joints by 39.1 ± 4.0° (front leg) and 31.7 ± 6.9° (hind leg). The much smaller joint angle range for the distal joints suggests the distal joints may act more like struts during running in tarantulas. The kinematics during running indicate that hemolymph viscosity does not seem to limit joint movement as temperature increases from 15 to 40°C, which includes ecologically relevant temperatures. We thank HHMI, Barbara Stokes Dewey, and the Biology Department of HMC for funding.

P1.51 BOOTH, C.E.*; HENRY, R.P.; Eastern Conn. State Univ., Auburn Univ.; *booth@easternct.edu*

Mechanisms of H+ and Ammonia Excretion in Exercising Blue Crabs, Callinectes sapidus

David Towle made seminal contributions to our understanding of ion transport across the crustacean gill epithelium, including the discovery of an apical electrogenic 2Na+/H+ exchanger (2NHE). Gill ion transport (Na+/H+; Cl-/HCO3-) and ammonia excretion are thought to play key roles in the regulation of internal acid-base balance in crustaceans. However, our understanding of these processes is based largely on animals ionoregulating in FW or dilute SW. Little is known about gill mechanisms of acid-base regulation in SW-acclimated animals in which active Na+ and Cl- uptake are not required. We examined the mechanisms by which SW-acclimated blue crabs excrete H+ and ammonia during exercise. Net H+ excretion during exercise was reduced by 54% in Na+-free ASW and by 27% in HCO3--free ASW, and was abolished in ASW lacking both ions. Ammonia excretion during exercise was independent of ambient Na+, increased in HC03- -free ASW, and was depressed in alkaline ASW. These results implicate branchial Na+/H+ and Cl-/HCO3- exchange in the excretion of H ions, and NH3 diffusion as the major route for ammonia excretion during exercise. However, we are unable to determine if H+ excretion occurs by electroneutral Na+/H+ exchange, or via Towle's electrogenic 2NHE and parallel electrogenic H+ excretion.

P2.140 BORSUK, P.*; KROHMER, R.W.; Saint Xavier University, Chicago; *borsuk.p25@mymail.sxu.edu*
Colocalization of Aromatase and Nitric Oxide Immunoreactive Neurons in the Forebrain of the Male Red-Sided Garter Snake
Nitric oxide (NO) first identified as an endogenous regulator of blood vessel tone, may also serve as a neurotransmitter. With a half-life of less than five seconds, NO has been examined by assessing the presence enzymes responsible for the formation of NO. The NO producing enzyme, reduced nicotinamide dinucleotide phosphate-diaphorase (NADPH-d) is broadly distributed in the mammalian and avian brain, particularly in steroid-sensitive areas implicated in the control of reproductive behavior. In addition, distribution of NADPH-d corresponds to areas with dense populations of cells containing the aromatase enzyme (ARO). Previously, we found aromatase immunoreactive (ARO-ir) cells to occur at all levels of the male red-sided garter snake (RSGS) brain. However, cells containing the highest concentration of ARO-ir were concentrated in regions classically associated with the control of courtship behavior and mating. In the current study, we examine the anatomical relationship between ARO and NO by labelling ARO-ir and NADPH-d (NO-ir) cells. The distribution of ARO-ir cells was similar to that reported by Krohmer et al (2002) with NO-ir cells significantly overlapping the ARO-ir cells in regions critical for the control of courtship behavior, such as the preoptic area, bed nucleus of the stria terminalis, nucleus sphericus, hypothalamus, and septum. Tissues double labelled for ARO and NADPH-d revealed a possible co-localization of these enzymes within the same cell subset. Based on these data, the close association of ARO-ir and NO-ir cells suggest input from NO-positive neurons may modulate the expression or activity of ARO in the male red-sided garter snake brain.

P2.167 BORUTA, M.*; BRACE, A.J.; LIEBL, A.L.; MARTIN, L.B.; Univ. of South Florida, Tampa; *mboruta@mail.usf.edu*
Does variation in host physiology occur among urban-rural habitats in disease prevalence?
Interactions between hosts, parasites, and their environments strongly influence disease emergence and persistence. For example, many avian zoonotic diseases are more commonly found in urban rather than rural environments. Closer proximity and higher densities of human and wildlife populations in urban areas allow for increased contact rates between inter- and intraspecifics. Often urbanization changes patterns in parasite, vector, or host densities, which influence transmission rate, but host physiological variation and behavior may also be important. Urban ecosystems expose organisms to recurring or prolonged stressors favoring individuals able to cope and survive. In particular, anthropological stressors (e.g. habitat modification, increased competition, exposure to pollutants) are likely to affect both immune function and glucocorticoid regulation, which is responsible for stress attenuation and recovery. In this study, we looked at whether urbanization affected host variation of corticosterone levels and corticosterone-sensitive immune functions in Northern Cardinals *Cardinalis cardinalis*, an abundant passerine commonly found in both urban and rural environments throughout the Eastern United States. Comparisons regarding host physiological variation between paired urban and rural sites and their relationship to habitat characteristics could provide a rigorous framework for further research on how urban-rural gradation impacts host physiology and disease incidence.

P3.23 BOSWELL, L/C*; MOORE, D/S; HAND, S/C; Louisiana State University; *lboswe1@lsu.edu*
Identification of splice variants and protein expression levels for two Late Embryogenesis Abundant proteins in embryos of Artemia franciscana
Late Embryogenesis Abundant (LEA) proteins are highly hydrophilic, low complexity proteins that were originally discovered in plants. The expression of LEA proteins has been tightly correlated with desiccation tolerance in anhydrobiotic organisms. We have currently identified and sequenced six LEA genes in embryos of the brine shrimp *Artemia franciscana*. Two of the six *Afrlea* genes (*Afrlea2* and *Afrlea3m*) have been cloned into a bacterial expression system, over-expressed, and purified. Based on deduced amino acid sequences, AfrLEA3m is predicted by subcellular targeting programs to be mitochondrial localized (now confirmed experimentally), while AfrLEA2 is predicted to be cytosolic. Multiple splice variants for both AfrLEA2 and AfrEA3m have been detected in *A. franciscana* using antibodies produced against recombinant AfrLEA2 and AfrLEA3m. Two splice variants are observed for AfrLEA2 with estimated molecular weights of 75 and 45 kDa, and four splice variants are observed for AfrLEA3m with estimated molecular weights of 29, 35, 45, and 52 kDa. The four splice variants detected for AfrLEA3m have been verified with LC tandem mass spectrometry. We have previously reported the mRNA expression of *Afrlea2* and *Afrlea3m* to be several fold higher in two embryonic stages of *A. franciscana* that possess desiccation tolerance, when compared to the desiccation-intolerant nauplius larva. Furthermore we have now shown that protein expression for each of these two AfrLEA proteins is highest in diapause embryos and decreases throughout development to undetectable levels in 24 h nauplius larvae. We have also quantified the endogenous AfrLEA2 protein concentration of the 75 kDa splice variant to be approximately 0.9 mg per g embryo water for early post-diapause embryos. (Supported by NSF grant IOS-0920254)

P2.142 BOTTERI, N.L.*; MOORE, B.C.; ALBERGOTTI, L.C.; HAMLIN, H.J.; LAWLER, A.N.; MATHAVAN, K.; GUILLETTE JR., L.J.; University of Florida, Louisiana Tech University, University of Maine, University of Miami, University of Massachusetts Amherst, Medical University of South Carolina; *nbotteri@ufl.edu*
The Medullary Rest: A Naturally Occurring Intersex Region of American Alligator Ovary
In the American alligator, temperature dependent sex determination (TSD) directs gonadal differentiation and is characterized as being an absolute process, producing either an ovary or a testis. However, in depth histological investigation of the alligator ovary reveals a naturally occurring intersex region. The “medullary rest”, first described by T.R. Forbes in the 1930s, is an atypical ovarian region lacking cortical and medullary morphology characteristic of an alligator ovary. In contrast, the medullary rest is comprised of disorganized tubule-like structures containing presumptive germ cells, reminiscent of testicular tissue. Here, we further Forbes’ investigation of this region by using differential histological stains to show that the medullary rest is a dynamic region, maturing throughout ontogeny, demonstrating both ovarian and testicular characteristics. Current investigations seek to quantify gene expression of adult alligator medullary rest using sexually dimorphic molecular markers previously described by our group. Future endeavors will quantify the potential hormonal responsiveness of the medullary rest using both histological and molecular endpoints. Characterization of the medullary rest is essential in order to ascertain potential ramifications for reproduction.

P2.123 BOUCHARD, J.B.; MITCHELL, R.; CAMPBELL, A.; KIROUAC, L.E.; LACHANCE, S.; NAIMIE, A.A.; WATSON, III, W.H.; NEWCOMB, J.M.*; New England College, University of New Hampshire; *jnewcomb@nec.edu*

In search of biological clock neurons in the central nervous system of the nudibranch Melibe leonina

Daily rhythms of activity are controlled by neural networks that function as endogenous biological clocks. The molecular time-keeping mechanisms involve the rhythmic expression of various proteins, such as clock and timeless. In addition, pigment dispersing hormone (PDH) is believed to be a putative output signal from the clock in certain invertebrates. The goal of this project was to determine the location of the circadian clock in the marine gastropod *Melibe leonina* by treating brains with antibodies to clock, timeless, and PDH. Two large clock-immunoreactive neurons were consistently present in the left pleural ganglion, with a small number of other neurons labeled in a subset of the brains examined. The location and number of clock-immunoreactive neurons was not significantly different between animals sacrificed at different times during a twenty-four period. Timeless-immunoreactive neurons were present near the eyes in the middle of each cerebropleural ganglion. PDH-immunoreactive nerve tracts were present in the anterior cerebral ganglia and smaller tracts spanned the pedal connectives. PDH-immunoreactive axons and cell bodies were also visible in the buccal ganglia and throughout the esophagus and associated ganglia, suggesting PDH may play a role in feeding. Additional genome sequencing and custom species-specific antibody construction will facilitate continuing studies investigating the location of the circadian clock in *M. leonina*. In conjunction with planned pharmacological and electrophysiological studies, these results will eventually be used to establish *M. leonina* as a model system to investigate the neuroethology of circadian rhythms.

P2.201 BOUMIS, R.J.; GIBB, A.C*; Northern Arizona University; *Robertjb78@gmail.com*

Orientation and movement strategies determine the success of down-slope movement in stranded Gambusia affinis

Gambusia affinis are known to voluntarily strand themselves to avoid predators. In addition, this species is of interest as biological pest control agent, a model organism, and a highly invasive species. In the laboratory, individuals of *G. affinis* (n=53) were manually stranded on a ramp covered with damp sand that was elevated at one end to create a slope of thirty degrees. Individuals were placed on the slope in one of four orientations: "cranial-end-up," "cranial-end-down," "dorsal-surface-up," and "dorsal-surface-down," with "down" denoting the down-slope direction, where the water would be located in the wild. The response to stranding was recorded using a digital-video camera at 60 FPS. Statistical analysis revealed that two factors, starting orientation and the type of movement employed, affected how likely a fish was to make it to the bottom of the slope. Specifically, a fish in the "dorsal-surface-down" orientation was the most likely to return to the water in a single movement. Two separate types of movement, a jump pushing off from the caudal peduncle, and a bending motion where the tail bends towards the upper body were more likely to succeed than other observed movement types. This finding suggests that if a fish voluntarily strands itself, it will be more likely to successfully return to the water if it lands at a particular orientation on the bank.

P2.159 BOURCIER, Timothy*; SOLA GRACIA, Emilia; MARTIN III, Arthur L.; Saginaw Valley State University, University of Rochester; *tmbourci@svsu.edu*

The effects of flow on social dynamics of the crayfish, Orconectes propinquus

Agonism influences the development of social status amongst animal conspecifics. These interactions structure the social dynamics that develop within a population. A variety of factors influence the outcome of social interactions such as size of conspecifics, sex, resource availability, and environmental dynamics. Environmental factors, including flow and shelter availability, dramatically influence and alter fight interactions between individuals, which will influence population social structure. These external factors influence an animal's decision by modifying signals during communication and an increased resource value may influence competition. Environmental factors influence behavior by altering the agnostic interactions that structure social dynamics. Flow is a very important environmental factor in a lotic environment. We are analyzing the influence flow has on social interactions and the dynamics that develop among a populatoin. The role that flow plays in structuring population dynamics has been understudied. To analyze the effects of flow a 7.569 X 0.991 X 0.175 m3 artificial stream was constructed to run trials on crayfish populations. Trials consisted of populations with 4 size matched (within 10%) male crayfish, *Orconectes propinquus*. Video analysis was used to observe these interactions over a 72 hour time period. Through video analysis, time spent up and downstream relative to one another was cataloged and quantified. Crayfish were identified by using white liquid correction fluid to mark the carapace. This experiment allowed for the measurement of time spent in a location relative to conspecifics within the trial.

P1.228 BOURKE, Jason*; WITMER, Lawrence; Ohio University, Athens; *jb513009@ohio.edu*

Baffling bird noses: Modeling the effects of turbinate structure on airflow dynamics in ostriches and turkeys

Respiratory turbinates in birds vary in their structure and complexity. Some are relatively simple infoldings of the cartilaginous nasal capsule while others exhibit a more scrolled, branch-like formation similar to that of many mammals. The effects of these turbinates on airflow through the nasal passage have not been fully explored. Earlier models of avian nasal airflow relied on general fluid dynamics to estimate airflow patterns through the nasal passage. To better assess these flow patterns, a computational fluid dynamics (CFD) analysis was performed on the nasal passages of a galliform (turkey) and a ratite (ostrich). Results from the turkey uncovered two major routes of airflow through the nasal passage. The majority of inspired air traveled past the rostral and middle conchae in a cyclonic manner, ultimately exiting at the choana. A second, lower-speed airstream occurred on the medial side of the rostral concha, bypassing the middle concha and flowing around the caudal concha within the olfactory chamber. This secondary flow appeared to be the main route in which odorant molecules would enter the olfactory chamber. These data validate previous suppositions that the atrial and rostral conchae act as baffles that split and redirect the incoming air field. Results from the turkey model were compared to a CFD model of an ostrich, which lacks an atrial concha. Differences in airflow between these two taxa may relate to the role of olfaction in the ecology of each taxon.

P2.67 BOWIE, Emily J.*; SMITH, Julian P.S.; Winthrop University; *bowiee2@winthrop.edu*

Diurnal Synchronization of the Cell Cycle in Aeolosoma (Annelida)

In many organisms, the cell cycle is at least partly synchronized to a diurnal rhythm. At least two possible hypotheses have emerged to explain this. First, consigning sensitive portions of the cell cycle to periods of low aerobic activity may be one way of protecting the cell's genetic material. A second hypothesis is that consignment of the sensitive portions of the cell cycle to the scotophase may be a way of reducing light-mediated DNA damage. In order to investigate these hypotheses further, we determined whether the cell cycle in *Aeolosoma* (a small, transparent annelid common in freshwater habitats) varies diurnally. If so, it might be expected that the stem cells present in *Aeolosoma* will divide more frequently at night than during the day. *Aeolosoma*reproduces prolifically by asexual fission in culture, and has proven useful in our lab for studying stem cells and the mitotic cycle. *Aeolosoma*were cultured under a clock-shifted photoperiod of 12L/12D; with artificial noon being around 5:00PM. After the *Aeolosoma*acclimated to this new diurnal rhythm, they were killed by freezing, which provided a way to preserve any cells undergoing mitoses at the time of death. One group was frozen at relative 3:00AM (dark group) and the second group was frozen at relative 3:00PM (light group). Mitotic cells were labeled with anti-phosH3, the nuclei of the cells were stained with Hoechst 33342, and the cells undergoing mitosis were counted from confocal-laser-scanning microscope stacks. Mitoses were significantly (approximately 77%) higher in the dark group. These results show that the stem cells are more likely to undergo mitosis at night than during the day. Future studies will include more samples at different times to find the time of maximal mitosis, and include the use of EdU labeling to observe S-phase. Support for this research was provided by SC-INBRE II.

P3.191 BOYKO, CB*; MOSCATO, DJ; Dowling College; *cboyko@amnh.org*

Sexual Dimorphism and Species Distinctions in the Genus Edotia (Crustacea: Isopoda)

Since 1818, 21 species of isopods have been described in the genus *Edotia*. Two of these have been removed to other genera and two have been relegated to synonymy. In the northwestern Atlantic three species have been described: *E. triloba* (Say, 1818), *E. montosa* (Stimpson, 1853), and *E. acuta* (Richardson, 1900). There has been discussion concerning the relative distinctiveness of these three species and some zoologists, starting with Wallace (1919), argued that the latter two species are not distinct enough for recognition and are synonymous with *E. triloba*. Others consider *E. triloba* and *E. montosa* as distinct (Kropp 1995), while yet others recognize all three species (Brandt and Bruce 2006). A preliminary study of samples from Georgia indicated that each northwestern Atlantic species of *Edotia* may represent different sexes and/or stages of development. We examined a large series of *Edotia* to address the issue of such ambiguous distinctions. Morphological proportions and sexes of over 130 specimens obtained from various collections and from throughout the range of the three species (ca. Nova Scotia to Georgia) were recorded. There is a clear sexual dimorphism between males and females based on the relative proportions of pereomere widths relative to body length. The ratio of length to width in males was found to be larger than in females. Our data suggests that there is only a single species of *Edotia* in the northwestern Atlantic. Based on this data and a review of the literature, there is a need to revise the genus in order to clarify the distinctions between *Edotia* species worldwide. Some species may be based on only a single sex but few descriptions or mentions of *Edotia* specimens in the literature include data on the sex of specimens.

P2.97 BRACE, A.J.*; LIEBL, A.L.; BORUTA, M.; MARTIN, L.B.; University of South Florida; *abrace@mail.usf.edu*

The effects of captivity on immune function and physical performance in house sparrows

Exposure of an organism to a chronic stressor can result in suppression of the immune system through increases in glucocorticoids. Although the mechanisms of immune suppression are well-known, there are presently only two organismal-level hypotheses to explain this effect: i) immune suppression occurs to decrease the chance of an autoimmune response to self-antigens that an organism releases in response to a stressor and/or ii) immune suppression allows for the reallocation of resources towards immediate survival traits, such as flight capacity, an essential component of escape behavior in songbirds. Previous work in house sparrows (*Passer domesticus*) has shown that captivity alters regulation of corticosterone, induces hyperinflammation, deregulates leukocyte flux to the skin post-wounding and compromises antibacterial activity in blood, indicating that prolonged captivity acts as a chronic stressor. Previous work has also indicated that flight performance changes in captivity, although it could not be determined whether these effects were due to a decline in physical condition or psychological habituation to the flight performance apparatus. Here, we used a modified version of the flight performance apparatus to test whether several immune functions declined faster than physical performance. Such a trend would support the hypothesis that immune suppression in response to stressors occurs to promote other functions, at least over a short time scale.

P1.100 BRANDT, E; MORRIS, JS*; CARRIER, DR; University of Utah; *j.s.morris@utah.edu*

Skeletal sexual dimorphism in Gray Wolves indicates functional trade-offs in specialization for competition versus locomotor economy.

Sexual selection theory predicts that male mammals will be more specialized for physical competition than females. Specialization for fighting in males may, however, result in functional conflicts with the locomotor demands that females face. Specialization for locomotion results in a suite of correlated characters; i.e., long, gracile limbs that reduce the cost of transport by increasing stride length and decreasing the energy required to swing the limbs. In contrast, specialization for physical competition appears to result in stout bones and large distal muscles with high mechanical advantage that increase force available to strike or manipulate opponents. In this context, gray wolves (*Canis lupus*), are interesting because although males are likely subject to sexual selection on male-male competition, both sexes actively participate in the defense of territory and both forage over great distances and run down prey. Thus, a phenotype specialized for efficient locomotion is expected in both sexes and therefore wolves might exhibit a low level of musculo-skeletal sexual dimorphism. To determine whether or not wolves exhibit sexual dimorphism, a series of skeletal metrics were taken from fresh cadavers and museum specimens. All measures were size-corrected and analyzed to detect relative differences in size and shape. Males were found to have relatively shorter, more robust limb bones with higher muscle mechanical advantage, while the limbs of females were relatively longer and more slender. These differences are consistent with specialization of males for physical competition, and greater specialization in females for efficient locomotion.

P1.139 BRICKER, E.A.*; GREENWOLD, M.J.; SAWYER, R.H.; University of South Carolina, Columbia; *bricker@email.sc.edu*
The Molecular Evolution of Alpha Keratins in Reptiles and Birds
Alpha keratins are filamentous proteins in epithelial cells that are necessary for supplying mechanical stability to those cells against stress. There are two main types of alpha keratins based on acidity, one is acidic (Type I) and the other is basic-neutral (Type II). A large protein-family of alpha keratins is found in mammals which provides the structural proteins for the wide array of mammalian epidermal appendages such as hair and nails. BLAST searches were performed against the preliminary genomes of the saltwater crocodile (*Crocodylus porosus*) and the American alligator (*Alligator mississippiensis*). Using phylogenetic analyses we compared the alpha keratin protein and nucleotide sequences of one lizard (*Anolis carolinensis*), three birds (*Taeniopygia guttata* , *Gallus gallus*, *Meleagris gallopavo*), and the two crocodilians mentioned above. We found three complete Type II keratin sequences, one in the alligator and two in the crocodile. There appears to be two Type II alpha keratin pseudogenes in the crocodile and one in the alligator. Our phylogenetic analyses revealed that two incomplete alpha keratin sequences on the same scaffold in the alligator are more closely related to each other than to any other gene, possibly indicating lineage specific tandem duplication. An orthologous relationship exists between the complete Type II alligator sequence and the Type IIA chicken. The two complete saltwater crocodile Type II alpha keratins formed a paralogous relationship. The sequences found in these crocodilian species suggest lineage specific duplication, like that seen in mammals, although to a much smaller degree.

P2.124 BROWN, C.*; SADCHLA, M.; MATTHEW, K.; COCHRAN, T.; CARROLL, M.A.; CATAPANE, E.J.; Medgar Evers College, Brooklyn, NY; *catapane@mec.cuny.edu*
A Study of GABA in Bivalve Molluscs
The nervous systems of most studied bivalves contain serotonin and dopamine in their ganglia that serve as neurotransmitters regulating various physiological functions such as heart rate, foot movement, reproduction and gill lateral cilia beating. GABA (gamma aminobutyric acid) is a major inhibitory neurotransmitter found in the CNS of vertebrates and the ganglia of many invertebrates. Its presence and functions have not been well studied in bivalve molluscs. In this study we used a HPLC method with pre-column derivatization and fluorescence detection to look for GABA in ganglia of *Crassostrea virginica, Mercenaria mercenaria* and *Mytilus edulis*. We also examined effects of GABA on beating of gill lateral cilia in *C. virginica* and *M. edulis*. GABA was detected in low ng amounts in each of the ganglia of each of the bivalves. In *C. virginica* and *M. edulis* GABA had no direct effect on lateral cilia activity whether superfused to the cerebral ganglia or applied directly on the gill. However, in *C. virginica* when serotonin was applied to the cerebral ganglia, the presence of GABA, whether applied prior to or after serotonin, blocked the normal excitatory response of serotonin on the beating of the cilia. Furthermore, the GABA antagonist bicuculline methchloride blocked the effects of GABA in the cerebral ganglia of *C. virginica*. Similar experiments with *M. edulis* did not demonstrate that GABA had a serotonin blocking effect at the cerebral ganglia. This study is showing that GABA is present and has a neurophysiological role in bivalve ganglia. This work was supported by grants 2R25GM0600309 of the Bridge Program of NIGMS, 0516041071 of NYSDOE and 0622197 of the DUE Program of NSF.

P2.125 BUBAK, A. N.*; SWALLOW, J. G.; RENNER, K. J.; Univ. of South Dakota; *andrew.bubak@usd.edu*
Whole brain monoamine detection in a stalk-eyed fly
Male stalk-eyed flies (*Teleopsis dalmanni*) compete over territory and mates and provide an excellent model system to study aggression. In order to investigate the potential effects of serotonin (5-HT) on aggressive behavior in these flies, we developed a dissection and sample preparation method for whole brain that allows the detection of monoamines from a single fly using high performance liquid chromatography with electrochemical detection. The successful determination of the monoamines norepinephrine (NE), epinephrine (EPI), 5-hydroxytryptophan (5-HTP), dopamine (DA), 5-hydroxyindoleacetic acid (5-HIAA), tyramine (TA), and serotonin (5-HT) provide a means of assessing changes in stalk-eyed fly brain monoamine concentrations as a response to drug administration in the food media. This approach was successfully used to elevate 5-HT levels in stalk-eyed fly brains by oral administration of the precursor 5-HTP. We successfully increased 5-HT levels approximately 8 fold that of the mean control levels by orally administering 5-HTP and found that the response was dose-dependent. We are currently evaluating the time course over which serotonin remains elevated after the food source of 5-HTP is removed. The ability to manipulate neurotransmitter levels in the brain will allow us to develop experiments to explore the neurochemical mechanisms underlying behavioral interactions exhibited by stalk-eyed flies. Specifically, the method described to successfully raise 5-HT levels in the brain will be applied to intraspecific aggressive competitions as well as predator-prey interactions. The trials will be scored to determine if heightened levels of 5-HT have an impact on aggressive behavior and subsequent effects on dominance or survival. This work was supported by NSF grants IOS 0921874 and IOB 0448060.

P1.128 BURCH, Sara H.*; SMITH, Nathan D.; NESBITT, Sterling J.; IRMIS, Randall B.; TURNER, Alan H.; Stony Brook University, Field Museum, The University of Washington, Utah Museum of Natural History; *sara.burch@stonybrook.edu*
Reconstructing the antebrachial and manual musculature in the basal theropod dinosaur Tawa hallae
Reconstructing limb musculature provides important information about the function and capability of extinct tetrapod limbs, but previous reconstructions of theropod forelimb myology have focused on shoulder musculature in crownward taxa. The antebrachial and manual musculature in particular have remained largely unstudied due to uncertain muscular homologies in archosaurs. The theropod *Tawa hallae* from the Late Triassic of New Mexico provides a complete osteology of the forelimb, allowing a full reconstruction of the musculature in a basal taxon. Data on the morphology and development of this musculature in extant crocodylians, birds, squamates, and turtles were collected from the literature and dissections, and analyzed to form new hypotheses of antebrachial and manual muscle homology in archosaurs and other reptiles. Integrative phylogenetic methods were used to make well-supported inferences for muscle presence and attachment sites in *Tawa*. Although muscles of the antebrachium leave few scars on the bone surface, the radius and ulna of *Tawa* feature distinct, flat faces which serve as correlates for the attachment of muscles such as supinator and pronator teres. A medial flange on metacarpal I likely represents the attachment for abductor pollicis longus, indicating the retention of a plesiomorphic metacarpal insertion as in birds and squamates, rather than a derived insertion on the radiale as in crocodylians. The antebrachial and manual myology of *Tawa* clarifies the basal conformation of this musculature in Theropoda and is critical for investigations addressing the evolution of specialized forelimb function in this diverse clade.

P1.66 BURKE, RL; DOLCEMASCOLO, P*; KANONIK, A; Hofstra University, Montclair State University, Town of Hempstead Dept of Conservation and Waterways; *dolcemascop1@gmail.com*

Investigating Changes in Diamondback Terrapin Nesting Behavior in Jamaica Bay, New York

Little is known about the process by which turtles abandon old nesting areas and colonize new nesting areas, but this process must occur with some frequency as habitats undergo succession and erosion. This must be especially rapid in areas that are highly impacted by urban development. Jamaica Bay (JB) is a large estuary in New York City whose shore lines, islands, and marshes were heavily modified in the 20th century. Many nesting and feeding sites were destroyed and some new nesting sites were created. This process is ongoing, as salt marshes in the area are currently eroding at a rapid rate. A mark-recapture study of diamondback terrapins (*Malaclemys terrapin*) has been conducted in JB since 1998 to determine whether this population is sustained by recruitment. Nearly all nesting now occurs on an island known as Ruler's Bar Hassock that was created in the 1920s. The number of nesting females in the population has remained fairly constant at just under 1000 adults but the number of nests on Ruler's Bar has been dropping steadily and is now 37% lower than in 1999. The decrease may be the result of females moving to other sites to oviposit, perhaps sites closer to remaining marshes. A genetic analysis of the terrapins in Gateway National Recreation area is currently being conducted to better understand the history of terrapin colonization and abandonment of nesting sites in Jamaica Bay and elsewhere in the region.

P3.193 BURSEY, JB*; GRAHAM, L; SMITH, JSIII; LITVAITIS, MK; Winthrop University, University of New Hampshire; *jrbursey@gmail.com*

Parotoplana hannahfloydae (Proseriata: Otoplanidae) from the Coast of North Carolina, USA

Parotoplana hannahfloydae n.sp., a new turbellarian species of the family Otoplanidae was found in shoreline sediments collected from swash and shiny zones at low tide on Emerald Isle (Bogue Banks, NC) and near Long Beach (Oak Island, NC). Brightfield and confocal laser scanning microscopy (CLSM), as well as traditional serial sections were used to study the organism's internal and external anatomy. *P. hannahfloydae* was golden brown with a peripheral translucent zone and an elongated oval body shape averaging 500 µm in length. The distribution of motile cilia is typical for the family—two lateral patches on the head and a ventral creeping-sole. *P. hannahfloydae* is just one of three very similar highly-active parotoplanine otoplanids from the sites above; all are presently undescribed. Data so far obtained on this new species place it into the genus *Parotoplana*; it differs from presently-known members of the genus by its post-pharyngeal germaria and unique stylet grouping consisting of a closed-circular group of eight winged stylets just anterior and dorsal to a half-circle wreath of eight hook-shaped stylets. A 408bp fragment of the 18s rDNA gene was obtained using universal primers, and aligned with selected proseriate sequences from GenBank and with other unpublished otoplanid sequences from our lab. Maximum Likelihood (ML) and Bayesian Inference (BI) trees suggest that both the Parotoplaninae (the subfamily to which our species belongs) and the genus *Parotoplana* are paraphyletic. Our new data on North Carolina otoplanids will contribute to elucidating evolutionary relationships within the family Otoplanidae. Support for this research was provided by SC INBRE and the Winthrop Research Council to JSIII and by the New Hampshire Agricultural Experiment Station to MKL.

P1.170 BUTLER, M.R.*; CHUGHTAI, A.; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *butlermr@hendrix.edu*

The effect of prenatal steroids on the fast-twitch fibers of the fetal guinea pig scalenus

Glucocorticoids, like betamethasone and dexamethasone, are commonly used to prevent infant mortality in premature births. Injecting mothers with these steroids has been shown to greatly improve lung function in premature infants. However, their effects on ventilatory muscles are not very well documented. In this study, the effect of betamethasone on the size and proportions of fast-twitch types IIA and IIX fibers of the scalenus, an accessory ventilatory muscle used in labored breathing, of fetal guinea pigs will be determined. Based on a previous study of the rectus thoracis, another inspiratory muscle, we hypothesize that there will be an increase in the number of IIA fast-twitch fibers and the diameter of both IIA and IIX fibers will be larger in treated individuals. Pregnant guinea pigs were injected with either betamethasone or sterile water twice a week, twenty-four hours apart, at 65%, 75%, and 85% gestation. Muscle samples were collected and stained for their myosin ATPase activity, or with an antibody to slow myosin, to identify slow-twitch fibers. Additional samples were stained with 2F7 (antibody to IIA myosin) to identify IIA and IIX fibers. Digital images of the stained sections were taken and analyzed for 2F7 staining density and fiber diameter using Scion Image. If our hypothesis is supported, babies treated with prenatal steroids may have a less difficult time in labored breathing involving the scalenus than their untreated counterparts, due to the ability of the muscle to contract quicker and with more force.

P2.202 BYRNES, Greg*; JAYNE, Bruce C; University of Cincinnati; *byrnesgt@ucmail.uc.edu*

The effects of branch structure on the locomotion of a specialized arboreal snake (Boiga irregularis)

The surfaces in arboreal habitats have variation in diameter, incline, and branching structure that pose functional challenges for animal locomotion, but many lineages of snakes have independently evolved arboreality. We tested the effects of arboreal habitat structure on the locomotor performance of a highly arboreal snake, the brown tree snake (*Boiga irregularis*). We used 7 diameters of cylindrical perches (0.6 – 21 cm), 3 inclines (0, 45, 90 degrees) and 2 branching conditions (with and without pegs). For horizontal perches speed was maximized for an intermediate diameter approximating the diameter of the snake's body, and for a wide range of diameters for cylinders lacking pegs, speed decreased with increasing diameter. With increased inclines performance decreased, and the snakes shifted from lateral undulation, which relied on balancing, to concertina locomotion, which involved periodic gripping when crawling uphill. For both of the uphill inclines some large diameters were impassable, and several snakes were not even able to maintain a grip on the largest diameter. When pegs were present the brown tree snakes exclusively used lateral undulation on all diameters and inclines, and the snakes had up to 5-fold improvements in maximum speed. The locomotion of brown tree snakes differed in two major ways from that of rat snakes and boa constrictors. First, brown tree snakes were much faster than the other species on all combinations of perch tested. Second, brown tree snakes relied more on lateral undulation rather than concertina locomotion on horizontal substrates. These comparative data may provide new insights into the consequences of specializations in axial morphology for arboreal habitats that have evolved repeatedly in snakes.

P3.60 BYRON, Margaret*; VARIANO, Evan; University of California, Berkeley; *mbyron@berkeley.edu*
Measuring angular velocity of models in turbulence using Refractive-Index-Matched PIV
We introduce a method that extends the capabilities of quantitative imaging to reveal the kinematics of organisms in turbulent flow. This work focuses on relevance to animals larger than the Kolmogorov lengthscale (η=0.2mm in this case) but small enough that swimming does not dominate transport; however, the technique is broadly applicable across scales and taxa. We manufacture transparent refractive-index-matched models (RIMMs) for use in stereoscopic PIV. Since the transparency of the particles allows a laser light sheet to pass undistorted through both the fluid and solid phases, RIMMs allow an unprecedented level of access to wake structures, boundary layers, and fluid-phase coupling. RIMMs can be inexpensively fabricated into arbitrary shapes via injection-molding of hydrogels or polymers, and may be varied across many parameters (including size, specific gravity, and deformability). We obtain 3-component velocity fields around differently shaped RIMMs, which are tumbled in homogeneous isotropic turbulence of Re_λ=370 (where λ is the Taylor microscale). We then calculate for the first time the rotational dynamics and angular velocity statistics of idealized morphologies (spheres and prolate ellipsoids), using a nonlinear optimization method to solve the solid-body rotation equation. We apply Lagrangian particle-tracking methods to solve for the autocorrelation timescale, quantifying the rotational forcing experienced by organisms in turbulent flow. This information can potentially be used to analyze direction-control behaviors such as station-keeping, righting, or turning. This technique can be applied to large volumes and high Reynolds numbers without difficulty or expense, opening new areas of investigation previously unavailable with conventional refractive-index-matching methods.

P2.2 BYWATER, CL*; JAMES, C; MCELROY, E; The University of Queensland, The College of Charleston; *c.bywater@uq.edu.au*
Morphological determinants of aggression and fighting success in two species of Callinetes
Intra-specific competition between males is driven by the need to procure territories, food and mates and thereby maximize survival and reproductive success. Due to the potential costs of combat, specialised weapons are often displayed to resolve disputes without direct physical contact. It is predicted that the evolution of increased weapon size should be associated with increased competition for resources and weapon strength should increase simultaneously with size. We investigated the morphological predictors of aggression and fighting performance in two species of blue crab (*Callinectes similes* and *Callinectes sapidus*). Blue crabs have large claws used during displays and physical combat. We measured morphological features including body size, claw size, claw muscle mass, apodeme area and maximum claw closing strength for each individual. We also recorded contests between individuals to establish a dominance ranking. We found each species responded differently to stimulation in aggression tests as well is during individual contests. We will discuss the variation observed in size of male weaponry among species and whether this explains variation in fighting performance and aggression.

P3.169 CALHOON, E.A.*; HARPER, J.M.; JIMENEZ, A.G.; MILLER, R.A.; JURKOWITZ, M.S.; WILLIAMS, J.B.; Ohio State University, Michigan State University; *calhoon.18@owu.edu*
Lipids of mitochondria in fibroblasts and their nexus to life history in temperate and tropical birds
Life history attributes often fall along a “slow-fast” continuum. Temperate birds are thought to have a fast pace of life whereas tropical birds have a slow pace of life. In support of this idea, tropical birds have lower metabolic rate, invest fewer resources in reproduction, and have higher adult survival rates compared with temperate birds. These organismal differences may be rooted in differences in the cellular level, a hypothesis in need of testing. Here, we cultured fibroblasts of phylogenetically-paired tropical and temperate species, isolated mitochondria from each, and compared their mitochondrial membrane lipids. We found that mitochondria from tropical species had higher amounts of lipids that could serve as an antioxidant, especially plasmalogens. Additionally, multiple proxies for amount of mitochondria suggested that large tropical species have fewer mitochondria than large temperate ones, whereas small tropical and temperate species have similar amounts. We examined the lethal dose of xenobiotics required to kill 50% of fibroblast cells (LD50) from tropical and temperate species and related LD50 to lipid composition of mitochondrial membranes. We found that lipids associated with preventing oxidative damage, such as plasmalogens, or with anti-apoptotic signaling were correlated with increased cellular stress resistance, whereas lipids that were associated with pro-apoptotic signaling were correlated with decreased stress resistance. These findings suggest that mitochondrial lipid composition could play an important role in cellular stress resistance and senescence.

P2.149 CALISI, RM*; KNUDSEN, D; KRAUSE, J; WINGFIELD, JC; GENTNER, TQ; Univ. of California, Davis, Univ. of California, San Diego; *beccacalisi@gmail.com*
Estradiol and reproductive state affect song pattern recognition and performance in a songbird
While a great deal of our vocabulary is acquired early in life, we continue to acquire new words and string together new phrases throughout adulthood. This trait is not entirely unique to humans. Many species of songbirds are “open-ended learners,” meaning their repertoire size increases with age as opposed to crystallizing during development. Previous research suggests an important role for estrogens in verbal memory. To begin to better understand the functional significance of this phenomenon, we asked, 1) can circulating concentrations of estradiol in the body, or lack thereof, affect a bird’s ability to recognize and behaviorally respond to novel song patterns, as encountered naturally in the wild, and 2) does this change according to the reproductive state of the bird. European starlings (*Sturnus vulgaris*) are seasonally breeding, open-ended learners that can be trained to recognize and respond to new song patterns. We measured the latency of birds to learn and respond to new song patterns under estradiol treatment during three main stages of reproductive activity: the breeding period, characterized by high concentrations of estradiol, the non-breeding period and the transitional phase between the two, both characterized by low estradiol concentrations. In addition, we treated birds with fadrozole, an aromatase inhibitor that suppresses circulating estradiol concentrations. Understanding how these hormonal changes affect the recognition of novel song patterns in birds can shed light upon not only song pattern processing in the avian brain, but present a model for how endocrine changes can modulate human language development.

P2.101 CARLSON, B.M.*; GROSS, J.B.; University of Cincinnati; *carlsobm@mail.uc.edu*

Sundials in the Void: Assessing Circadian Rhythms in a Cave Adapted Species

The coordination of biological processes with the surrounding environment is critical to the success and survival of organisms. For instance, photic input (sunlight) entrains rhythmic gene expression, which in turn influences patterns in metabolism, activity and other biological "outputs". It has long remained unclear how deviation from a normal light-dark phase can negatively influence these biological processes in organisms that do not encounter sunlight; regressive and constructive morphological traits are well characterized across many cave-dwelling species, but little is known about changes to physiological processes that normally rely on periodic photic input. We aim to explore this question by assessing the fate and function of circadian biology in *Astyanax mexicanus*, an emerging model fish system consisting of a derived, cave-dwelling morphotype and an extant, "ancestral" surface morphotype. Based on studies in other species, we expect to observe significant changes in the circadian biology of the cave morphotype, relative to the surface form, as a consequence of life in perpetual darkness. Presumably, these changes will manifest as a decoupling of circadian rhythms from photic input or even complete abandonment of circadian rhythmicity. To determine whether, and to what extent, a biological rhythm persists in *A. mexicanus*, we have devised a technique to measure and quantify activity patterns in adult surface, cave and hybrid fish. We also present preliminary data investigating potential structural and expression differences of candidate genes governing circadian rhythms in surface v. cave morphs. This work provides a starting point for exploring the presence v. absence of a persistent biological rhythm in *A. mexicanus* after millions of generations spent in the darkness of a cave.

P1.151 CARLTON, E.D.*; DEMAS, G.E.; Indiana University, Bloomington; *elcarlto@indiana.edu*

Leptin and seasonal variation in sickness responses in Siberian hamsters (Phodopus sungorus)

Sickness behaviors (e.g. fever, anorexia) characterize an adaptive response generated by an organism to aid in clearance of pathogens. However, these behaviors are energetically costly, and the magnitude to which organisms display these behaviors varies seasonally. One hypothesis regarding this seasonal variation is that the intensity of the sickness response may track the energetic state of an organism, such that the response is attenuated in the season in which an animal has the lowest fat stores. Energetic state may be signaled via leptin, a peptide hormone that is produced by body fat in direct proportion with tissue mass. Siberian hamsters respond to short, winter-like days by reducing food intake and thus, decreasing fat stores and circulating leptin levels. Previous work in this species has demonstrated that sickness behavior is attenuated in animals exposed to short photoperiods compared with long, summer-like photoperiods. We hypothesized that circulating leptin provides a physiological signal by which animals modulate sickness responses. To test this, we housed male Siberian hamsters in long-day (LD) or short-day (SD) photoperiods for 10 weeks and collected baseline food intake and body mass measurements for 10 days. Next, we provided LD and SD hamsters with daily injections of leptin (or saline control), to provide SD animals with a LD-like leptin signal. After 6 days of injections, animals were inoculated with lipopolysaccharide (LPS), to induce a sickness response, or a saline control. Data (i.e. body temperature, food intake, body mass, and blood serum levels of cortisol and cytokines) will be presented and discussed in regards to the effects of photoperiod manipulation and leptin supplementation on the modulation of the sickness response.

P3.196 CARMACK, CA*; REDMOND, N; THACKER, RW; COLIN, L; COLIN, P; HILL, M; HILL, A; LOPEZ, J; DIAZ, MC; POMPONI, S; BANGALORE, P; Univ. of Alabama at Birmingham, Smithsonian Institution, Coral Reef Research Foundation, Univ. of Richmond, Nova Southeastern Univ., Museo Margarita, Harbor Branch Oceanographic Institute ; *thacker@uab.edu*

Nuclear 28S ribosomal subunit gene sequences support new relationships among families and orders of Porifera

Our understanding of phylogenetic relationships within the Phylum Porifera is changing considerably with increased taxon sampling and additional molecular markers. We present new phylogenies constructed from a backbone of over 150 nearly complete 28S ribosomal subunit gene sequences, augmented with over 600 partial 28S sequences. We recovered monophyletic clades for all four classes of sponges, as well as the major clades of Demospongiae (G1, G2, G3, and G4). Our phylogeny differed in several aspects from traditional classifications. For example, a deep divergence within the marine Haplosclerida was associated with large-scale insertions that alter the structure of the ribosome. Although Keratosa (G1, containing Dictyoceratida and Dendroceratida) was constructed as a monophyletic clade, the family Dysideidae formed a clade separated from other Dictyoceratida, whose remaining families appeared paraphyletic. Indeed, families within orders appeared to be paraphyletic for most major clades, including Hexactinellida and Calcarea. While additional gene and taxon sampling are needed to establish whether this pattern results from a lack of phylogenetic resolution or from a paraphyletic classification system, many of our results are congruent with those obtained from 18S ribosomal subunit gene sequences and complete mitochondrial genomes. These data provide further support for a revision of the traditional classification of sponges.

P3.139 CARPENTER-CARTER, S.*; PERLMAN, B.M.; ASHLEY-ROSS, M.A.; Wake Forest University; *perlbm0@wfu.edu*

Jumping performance of largemouth bass (Micropterus salmoides) across a size gradient

Some fishes may temporarily become stranded on land due to efforts to escape predation, find resources, or escape poor water quality. While adult mangrove rivulus and mosquito fish are capable of tail-flipping to produce directed movements on land, adult largemouth bass (*Micropterus salmoides*) do not seem to possess this ability. We hypothesized that scaling of body mass versus muscle cross-sectional area may result in a threshold size, above which a fish is no longer able to jump or attempt to tail-flip on land. We examined the relationship between body size and jumping ability in juvenile largemouth bass, specifically hypothesizing that the propensity to jump and jump distance would decrease with increasing body size. Individual fish (n = 9) were placed in the center of a kiddie pool and allowed to voluntarily jump for two minutes; all movements were recorded with a video camera (60 fps) above the pool. Videos were imported into ImageJ and the following variables were recorded: number of jumps, average and maximum jump distance, jump trajectory, and other movements. Jump trajectories were variable, but clustered around 180 degrees, indicating that bass tended to jump over their tail. Linear regressions showed that number of average and maximum jumps and jump distance were not correlated with increasing body length or mass. Though not statistically significant, there was a trend of decreasing maximum jump distance as body length increased. Regardless of body length or mass, juvenile largemouth bass spent proportionally more time flipping, bouncing, rolling, or twisting their body than jumping, suggesting that bass of any size possess limited capacity for producing directed movements on land.

P3.26A CARRERA, JV*; CATLIN, D; WALLING, KM; MONAGHAN, C; BOWLES, S; SCHMITTHENNER, H; CODY, JC; TAN, LT; CONNELLY, SJ; Rochester Institute of Technology; *jvc3048@rit.edu*

High Performance Liquid Chromatography (HPLC) analysis of Vitamin D_3 in a Daphnia microcosm experiment

Increasing levels of ultraviolet radiation (UVR) in freshwater systems has been detected with constantly changing environmental conditions. Freshwater ecosystems are particularly susceptible due to their high exposures to solar radiation, and the organisms of these systems must adapt accordingly. The overall purpose of this collaborative research is to determine the survival and reproduction rates of vitamin D_3 exposed *Daphnia* spp. under varying ultraviolet radiation (UVR) conditions. The vitamin D_3 was assessed for its photoprotective properties in *Daphnia* spp. under chronic and acute UV-A and UV-B exposure. Vitamin D_3 and its metabolites were analyzed in experimental samples using High Performance Liquid Chromatography (HPLC). We have developed an improved method of HPLC analysis by adjusting the variable parameters to increase sensitivity in the biological samples. Vitamin D_3 and several metabolites were recovered in the *Daphnia* spp., algae food source (*Selenastrum capricornutum*), and aqueous samples following UV exposure in a controlled microcosm setting. Vitamin D_3 was also recovered in the control sample (0% vitamin D_3 addition), indicating a strong role of algae in the transport of nutrients to the *Daphnia* spp. Algae were also tested under stressed conditions to better understand the metabolic effects of vitamin D_3 and UVR with and without *Daphnia* (spp.). Through this experimentation, we can better understand the source of vitamin D_3 metabolic conversion in freshwater ecosystems and the potential for the vitamin D_3 to act as a reducer of environmental stresses in the *Daphnia* spp.

P1.78 CARROLL, M.A.*; SKEETE, D.; CATAPANE, E.J.; Medgar Evers College, Brooklyn, NY; *margie@mec.cuny.edu*

STEP into Science at Medgar Evers College, a Successful Strategic Plan

STEP into Science was designed to increase the number of students earning BS degrees in Biology and Environmental Science. Our program is an interdisciplinary effort between the Depts. of Biology and Physical, Environmental and Computer Sciences with goals to: (1) recruit new students and non-STEM students from within the college who select majors in either Biology, or Environmental Sciences; (2) improve retention of science majors by providing academic, financial and mentoring support; (3) strengthen both departments with curricula to fosters integration of research, technology and academics to better equip majors with skills and knowledge necessary to be successful applicants to graduate/professional programs; and (4) increase the number of students graduating with BS degrees in Biology or Environmental Science, and ultimately enter rewarding careers in the science enterprise. Now in our fifth year, the program has had great success implementing the use of peer recruiters to attract more high school, transfer, and non-science college students into STEM majors and places emphasis on the role of undergraduate research experiences as a successful strategy to increase the quality and retention of science majors through their BS degree. Since the inception of the program, STEM enrollment more than doubled and the number of majors actively engaged in research has risen more than 90% with a concurrent increase in student research presentations at scientific conference, and an 87% increase in the number of students receiving external research internships and travel awards to attend national conferences. STEM graduates have also increased and the program anticipates that these and future STEP into Science graduates will continue on to Masters and Doctoral programs in STEM and ultimately enter rewarding careers in the science enterprise.

P3.109 CARTER, H.A.*; CEBALLOS, L.; MILLER, N.; STILLMAN, J.H.; San Francisco State University; *hacarter@sfsu.edu*

Impact of ocean acidification on development and energetics of porcelain crab early life history stages

Oceans are acidifying as a consequence of absorbing elevated levels of atmospheric CO_2. Results of ocean acidification (OA) studies in crustaceans are conflicting and few assess impacts on coastal intertidal organism and their early life stages. Adult porcelain crabs of genus *Petrolisthes* are common intertidal inhabitants and have a complex life cycle. Little is known about the physiological mechanisms allowing larvae to transition from a stable CO_2 environment (open ocean) to a habitat with daily and seasonal CO_2 fluctuations (intertidal). When during development does CO_2 tolerance occur? Do larvae hatch with physiological mechanisms to compensate for decreases in pH? Are life stages differentially affected by CO_2, and if so, which are most vulnerable? In this study, embryos, larvae and juvenile *P. cinctipes* were reared under two pH levels (ambient pH~8.0, and low pH~7.6), achieved by bubbling seawater with pure CO_2 gas. Oxygen consumption rate, total protein, dry weight, lipid consumption rate and survival were determined at each developmental stage. Results suggest significant maternal effects among a sample of 13 broods, with high variability among individuals in response to OA. However, when reared in low pH, embryonic metabolism was 5% lower, while larvae and juveniles displayed a trend of higher metabolic rates compared to control (7% and 29% respectively). Furthermore, embryo lipid consumption rates were 40% lower in individuals reared in acidified water. Alternatively, no significant differences were observed in larval dry weight or survival of larvae and juveniles. Results thus far indicate certain stages of *P. cinctipes* compensate for high CO_2, but potential tolerance may differ between female broods. Studying responses to OA at different stages will give us a better understanding of physiological mechanisms allowing organisms to persist in an acidifying ocean.

P3.87 CARTER, Ariel L*; MARTIN, Karen L; Charleston Southern University, Pepperdine University ; *kmartin@pepperdine.edu*

Maternal Investment in a Short-Lived, Iteroparous Marine Fish

In many marine fish species, big older females produce significantly more eggs and clutches than smaller, younger females. Females of the marine silverside fish California Grunion (*Leuresthes tenuis*) are able to spawn after one year, and spawn repeatedly every two weeks. A female may produce several hundred or up to 3000 large demersal eggs per clutch, potentially 18,000 eggs over the spawning season. Very few females survive to spawn more than two years. *L. tenuis* spawn completely out of water on sandy beaches at high tides following the full and new moons of spring and summer. Embryos incubate buried in the damp sand until hatching is environmentally cued by wave action. The large yolk of these demersal eggs may provision for large hatchlings, or for potential to extend incubation, or both. This study examines individual differences in the maternal investment between 22 clutches from different females. We found significant variability in clutch volumes, number of eggs, and egg diameters between females, as well as differences in the amount of lipid yolk. However none of these differences were correlated with maternal mass or length. Hatchling length is correlated with egg diameter but not with maternal length. We suggest that yolk provisioning of clutches may be independent of female size in *L. tenuis* and subject to availability of their planktonic prey resources for these short lived, iteroparous fish.

P2.68 CASTRO, D.A.*; PODOLSKY, R.D.; College of Charleston; *dacastro1@g.cofc.edu*
Effects of Elevated Oceanic CO_2 on Sperm Motility and Swimming Speed in Sea Urchins: Implications of Ocean Acidification for Fertilization Success
Increases in atmospheric CO_2 are dramatically increasing CO_2 levels in the ocean, driving a decrease in oceanic pH. Because several key biological processes are sensitive to small changes in pH, there is increasing concern about continued introduction of CO_2 into the atmosphere. Research on ocean acidification is rapidly expanding, though most efforts to date have focused on risks to calcifying organisms. In contrast, relatively little attention has been paid to other biological processes that are pH sensitive, especially involving developmental stages that may be especially vulnerable to environmental change. We focused on the consequences of ocean acidification for external fertilization by analyzing the effect of CO_2-induced acidification on sperm activity in the sea urchin *Arbacia punctulata*. CO_2-driven declines in pH equivalent to increases predicted 100, 200, and 300 years in the future led to significant decreases in both sperm motility and swimming speed, with the most dramatic declines in the near-term. These changes in motility and speed relate directly to parameters used in standard models of fertilization kinetics. We are coupling predictions of these models with measures of fertilization rate under the same gas concentrations to estimate the impact of changes in sperm activity on fertilization success in sea urchins.

P2.127 CAVANAUGH, M.R.*; GIACOMINI, J.; MCPHERSON, D.R.; LOVETT, J.A.; SUNY at Geneseo; *mrc10@geneseo.edu*
Mapping Expression of a Novel 5-HT7 Receptor in Aplysia californica
Aplysia californica is a marine gastropod commonly used in neurobiology. Serotonin, a neurotransmitter, plays a major role in modulating locomotion in Aplysia. In the foot muscle of Aplysia serotonin has been found to raise levels of cAMP, causing a stronger muscle contraction. Serotonin produces this reaction by interacting with the cell through a specific G-protein coupled receptor in the cell membrane. Our lab has previously isolated and cloned a serotonergic receptor that increases cAMP levels, a 5-HT7 subtype. We have mapped the expression of this 5-HT7 receptor at the tissue level. Expression levels were tested in samples from foot muscle, kidney, heart, and the I5 buccal muscle, as well as the pedal, pleural, cerebral, abdominal and buccal ganglia. mRNA was extracted from each of these samples and used to create cDNA, which underwent PCR amplification with primers specific to the 5-HT7 receptor. Actin cDNA was also amplified to test for expression levels. Actin is a ubiquitous housekeeping protein that is expected to maintain relatively constant levels of expression throughout all tissue types. The level of expression of 5-HT7 mRNA for each sample was compared to the level of actin mRNA detected to determine the relative expression of the receptor. Our results show that the 5-HT7 receptor is absent from heart muscle but is expressed with similar abundance in all the other tissues tested. This project was funded in part by a Geneseo Foundation Summer Fellowship.

P3.108 CEBALLOS, L*; CARTER, HA; MILLER, N; STILLMAN, JH; San Francisco State University; *linaco@sfsu.edu*
Developmental effects of ocean acidification on porcelain crabs
Intertidal zone organisms, like porcelain crabs of the genus *Petrolisthes*, naturally experience daily pH fluctuations with extremes values lower than the predictions for future ocean acidification (OA). Porcelain crabs spend their embryonic stage in the intertidal zone, then hatch as planktonic larvae, and spend several months in the plankton living under stable conditions before returning to the variable intertidal zone as juveniles. In order to understand the response to an acidified environment, the physiology of *P. cinctipes* under future OA conditions at different life-history stages was studied. *P. cinctipes* embryos and newly hatched larvae were acclimated to two different pH conditions, ambient (pH~8.0) and acidified (pH~7.6, achieved by bubbling water with CO_2). Heart rate and morphology were measured in both stages after 8-10 days exposure to acidified water. Hatching success and yolk consumption rate was assessed in embryos. Larval heart rate was 21% lower in the individuals kept at low pH compared to the ambient pH. Embryonic heart rate was 36% lower in the individuals kept at low pH. Body size and shape of both stages were not affected by acidification. The results show non-significant effects of low pH in hatching success (~60% +/- 26% hatching in both conditions). Changes in heart rate may suggest larval and embryonic metabolic depression under continuous acidification, which in the long-term has the potential to affect growth and developmental timing.

P1.79 CHAN, K.Y.K.; Univ. of Washington, Seattle; *kychan@uw.edu*
Scientific process in practice, an activity based seminar for beginning science majors
The skills need to participate in the scientific process include making observations, inferences, predictions, and communicating effectively. Learning these skills not only helps students succeed in research, but also helps them improve their performance in rigorous college classes and in daily life when making critical decisions. However, these essentials skills are rarely taught explicitly. I developed and taught a weekly, 2-hour long activity-based seminar that complemented an existing, mandatory field course for junior-level oceanography majors. The learning goals were to 1) develop information literacy skills; 2) practice articulating testable hypotheses; and 3) hone scientific presentation skills. I assessed the effectiveness of the seminar qualitatively and quantitatively through minute papers, in-class observations and pre- and post-course surveys. Students were highly engaged in in-class activities and found them both fun and educational. An example of such activities was the statistics carousel: student worked in pairs, rotating around flipchart papers with case studies on data analysis every 3-5 minutes such that they collaboratively worked out the solutions. The seminar improved students' self-efficacy towards conducting scientific research. Students who were enrolled in both the mandatory field course and complementary seminar showed significantly greater gain in the Student Understanding of Scientific Inquiry Survey than students who were enrolled only in the mandatory field course. Students who were enrolled in both courses responded more like experts by stating that science is a dynamic process rather than a single, step-by-step recipe. These results suggest that explicit, inquiry-based course focusing on scientific process skills can help improve students' learning experience and understanding of science.

P2.197 CHANG-SIU, E.H.*; LIBBY, T.; FULL, R.J.; TOMIZUKA, M.; Univ. of California, Berkeley; *evancs@berkeley.edu*

Tailbot – Robot with Inertial Assisted Control by an Active Tail Inspired by Lizards

Lizards, discovered to pitch correct in mid-air with their tail when subjected to slippery take-off surfaces, have inspired a novel approach to stabilizing rapid locomotion in mobile terrestrial robots. To demonstrate the benefit and feasibility of this behavior we built a 177 g wheeled robot, Tailbot, with inertial sensors, a microprocessor, motor drivers, front wheel drive, and a single degree-of-freedom active tail. Since the relative inertia of the tail is dependent on the squared value of length, the mass of the tail was designed to be less than 20% of the body mass while still allowing for a one to one ratio of relative angular stroke. By estimating the body angle from the inertial sensors and utilizing both contact forces and zero net angular momentum maneuvering, Tailbot could take advantage of closed loop feedback control. Feedback produced rapid reorientation during a fall, smooth transitions between surfaces of different slopes, and stability when faced with perturbations that would overturn a tailless robot. Specifically, Tailbot could perform a 90 degree self-righting maneuver during free fall in 138 (ms) corresponding to a drop distance of approximately one body length. A perturbation, which completely overturned a tailless robot, produced a 60 degree rotation in a passive tailed robot, but resulted in only a 30 degree rotation in our feedback controlled tailed robot. Landing transitions that were not possible with a tailless robot were made feasible by properly adjusting the reference angle to the tail controller. Capabilities of Tailbot demonstrate how an active tail can improve the stability and maneuverability of terrestrial and aerial search-and-rescue vehicles and serve as a physical model to generate new hypotheses of inertial appendage control in animals.

P1.156 CHARBONNIER, J.F.*; GERALD, G; PURRENHAGE, J; SCHAEFFER, P; Virginia Commonwealth University, Richmond, Nebraska Wesleyan University, Lincoln, University of New Hampshire, Durham, Miami University of Ohio, Oxford; *charbonnierj@vcu.edu*

Carry-over effects of pond canopy cover on locomotor performance of the American toad (Anaxyrus americanus)

Animals with complex life cycles pass through one or more ecologically distinct phases during ontogeny. These life stages are highly interconnected and conditions experienced during one life stage may influence size, locomotor performance, and physiology in later life stages. Since many pond-breeding species must disperse to suitable terrestrial habitat following metamorphosis, identifying how larval experience impacts locomotor performance of juveniles is important. Larvae from open and closed canopy pond experience different environmental conditions (e.g. light, temperature, dissolved oxygen) which may affect subsequent performance in later life stages. To investigate the potential carry-over effects of canopy cover on locomotor performance we raised American toad (*Anaxyrus americanus*) larvae in open and closed canopy pond mesocosms. We retained 40 metamorphs from each treatment for speed and endurance trials. We also examined citrate synthase activity of hindlimb skeletal muscle to estimate the proportion of endurance vs. speed type muscle. We found that toads from closed-canopy ponds were 63% heavier and had higher absolute endurance and speed. Toads from open-canopy pond had higher endurance relative to their body size, despite having lower citrate synthase activity. Since citrate synthase activity cannot explain the relatively higher endurance of open-canopy toads, another mechanism is likely involved in the differential performance. Our results demonstrate that the larval environment may impact multiple components of locomotor performance in complex ways.

P3.145 CHARLES, Curtisha*; BELTON, Sheena; SHIELDS, Vonnie; Towson University, Baltimore City Community College; *vshields@towson.edu*

Inventory and Distribution of Sensory Organs on the Antennae of the House Cricket, Acheta domesticus (L.)

House crickets, *Acheta domesticus* (L.), are serious pests of stored grain. They have paired antennae that bear many sensory organs (sensilla). These sensilla allow them to gain information about olfactory, gustatory, and mechanosensory cues pertaining to their environment. There are approximately 200 segments comprising each antenna. Scanning electron microscopy reveals that each antenna bears nine sensillum types. Five of these types bear external morphological features suggestive of olfactory sensilla: two types resemble short to medium-sized pegs (basiconic sensilla) with cuticular shafts perforated by multiple pores; two types resemble very short pegs recessed in deep pits (coeloconic sensilla), and the last type resembles a small cone-shaped basiconic sensillum with longitudinal ridges. Three other sensillum types have external features suggestive of mechanosensory sensilla: two types resemble long hairs (trichoid sensilla) with cuticular shafts that lack pores and bear diagonal ridges, while the other type resembles a small circular depression on the antennal surface. The antenna also bears one sensillum type with external features suggestive of gustatory sensilla. This type resembles a medium-sized basiconic sensillum with a single terminal pore and cuticular ridges that form a circular pattern. This study was supported by NIH grant 5R25GM058264-08 to G. Gasparich.

P3.176 CHENEY, J. A.*; BEARNOT, A.; BREUER, K. S.; SWARTZ, S. M.; Brown University; *Jorn_Cheney@Brown.edu*

Pre-stressed compliant fibers within the wing membrane of Glossophaga soricina, Pallas' long tongued bat

The wing membrane of bats is composed of a double-layer of skin, with macroscopic bundles of elastin fibrils located within the dermis. These fibers run primarily along the proximo-distal, or spanwise, axis of the wing. In typical human-engineered fiber-reinforced composites, fibers have a higher elastic modulus than the surrounding material or matrix, and their functional roles include increasing toughness and strength. Bat wing membranes therefore comprise an unusual fiber composite, in that the embedded elastin fibers are more compliant than the surrounding tissue.

To better understand the role of compliant fibers in a more rigid matrix, we conducted quasi-static tensile mechanical tests of fresh wing membrane tissue from *Glossophaga soricina*, Pallas' long-tongued bat. As expected from previous studies, the wing membrane displayed anisotropic behavior. We found that specimens oriented with elastin fibers parallel to the sample axis were more compliant than those with elastin fibers oriented transversely.

To explain the greater compliance parallel to the fibers, we propose a simple model of wing membrane mechanics based on key aspects of wing histology and mechanical behavior of wing tissue. We hypothesize that like most mammalian skin, the dermis and epidermis are isotropic; therefore, the anisotropic behavior is due specifically to the elastin fibers, even though they are more compliant than the matrix. Our model proposes that the elastin fibers are pre-stressed and modify tissue mechanical behavior by causing the thin surrounding matrix to buckle. Therefore in tensile tests, at low strain the measured stress is due to the elastin fibers, and at high strain the matrix is unfolded and engaged and the measured stress is due to both fiber and matrix.

P1.206 CHICK, L.D.*; FOWLER, D.A.; SANDERS, N.J.; Univ. of Tennessee, Knoxville; *ldanikas@utk.edu*

Variation in critical thermal limits of ant species along an elevational gradient

Understanding the factors that limit the distribution of species and patterns of biodiversity is at the core of ecological and biogeographical research. The complex relationship between environmental conditions and distribution often relies on large-scale climatic information and macroecological data from museum records or field guides. Few studies, however, incorporate actual physiological mechanisms and measurements of the studied organisms to understand patterns of diversity and predict their distributions in a changing world. Through controlled lab experiments coupled with observational field data, I investigated critical thermal minima and maxima of 20 ant species collected at 18 sites along an elevational gradient in Great Smoky Mountains National Park. Preliminary data demonstrate both within- and among-species variation in critical thermal limits, which could be correlated to species' ranges. From these data, we can attempt to disentangle the underlying factors that constrain the distributions of species, which may be critical in predicting the response of biodiversity to ongoing climatic changes.

P3.44 CHILTON, H; MIER, J; ZUZOW, M; TOMANEK, L*; California Polytechnic State Univ., San Luis Obispo; *hchilton@calpoly.edu*

The Proteomic Response of Mytilus californianus to Acute Oxidative Stress in the Presence of a Sirtuin Inhibitor

The ribbed mussel (*Mytilus californianus*) occurs in the in the rocky intertidal zone along the Pacific coast of North America where it experiences greatly varying environmental conditions in terms of temperature and hypoxia, stressors that are known to induce oxidative stress. It has been hypothesized that while under acute heat stress, related *Mytilus* congeners undergo a shift in redox potential through the reduction of NADH fueled respiration pathways to the production of the reducing agent NADPH as a potential defensive mechanism against the production of reactive oxygen species. In addition, it has been hypothesized that sirtuins (a family of NAD-dependent deacetylases) might be involved in the regulation of this metabolic transition. To test the latter hypothesis, we used a discovery approach to analyze the proteomic response of this species to varying concentrations of menadione and suramin. Menadione is a cytotoxic agent that can induce apoptosis through the elevated production of peroxide and superoxide radicals while suramin is an effective inhibitor of sirtuin activity. Gill tissue was exposed to these compounds in filtered seawater for 8 h, followed by a 24 h recovery period under constant aeration. Tissues were homogenized and prepared for 2D-gel electrophoresis. Following separation, protein expression patterns suggested that the action of suramin affects a third of the changes in protein abundance during menadione-induced oxidative stress. These results prove that sirtuin activity (protein deacetylation) affects the cell's response to oxidative stress. We are now identifying the proteins with tandem mass spectrometry and an expressed sequence tag library specific to *Mytilus*.

P2.84 CHOW, B.*; WRAY, M.; VILLINES, B.; PINNICK, G.; SHEETS, E.; SPAULDING, J.; COHEN, C.S.; RTC, San Francisco State University, CSU, SLO; *bensonc@mail.sfsu.edu*

Experimental whole body regeneration among botryllid ascidian species in San Francisco Bay

Regeneration processes show a broad phyletic distribution and dramatic variation in potential across diverse organisms. Colonial ascidians in the family Botryllidae are the only chordates known to be capable of whole body regeneration (WBR). WBR may occur following the artificial removal of zooids and buds, leaving behind ampullar fragments that may ultimately lead to production of new functional zooids. Prior work on botryllid WBR has relied on laboratory assays, primed by application of retinoic acid, and aimed at elucidating intrinsic differences in mechanism through morphological observations. We compared the regenerative abilities of three botryllid species (*Botryllus schlosseri*, *Botrylloides violaceus*, and *Botrylloides* sp.) at three separate locations in San Francisco Bay. All three species were successful in regenerating complete zooids from ampullar fragments in the field without exogenous application of retinoic acid; however, success rate varied among sites and species. *B. violaceus* had significantly lower success overall with complete regeneration occurring at only one site. Conversely, *B. schlosseri* and *Botrylloides* sp. showed success at both early and later stages at all three sites. Mean time to regeneration for successful individuals was significantly longer between *B. violaceus* and the other two species and field regeneration times were longer than published laboratory studies with RA. This study shows that WBR occurs in the field and varies among species and populations, thus potentially affecting population viability following disruptive processes such as predation, senescence, or intentional human removal.

P1.200 CHURCH, A.; LEGTERS, C.; PAPA, J.; TYMOCHKO, L.; ELNITSKY, M.A.*; Mercyhurst College; *melnitsky@mercyhurst.edu*

Antioxidant capacity and oxidative stress in the freeze-tolerant woolly bear caterpillar, Pyrrharctia isabella

Reactive oxygen species (ROS) are normal byproducts of aerobic metabolism. However, increased production of these molecules may overwhelm antioxidant systems resulting in oxidative damage to cellular membranes, proteins, and nucleic acids. Freeze-tolerant ectotherms may experience such increased production of ROS and oxidative stress during frequent cycles of freeze/thaw and the accompanying tissue ischemia/reperfusion. Therefore, the purpose of this study was to investigate the effects of subfreezing temperature exposures on the metabolic rate, antioxidant capacity, and measures of oxidative stress in freeze-tolerant woolly bear caterpillars, *Pyrrharctia isabella*. Following freezing, a slight decrease in the rate of oxygen consumption was observed at 1 and 5 h post-thaw, suggesting the organisms may reduce metabolic rate in an attempt to limit ROS production. However, lipid peroxidation was significantly elevated at 4 h post-thaw, demonstrating the caterpillars did still incur an oxidative stress. At 24 and 48 h post-thaw, the rate of oxygen consumption was markedly increased, while lipid peroxidation was significantly lower, perhaps as a result of the activation of cellular repair mechanisms. The total antioxidant capacity of fat body isolated from *P. isabella* was comparable to that of whole body homogenates of other freeze-tolerant insects, the goldenrod gall fly *Eurosta solidaginis* and Antarctic midge *Belgica antarctica*, and significantly higher than that of the freeze-intolerant *Drosophila melanogaster*. These results provide insight into the nature of freeze/thaw injury and the mechanisms used by naturally freeze-tolerant species to limit and repair oxidative damage.

P1.135 CITARELLA, M.R.*; GIRARDO, D.O.; KOHN, A.B.; MOROZ, L.L.; Whitney Lab for Marine Bioscience, University of Florida, St Augustine, FL , Whitney Lab for Marine Bioscience, University of Florida, St Augustine, FL, Dept of Neuroscience,University of Florida, Gainesville, FL ; *mathew.citarella@gmail.com*

Global Discovery and Validation of Signaling Molecules in the Ctenophore,

Neuropeptides and protein hormones are ancient signaling molecules involved in neural integration, plasticity and development. Here, we present the first genome-wide identification of putative signaling molecules in the phylum Ctenophora. Our lab has recently finished the sequencing and assembly of the genome as well as deep transcriptome analysis of four related ctenophore species (, , ,). We also developed an automated annotation pipeline, which enables rapid genome-wide prediction and discovery of intercellular signaling molecules in ctenophores. As a result, we identified 458 candidates and searched for their homologs across basal metazoans and bilaterians (including Hemichordates, Echinoderms and< Xenoturbella>). When combined, these genome-wide comparative surveys provide the unique opportunity to reconstruct ancestral neuronal lineages, identify cell homologies across species and reveal trends in evolution within neural circuits. The majority of neuropeptides appear to be class and phylum-specific ligands suggesting that these intercellular messengers are among the most evolutionarily dynamic signaling molecules, demonstrating a high degree of parallel evolution and apparently independent origins across animal phyla.

P1.121 CLAESON, Kerin M.; Ohio University Heritage College of Osteopathic Medicine; *claeson@ohio.edu*

Connective Tissues of the Craniovertebral Joint in Rajidae

The craniovertebral joint (CVJ) exhibits arrangements and morphologies of skeletal and connective tissues that vary according to ontogeny and systematics. For instance, within chondrichthyans a broad articulation between the skull and basiventral skeletal cartilages of the adjacent vertebrae is known to occur in Squatiniformes, Orectolobiformes, Carcharhiniformes, Pristiophoriformes, and Batoidea. Among these taxa, there is a difference in the number of expanded basiventrals, the ultimate length of each expanded basiventral, and the degree and/or direction of curvature of each basiventral. To begin to quantify the connective tissues at the CVJ in chondrichthyans, I examined histological sections of embryonic specimens of three species of skate (Batoidea:Rajidae), *Raja asterias*, *Raja sp.*, and *Leucoraja erinacea*. These embryonic data are part of a broader project examining the ontogenetic changes in chondrichthyans. Preliminary data indicate tight junctions between the occipital cotyle and occipital condyle with little articular cartilage present early in development. In addition, there is a distinct septum of dense connective tissue that extends between the anterior tip of the median crest of the synarcual and a perpendicular sheet of dense connective tissue above the foramen magnum. This septum is broadest ventrally and tapers dorsally. Epaxial musculature appears to connect directly to the median crest of the synarcual proximally but does not adhere to the dense connective tissue septum or sheet distally. Understanding the evolutionary and developmental history of variability of both skeletal and connective tissues in the CVJ will facilitate biomechanical study of the stresses imposed on this joint during a variety of functions such as locomotion and feeding.

P1.96 CLARK, CJ*; PRUM, RO; Yale Univ. Peabody Museum; *christopher.clark@yale.edu*

Aeroelastic flutter and flight sounds across birds

Flight generates sound. Birds such as ducks, doves, loons, ravens, vultures and hornbills make tonal sounds during ordinary flight, while others such as flycatchers, snipe, honeyguide, manakins, guans and cotingas make tonal sounds during specialized displays. Recent work on hummingbird feathers has demonstrated that aeroelastic flutter of flight feathers can produce a wide variety of sounds. We tested the ability of flight feathers from a phylogenetically diverse array of birds to produce sound in a wind tunnel. Our results show that the capacity to aeroelasticaly flutter is intrinsic to all flight feathers, at airspeeds exceeding a critical velocity. In most but not all cases we replicated tonal flight sounds recorded from wild birds, indicating that this is a prevalent mechanism of sound production in birds.

P2.141 CLARKE, D. Nat; ZANI, Peter A.*; Whitman College, Pomona College; *bichodopei@yahoo.com*

Effects of nighttime warming on reproduction in side-blotched lizards (Uta stansburiana)

We experimentally simulated asymmetric nighttime temperature increase associated with climate change during the ovarian cycle of wild-caught female lizards and during subsequent incubation of eggs. We found that higher nighttime temperatures increased female's reproductive success and advanced reproductive timing, but did not affect clutch or egg size. Higher temperatures during incubation did not alter hatching success, but did shorten incubation period and result in longer, heavier hatchlings. Overwintering success of hatchlings was negatively related to hatch date with lizards requiring at least 45 d growth to ensure winter survival. Our results suggest that nighttime warming will primarily impact reproductive success and timing as well as subsequent fitness in temperate ectotherms.

P2.98 CLAVIJO-BAQUET, Sabrina*; CUMPLIDO, Nicolás; BOZINOVIC, Francisco; Pontificia Universidad CatÃ³lica de Chile; *sclavijo@bio.puc.cl*

Relationship between parental care and resting metabolic rate in Phodopus campbelli: testing parental care models for the origin of endothermy.

The origin of endothermy represents a puzzling phenomenon in the evolution of vertebrates; in order to address this issue several models have been proposed. The Farmer's and Koteja's parental care models are the most recently proposed ones and they are also those with less experimental support. Both suggest that parental care had an important role in the origin the endothermy, whether to explain the raise of resting metabolic rate (RMR) through an increase in the activity (Koteja's model) or an increase of body temperature (Tb) –due to an increase of tyrosine— during incubation period. For all this, we studied the relationship between RMR and parental care in the hamster *Phodopus campbelli*. Males of this species do parental care. This behaviour is well described permitting to manipulate males under controlled conditions. Each male was recorded three times. RMR increased as a result of subcutaneous tyrosine injections, in comparison to controls. Parental care was estimated through several tests during the first 12 days after pups birth. We measure time to contact, time to pick up and time to put the litter in the nest. We analyzed the relationship between parental care and RMR using mixed models which allows to analyze the fixed effect (RMR) blocking at the same time the male effect (random effect). We found that RMR has a negative effect on contact time, in other words, when RMR increases the contact time decreases. After that, we may point out that RMR has a positive effect over parental care supporting parental care models for the origin of endothermy. Funded by CONICYT AT- 24100180 PhD thesis fellowship and FONDAP 1501-0001.

P1.112 CLEMMENSEN, S.F.*; HULSEY, C.D.; University of Tennessee, Knoxville; *sclemmen@utk.edu*

Convergence in pharyngeal jaw morphology in Heroine cichlids

Trophic divergence in cichlids is linked to shifts in pharyngeal jaw morphology. In Heroine (Central American) cichlids, the ability to consume a novel prey type – mollusks – is a convergent phenotype with multiple evolutionary origins. We predict that the shift to hard-shelled prey causes similar shifts in tooth morphology in the pharyngeal jaw across taxa. Using CT scans of the lower pharyngeal jaw, tooth number, tooth size, and the size of visible replacement teeth were compared to evaluate the similarity among independently molluskivorous/molariform (M) cichlid species and compared against closely related non-molluskivorous/papilliform (P) species. We also compared M and P morphologies of the polymorphic species *Herichthys minckleyi* using both wild-caught and pond-raised individuals, to examine the degree of phenotypic plasticity that may be operating in these systems.

P2.195 CLIFTON, GT*; HONG, C; GEYER, H; BIEWENER, AA; Harvard , Harvard, Carnegie-Mellon; *glenna.clifton@gmail.com*

Limb swing dynamics of wild turkeys during normal and perturbed swings.

Existing research on muscle control of terrestrial locomotion focuses on stance, during which the limb supports the body and propels the center of mass forward. Limb swing has often been assumed to occur passively through inertial pendular motion. Past work suggests that this is unlikely, yet the limb dynamics during normal and perturbed swings is poorly understood. To characterize the swing phase we recorded limb kinematics using high-speed videography of wild turkeys (*M. gallopavo*) walking and running on a treadmill. Perturbation trials were taken using rectangular obstacles attached to the belt of the treadmill as swing-phase perturbations. We limited analysis of perturbed trials to steps directly upon the obstacle. Data for three turkeys showed consistent joint angle and dynamics patterns across a range of speeds (0.42 – 5.42 m/s). The hip and knee torques demonstrate almost exact inverse coupling. The ankle torque exhibits a smaller coupling with the knee, which increases during the latter portion of swing phase. This suggests that biarticular tissues, muscle or tendon, strongly contribute to the limb's swing dynamics in normal walking and running. Joint work patterns also reflect this coupling. Hip flexion work is paired with knee extension and ankle flexion. In contrast, the tarsometatarsophalangeal (TMP) joint works like a simple spring, extending quickly then flexing during swing. In perturbed swings, all three turkeys maintained strong coupling of the hip and knee torques, although the patterns significantly changed. Thus, control mechanisms for obstacle negotiation may continue to rely on biarticular structures across the hip and knee joints. These results contribute to our understanding of neuromuscular control of limb swing and perturbation recovery in bipeds.

P3.46 COCKETT, P.M.*; NEDVED, B.T.; HADFIELD, M.G.; Univ. of Hawaii, Manoa; *pcocket1@hawaii.edu*

Hawaiian littoral gastropods' heated existence.

Organisms that live within the littoral zone of Hawaii must tolerate extreme environmental stressors. In mid-summer, temperatures experienced by littoral organisms in a single tidal cycle range from 25° to 45°C. Other studies have shown that the expression of heat shock proteins (HSP) in gastropods occupying the highest portions of the temperate littoral zone is constituitive, while the HSPs of snails living closer to mean low tide are induced by increasing temperatures. The Intergovernmental Panel on Climate Change (IPCC) predicts that average surface temperatures will increase between 2° and 6°C by the end of the 21st century. This is cause for concern if the littoral gastropods are already living at or near their thermal limits. Thermal tolerances and vertical distributions were examined for four intertidal gastropods in Hawaii: *Littoraria pintado*, *Siphonaria normalis*, *Nerita picea*, and *Morula granulata*. These four gastropods occupy niches that extend from the uppermost portions of the littoral zone to mean low tide. Field surveys undertaken to determine the vertical distributions of these snails revealed significant differences in mean height among the four species, and temperatures of the rocks adjacent to the snails (collected with iButton® temperature loggers) showed significant differences among the snail habitats. Lethal temperatures for the four gastropods were determined in the laboratory and compared to the temperatures they experience in the field; resulting data confirmed that each species lives close to its uppermost thermal limit. Currently we are attempting to quantify HSP expression in each of the gastropod species using western blotting techniques.

P3.91 CONNELL, K. P.*; RAITHEL, S. J.; KERKOFF, A. J.; ITAGAKI, H. ; Kenyon College; *connellk@kenyon.edu*

Characterization of Midgut Morphology in Manduca sexta and the Development of a Model of Digestion

We aimed to characterize the growth and change in the midgut of larval *Manduca sexta* and see how changes in morphology affected digestive processes by utilizing a simplified model. We sampled from each of the five instars and measured changes in midgut perimeter over development. Our results so far demonstrate that the perimeter of the midgut scales as weight to the 0.48 power ($r^2 = 0.8651$, ANOVA p=0.00). This value indicates that the perimeter is increasing at a greater rate than by isometric growth, which would predict an exponent of 0.33. Observation of the morphology suggests that the increase in the level of infolding of the gut wall is responsible for the greater perimeter. This increase can have a huge impact on an organism's digestive capabilities and feeding behavior. To explore this, we characterized the midgut of *Manduca sexta* as a plug flow chemical reactor and parameterized the gut with our data to see how different sizes affected reactor performance. Based on our model, we made predictions about how maximal absorption rate, optimal consumption rate, optimal gut content flow rate, gut passage time, and absorption efficiency scale with weight. The predicted optimal consumption rate scaled as weight to the 0.89 power, a good approximation of third, fourth, and fifth instar caterpillar food intake. The predicted maximal amino acid absorbance rate scaled as weight to the 0.74 power, which overestimated the observed amino acid assimilation to an increasing degree as the caterpillar grew. However, the observed dry growth scaled as weight to the 0.88 which was very close throughout ontogeny to the predicted maximal absorbance rate. This model offers insights into digestion in this insect; we believe our results support the hypothesis that *Manduca* optimize their behavior to maximize absorbance given their gut morphology.

P3.26 CONNELLY, SJ*; TAN, LT; CODY, JC; Rochester Institute of Technology; *sjcsbi@rit.edu*

Establishing the role of vitamin D_3 in the fitness of Daphnia spp. exposed to UV radiation

Ultraviolet radiation (UV-R) has been shown to negatively affect exposed organisms through various means. Most can reduce UV-R exposure by behavioral changes, acquisition of UV-filtering pigments and DNA repair processes. Nevertheless, these defenses may be overwhelmed or costly in high UV-R environments, and organisms are known to use available compounds to further decrease their susceptibility. Recent studies of vertebrates have shown significant decreases of UV-R effects with vitamin D. Vitamin D is known to increase the fitness (survival and reproduction) of aquatic microcrustaceans, such as *Daphnia*. However, the potential for and the pathway by which vitamin D could decrease UV-R effects on *Daphnia* spp. are unknown. This biochemical study considers the photoprotective potential of vitamin D in *Daphnia* spp. under UV-A and UV-B conditions in controlled microcosms. Using high performance liquid chromatography (HPLC), we assess the web food transfer of vitamin D_3 and metabolites from environment to green algae (*Selenastrum capricornutum*) to *Daphnia* spp. under acute and chronic UV-R. Further, we are implementing a novel click-chemistry technique to fluorescently label vitamin D_3*in vivo*. Pin-pointing the vitamin will aid in understanding its utilization mechanism (photoprotection via changes in carapace, increased DNA repair, or some other process). We have demonstrated a significant increase in vitamin D_3 and 25-hydroxy vitamin D_3 transfer throughout our food web with increased availability of vitamin D_3. Further, we have correlated these food web effects to significant increases in the fitness of the species with increasing vitamin D_3 under chronic UV conditions. The future directions of this study will identify other metabolites of the vitamin using HPLC and will add additional food web constituents to better track the cycling of the vitamin D_3 within our microcosms.

P1.89 CONNOR, KR*; PRADHAN, DS; SOLOMON-LANE, TK; WILLIS, MC; NAUDE, PW; GROBER, MS; Georgia State Univ., Atlanta, Univ. of Georgia, Athens; *krcon85@gmail.com*

Endocrine correlates of initial sexual differentiation in the Bluebanded Goby

Socially controlled adult sex change is common in some fishes and is a marked divergence from the fixed sexes of mammals. While we know a great deal about the endocrine basis of initial sexual differentiation in mammals and adult sex change in fishes, little is known about endocrine regulation of initial sexual differentiation in sexually plastic animals, or its implications for adult plasticity. In many sex-changing fishes, planktonic larvae settle onto the reef and undergo metamorphosis into juveniles, during which sexual differentiation occurs. We collected newly recruited juvenile (N=14) *Lythrypnus dalli*, a bi-directional hermaphroditic fish species, and measured concentrations of 11-ketotestosterone (KT), a primary androgen indicator of male phenotype and behavior in most fish species, from water-borne steroids and whole body extractions. Average standard length and mass of recruits were 14.6 mm (range 12 - 17) and 43.7 mg (range 19.3 - 61.4) respectively. The length to width ratio of the genital papilla (a measure of sexual dimorphism in adults) ranged from male (>1.6) to female (±1) typical (range: 1.02 - 1.73; mean: 1.3 ± 0.21). Initial assays indicate the presence of KT in these maturing fish, and further analysis will examine the relationship between KT levels and both size and genital morphology. Additional studies will examine estradiol and testosterone with the goal to understand how sex steroid concentrations in recruits compare to those in sexually mature males and females. These studies will provide insights into the role of development and initial sexual differentiation in sexually plastic hermaphrodites.

P2.161 COOK, E.G.*; MURPHY, T.G.; JOHNSON, M.A.; Trinity University, San Antonio; *ecook1@trinity.edu*

Highly-parasitized Caribbean lizards (Anolis brevirostris) exhibit less colorful, less frequent social displays

Many animals utilize colorful displays to communicate with one another in behavioral interactions. The coloration of structures used in these displays can vary widely among individuals, but the underlying reasons for this variation are not well understood. In *Anolis* lizards, the dewlap, a brightly colored throat fan, is extended during courtship and territory defense. In this study, we examined whether lizard parasite load or investment in behavioral display were related to the variable red-orange dewlap coloration of male *Anolis brevirostris* from Barahona, Dominican Republic. In the field, we collected behavioral data on dewlap display rate for 30 individuals. We then captured each lizard, counted the number of ectoparasitic mites on the lizard, and measured its dewlap coloration. Color was measured with an objective spectrometer that quantified dewlap brightness (amount of white), hue (dominant wavelength of color), and red saturation (purity of color). We found that the relative abundance of ectoparasites was related to measures of dewlap brightness, suggesting that brightness can indicate a displaying individual's relative health – and that this information might be used by other lizards when making choices about whether to interact with a displaying male. Behavioral analyses indicate that individuals with drab (i.e., more white) dewlaps displayed their dewlaps less frequently than those with more colorful dewlaps, suggesting that more colorful males invest more in display behavior. The finding that males that perform fewer displays are less colorful indicates that display performance may be directly affected by parasitism.

P1.183 COOPER, Richard M.*; SCHAPKER FINUCANE, Heidi; ADAMI, Megan; COOPER, Robin L.; Dept of Biology, University of Kentucky , Dept of Biology, University of Kentucky; *RLCOOP1@email.uky.edu*
Heart and ventilatory measures in crayfish during copulation
Monitoring heart rate (HR) and ventilatory rate (VR) during defined sensory stimuli and during aggressive and submissive social interactions has provided additional information of a crayfish's physiological state which is not achieved by behavioral observations. In this study, the HR and VR of crayfish were monitored before, during and after the act of copulation in both heterosexual partners. The female crayfish abruptly reduces HR and VR during copulation but the male maintains HR and VR. After separation from copulation the female HR and VR are elevated, potentially paying back the O2 debt. The tight relationship with HR and VR in direction of change indicates a potential neural coupling. These physiological changes in cardiac and respiratory systems suggest an autonomic-like regulation of HR and VR. How these neuronal functions are driven and regulated remains to be determined. Olfactory cues from the female to the male during copulation maybe reduced by the reduction in VR in the female. These studies offer experimental paradigms for future neuronal and pharmacological investigations into autonomic regulation of HR and VR as well as the neural circuitry involved.

P3.3 COOPER, LN*; HALL, FM; DAVIS, JE; Radford University, Virginia Tech; *lncooper@radford.edu*
Color Oriented Neophobia and Sex Differences in the House Sparrow (Passer domesticus)
When encountering novel stimuli, animals must carefully evaluate their approach. Determining the balance of caution and curiosity, and the concomitant degree of neophobia or neophilia to exhibit, is a complex process. Particular features of an object interact with particular traits of the organism to determine rapidity and depth of investigatory behavior. Color, in particular, is a stimulus feature which may prove particularly relevant to many passerine birds, given its natural association with food, sexual display, and potential hazards. However, insufficient standardization of stimuli have often made it difficult to interpret results of previous studies. Here we describe several studies designed to test the specific effects of varying colors on food approach behavior in captive housed wild house sparrows (Passer domesticus). Due to the color red’s particular use in signaling in natural stimuli, we predicted that subjects would exhibit more caution in approaching red colored items than in approaching items of other colors. In addition to testing color of stimulus, we also explored variation in response profiles across sexes. Numerous previous studies have suggested that males display more aggressive behaviors than do females, and so we predicted that males would approach food items faster than females, regardless of food color. Our results suggest that house sparrows do exhibit increased caution in approaching red items and also that males approach novel items faster in general than do females. However, preliminary data also suggest that birds do not show an overall aversion to choosing red items over items of other colors, so much as a delay in approach when red items are presented as an option.

P2.148 COPENHAVER, P.E.*; POWERS, D.R.; FRIESEN, C.R.; MASON, R.T.; George Fox Univ, Newberg, OR, Oregon State Univ, Corvallis, OR, Oregon State Univ, Corvallis, OR; *pcopenhaver09@georgefox.edu*
Energy Investment in Copulatory Plug Production by Large vs. Small Male Red-Sided Garter Snakes (Thamnophis sirtalis parietalis)
Male red-sided garter snakes (*Thamnophis sirtalis parietals*) incur large energetic costs during reproduction due to prolonged courtship of females and male-male competition. When copulation occurs males deposit a copulatory plug (CP) into the female cloaca that delivers sperm, reduces female receptivity and attractivity, and passive mating guarding. Because CP material must be synthesized, plug production will constitute a portion of reproductive cost but the exact proportion is unknown. The rate of new plug synthesis might also play a role in mating frequency and reproductive success (smaller plugs/shorter mating intervals). If energetic cost or synthesis rate of CPs is size dependent, then plug production might play a role in male size-dependent reproductive success. We measured resting metabolic rate (RMR) of small (<30g) and large (>35g) recently-copulated and non-copulated but courting (control) males to see if post-copulation RMR > controls, and if any difference was size-group dependent. Small male post-copulative RMR (0.00396 ± 0.00059 mL O_2 g^{-1} min^{-1} ; 1.44xSMR) was higher than large-male post-copulative RMR (0.00355 ± 0.00073 mL O_2 g^{-1} min^{-1} ; 1.30xSMR), and post-copulative RMR in both small and large males was higher than controls. Control RMR in small males was 0.00332 ± 0.00045 mL O_2 g^{-1} min^{-1} (1.21xSMR) whereas control RMR in large males equalled SMR. CPs are composed of water (>90%) and protein and represent a meaningful energy investment of ~0.36 kJ. These data suggest that synthesis of CP material might cause elevation of post copulatory RMR and is consistent with the notion that larger males have an energetic advantage over smaller males in courtship.

P1.218 COPENHAVER, P.E.*; POWERS, D.R.; George Fox University, Newberg, OR; *pcopenhaver09@georgefox.edu*
Thermal Preference and Habitat Choice in the Rough-Skinned Newt (Taricha granulosa
For 10 months each year rough-skinned newts (*Taricha granulosa*) are confined to aquatic environments where temperatures vary (range: 5-25 °C). During this time newts must forage, undergo metamorphosis, and reproduce. To do this newts must behaviorally thermoregulate so that they can be active yet manage critical energy stores. In this study we measured behavior, SMR, and environmental conditions to assess how newts manage their thermal state and energy costs. Quadrat sampling was used to determine newt abundance and characterize water temperature for specific locations and depth. Newt body temperature (cloacal probe) was compared to environmental (water) temperature to verify temperature control. We measured SMR of aquatic-acclimated (AA) newts from 5-25 °C to assess basal energy costs. We compared SMR to SMR of terrestrial-acclimated (TA) newts to quantify the relative basal cost of aquatic existence. Newt abundance was higher in shallow regions (1-3m) with high vegetation (coverage >40%) and higher water temperatures (20-22 °C) than deeper (10-17 m), cooler (<10 °C) regions. Body temperature (20.6 ± 2.0 °C) did not differ from average water temperature where newts were present (20.5 ± 1.5 °C). SMR in AA newts was 1.1-1.5x lower than TA newts at all temperatures except at 5 °C where aquatic SMR was 1.8x higher. These data suggest that these newts are typical temperature conformers that select aquatic environments ~20 °C, which is likely within their preferred body temperature range. Their low SMR compared to TA newts might suggest metabolic adaptations favor the aquatic existence. The higher SMR observed at 5 °C in AA newts might help newts remain active during unpredictable cold spells that can occur during their reproductive period.

P2.31 CORDER, Katelynn M*; AYME-SOUTHGATE, Agnes J; College of Charleston, Charleston; *southgatea@cofc.edu*

Variation In Projectin Isoforms and Flight Performance In Drosophila melanogaster.

Insect flight muscles are extraordinary in their diversity at the anatomical, physiological and molecular levels. The myofibrillar structure provides the muscle with its contractile properties and contributes to muscle stiffness. Insect sarcomeres contain short, relatively inextensible filaments linking the Z-band to the myosin contractile filaments, which are known as C-filaments and contain two extremely large proteins, projectin and kettin/Sls. The molecular characterization of projectin in basal and derived insects reveals a highly conserved modular organization, including immunoglobulin and fibronectin domains together with a unique PEVK region. The PEVK domain is extensively alternatively spliced, giving rise to isoforms with PEVK regions ranging from 100 to 600 amino acids in *D. melanogaster*. The unusual amino acid composition of the PEVK segment, as well as its variable length may contribute to its proposed role as the elastic segment in the projecin protein. We investigated the possible correlation between the relative abundance of different projectin PEVK isoforms and parameters that are known to affect the fly's flight property. We will present data to determine the presence and ratio of different projectin PEVK isoforms under different conditions such as age, sex, and flight impairment by mutations or manipulations.

P1.57 CORTES, P.A.*; FRANCO, L.M.; CHAPPELL, M.A.; NESPOLO, R.F.; Universidad Austral de Chile, University of California, Riverside; *pablocortesgarcia@gmail.com*

Thermorregulatory capacities and energy-saving strategies in the South American marsupial,Dromiciops gliroides.

During periods of adverse conditions (e.g. winter) small endotherms depend on a continuous supply of food and energy to maintain body temperature (t_b). Thus, energy-saving strategies will be critical to reduce the energetic requirements for survival. We provide a quantitative description of thermoregulatory capacities and energy-saving strategies in *Dromiciops gliroides*. We evaluated: (1) the effect of thermal acclimation on basal (BMR) and maximum metabolic rate (MMR), thermal conductance (C) and torpor patterns, (2) the presence of non-shivering thermogenesis (NST) as a rewarming mechanism, (3) the energy costs associated to huddling under different thermal conditions and (4) the evolutionary potential of those traits. We found that cold-acclimated individuals presented higher BMR and longer torpor bouts. However, minimum tb and rewarming rate during torpor arousal was higher in warm-acclimated animals. Furthermore, we found that D. gliroides did not display NST in response to Norepinephrine. Comparisons of BMR and t_b between grouped and single-individuals, showed significant differences only at t_a =20°C, with higher values in grouped individuals. Repeatability of BMR, MMR and C were near-zero and non-significant. Also, body mass (m_b) was not a good predictor of these traits. Our study suggests that in *D. gliroides*, (1) unlike torpor, huddling is not an effective energy-saving strategy to endure unfavorable periods, (2) the ST is the main thermoregulatory mechanism during torpor arousal, (3) the components of energy metabolism evaluated not exhibit evolutionary potential (i.e. low or null repeatability) and (4) m_b is not a good predictor of this traits and thermal conductance.

P3.37 CORWIN, P.*; NOLAN, P.M.; SC Dept. of Natural Resources, The Citadel; *CorwinP@dnr.sc.gov*

Avian community response to seasonal and successional changes.

Secondary succession plays a critical role in driving the structure of natural communities. Vertebrate communities should respond to these successional changes on long time frames, but can also be expected to undergo significant seasonal changes differing from those seen on successional time scales. Avian communities in particular may show distinct changes, given the birds' ability to migrate long distances between habitats. We studied seasonal and successional changes in the abundance, diversity, and similarity of avian communities, in abandoned rice fields representing a variety of successional stages on the Cooper River, Berkeley County, South Carolina. We counted all birds detected from at least 20 census points, on each of three rice fields that differed in successional stage. We censused across all seasons of the year, using sight and sound to identify all birds. We used an ANOVA to test for differences in abundance, and in Shannon-Weaver diversity across seasons and successional stages, and used the Sorensen index to assess community similarity across seasons and successional stages. Successional stage significantly influenced the diversity of the avian community. Although we detected no seasonal differences in diversity, the significant seasonal variability in the particular species comprising the avian community on these ponds is noteworthy. Understanding how the avian community responds to succession is important for conservation biologists and land managers. More knowledge of this community response will enable us to make better land management decisions, with regards to allowing succession to return the land to a "natural state" or continuing to alter the landscape to benefit threatened or endangered species.

P1.59 COSENZA, K. S.*; SORACH, K.; CHANG, E. S.; MYKLES, D. L.; Colorado State Univ, UC Davis Bodega Marine Lab; *kcosenza@rams.colostate.edu*

Effects of molting on myostatin expression in crustacean skeletal muscle

In response to molting hormone (ecdysteroid), claw muscle atrophies to ease withdrawal at ecdysis. In blackback land crab, *Gecarcinus lateralis*, molting can be induced by eyestalk ablation (ESA) or multiple leg autotomy (MLA). Limb bud autotomy (LBA) suspends premolt by lowering hemolymph ecdysteroid titer. During premolt, down-regulation of myostatin (Gl-Mstn) is associated with increased protein synthesis during myofibril remodeling. Gl-Mstn levels are negatively correlated with ecdysteroid levels, suggesting that ecdysteroids inhibit Gl-Mstn expression. In thoracic muscle, which does not atrophy, Gl-Mstn mRNA and ecdysteroid are not correlated. The difference in response to ecdysteroids may be due to differences in ecdysteroid receptor (RXR/EcR) isoforms. The main goal is to determine how ecdysteroids control Mstn expression in *G. lateralis* and in *Carcinus maenas*. In *G. lateralis*, suspension of premolt by LBA maintained Gl-Mstn at elevated levels, which is consistent with the hypothesis. The effects of 20-hydroxyecdysone (20E) injection on Gl-Mstn expression in claw and thoracic muscle will be determined. dsRNA will be used to determine the effects of RXR/EcR knockdown on Gl-Mstn expression. As *C. maenas* is refractory to ESA and MLA, the expression of Cm-Mstn will be determined in muscles from spontaneously molting animals. Supported by NSF (IBN-0618203).

P1.110 COSTANTINI, KE*; HERNANDEZ, LP; George Washington University; *phernand@gwu.edu*
Morphological variation in the palatal organ of Cypriniformes
Cypriniform fishes are characterized by a number of trophic novelties that likely played an important role in the success of the group. These novelties include a unique mechanism of premaxillary protrusion, hypertrophied lower pharyngeal jaws, loss of upper pharyngeal jaw elements, and a muscular palatal organ. The palatal organ is a dorsal mass of muscle fibers within the buccal cavity that is strongly tied to the branchial elements laterally. Previous work on goldfish has shown that this muscular pad is incredibly well innervated and produces localized protrusions that are used to capture edible items while bottom feeding. While the neurobiology and physiology of palatal organ function in the goldfish has been well described, there is little data on palatal organ functional morphology across Cypriniformes. Indeed, previous reports have suggested that this important feeding structure is only found within Catostomidae and a few cyprinids. Many assume that the function of the palatal organ is conserved and as in goldfish, it is only used to selectively feed on the benthos. We suggest that the palatal organ may have become adapted for different purposes in feeding during the course of cypriniform evolution. However before testing such hypotheses we must first analyze the anatomical structure of the palatal organ in a diverse group of cypriniforms. Here we investigate the size, structure, and myosin composition of palatal organs of species within 8 subfamilies. Contrary to published results we found that nearly all species examined have some type of palatal organ. Although not as well developed or highly innervated as that of goldfish, a complex mesh of predominantly fast muscle fibers characterized all cypriniform palatal organs.

P1.219 COSTANZO, J.P.*; DO AMARAL, M.C.; ROSENDALE, A.R.; LEE, R.E.; Miami Univ., Oxford; *costanjp@muohio.edu*
Seasonal dynamics and influence of hibernaculum temperature on energy reserves in the wood frog, Rana sylvatica
The wood frog (*Rana sylvatica*), a terrestrial species that ranges to the Arctic Circle, overwinters beneath forest duff where it encounters subzero temperatures. Frogs may hibernate for >6 mo, during which time they do not feed and energy reserves are used to meet metabolic demands. We monitored seasonal dynamics of nutrient storage and consumption to determine the relative importance of lipid, carbohydrate, and protein in their overwintering energy budget. We also examined the influence of ambient temperature on energy consumption. Fat bodies, which were heaviest in summer frogs, were reduced in mass by 50% during the pre-hibernal period and fully expended between October and April. In contrast, the liver glycogen reserve (as well as dry liver mass) was sustained throughout the winter, but then decreased 75% by April, after frogs had aroused from hibernation. Glycogen sparing in winter supports the freezing adaptation in which glucose, a cryoprotectant, is copiously mobilized in response to ice nucleation. Marked reductions in dry masses of the carcass (20%) and gastrocnemius (25%) between November and January indicated that protein was also utilized in winter, but not in autumn. Frogs exposed to 4°C or 0°C in simulated hibernation survived from early November until early March (120 d), but half the frogs kept at 10°C died. Frogs in the 10°C group lost 18% of their initial body mass and had relatively small livers and fat bodies, and lower carcass and gastrocnemius masses. Frogs kept at 4°C or 0°C gained mass (from water retention) and consumed much less energy, suggesting that low temperatures are critical to successful hibernation in *R. sylvatica*. Supported in part by NSF IOS1022788.

P3.48 COX, Kelly M.*; FIELDS, Peter A.; Franklin and Marshall College; *kelly.cox@fandm.edu*
Time Course of Protein Expression Changes in Response to Acute Heat Stress in the Mussel Geukensia demissa
Little is known about the time course of change in protein expression following stress because proteomic changes are usually only examined at one recovery time point. In this experiment, I examine changes in protein expression in the ribbed mussel *Geukensia demissa* over time in response to acute heat stress. *Geukensia demissa* occurs in the intertidal zone of salt marshes from the Yucatan Peninsula to Maine, and can experience wide and rapid fluctuations in temperature. In this experiment, subjects obtained from a population in southern New Jersey were acclimated to 15° C for three weeks. Replicates of six mussels were heated to 40° C over a period of 40 minutes, held at temperature for one hour, then allowed to recover at 15° C for a period of 0, 3, 6, 12, 18 or 24 hours. Protein was extracted from gill tissue and separated by 2-D gel electrophoresis. Image analysis software was used to visualize the gels and to compare changes in spot density patterns between treatment groups. An ANOVA test was used to identify proteins whose abundance changed significantly after heat stress. Proteins found to have significantly different expression levels between treatment groups were excised and identified using liquid chromatography-tandem mass spectrometry (LC-MS) and bioinformatic (Mascot) analysis. Preliminary findings show that a stress response is detectable very early in the recovery period. Initial protein identifications suggest this rapid response addresses oxidative stress first (3 h), followed by an increase in chaperone proteins (12 h).

P1.90 COZ, J.H.*; DOHENY, B.M.; MCCOY, J.A.; RAINWATER, T.R.; BOGGS, A.S.P.; GUILLETTE, L.J.; College Of Charleston, Med. Uni. of SC/Hollings Marine Laboratory; *joeycoz@gmail.com*
Exploring genomic tools to sex non-sex chromosomal animal, American alligator (Alligator mississippiensis)
American alligators exhibit temperature dependent sex determination (TSD), by which sex is determined by egg incubation temperature. This makes them an excellent sentinel for studying the effects of endocrine disrupting chemicals (EDCs) on sex determination and reproductive system development. TSD can be overridden by estrogenic compounds or EDCs. One primary barrier to examining some of the endpoints of interest is that there is no minimally invasive way to sex hatchling alligators. This project examined whether the sex of adult alligators, of known sex, could be predicted by analyzing gene expression from samples of whole blood cells (BCs). Blood samples were collected from adult alligators at Yawkey Wildlife Refuge (Georgetown, SC) and mRNA was extracted from each sample of BCs. We selected four genes that are likely to be expressed in a sexually dimorphic fashion, including: aromatase (CYP19), estrogen receptor-1 (ESR1), estrogen receptor-2 (ESR2), and androgen receptor (AR). To test whether these genes are differentially expressed in males and females, we conducted quantitative real time reverse-transcription polymerase chain reaction (Q-PCR). We detected CYP19, ESR1, and AR mRNA in all samples, whereas we could not detect ESR2 mRNA. There were no statistically significant differences amongst the mRNA expression of CYP19, AR, and ESR1. These results, however, indicated that BCs could have steroidogenic function as well as receive sex steroid signals. This data suggest the BCs could be a target of EDCs that act through sex steroid receptors.

P1.30 CRAFT, Jonathan D*; RITSON-WILLIAMS, R; LANGDON, C; PAUL, V; Smithsonian Marine Station, Fort Pierce; *craftjd@gmail.com*

Impacts of ocean acidification on growth, calcification, and terpene concentrations in the green alga Halimeda opuntia

Increases in atmospheric carbon dioxide concentrations are reducing ocean pH and the calcification rates of marine organisms. Many calcified invertebrates and macroalgae need aragonite-saturated seawater to deposit calcium carbonate. Additionally, changes in carbon dioxide concentrations may cause sub-lethal stress to organisms and changes in concentrations of secondary metabolites (*e.g.*, terpenes) that protect macroalgae from herbivores. We exposed a calcareous terpene-producing macroalga, *Halimeda opuntia*, to seawater conditioned with increasing levels of atmospheric carbon dioxide (CO_2) to test for affects of ocean acidification on growth, calcification, and terpene concentrations. Growth and terpene concentrations did not differ among CO_2 levels that spanned 300-4100 ppm. However, calcification decreased with increasing CO_2 at levels over 1400ppm. Thus, growth and terpene concentrations in *H. opuntia* will not be impacted by the increases in atmospheric CO_2 predicted to occur at the end of the century, but calcification in this alga will decrease when atmospheric CO_2 levels exceed 2200 ppm. *Halimeda opuntia* is a conspicuous community member on coral reefs and in seagrass beds in tropical seas the world over, and the observed tolerance of this alga to increasing CO_2 suggests that it will continue to be a prolific community member. However, the success of *Halimeda opuntia* in a high CO_2 future could be to the detriment of more sensitive competitors such as corals.

P1.72 CRALL, J.D.*; COMBES, S.A.; Harvard University; *jcrall@oeb.harvard.edu*

Flying high: body size, flight performance, and vertical stratification of orchid bee communities in tropical rainforests

Forests are complex three-dimensional environments, characterized by significant gradients of wind speed and turbulence from the forest floor to the canopy. Such complexity is frequently accompanied by vertical stratification of animal communities. In this study, we collected orchid bees (*Apidae: Euglossini*) using scent-baiting at various heights in lowland tropical rainforests to investigate patterns of vertical stratification in relation to body size and flight performance. Orchid bee communities appear to be vertically differentiated, with larger-bodied species mostly absent from the upper canopy. Previous work has shown that, while energetically costly, extension of the hind legs improves flight stability of orchid bees in turbulent air by increasing moment of inertia and decreasing rolling moments. In contrast to expectations from isometric scaling, however, the contribution of leg extension to moment of inertia scales negatively with body size, indicating that smaller bees may be relatively more stable in turbulent air than larger bees. This increased stability, along with size-related differences in flight energetics, could help explain patterns of vertical stratification in relation to body size. Overall, our results imply that microhabitat use by flying insects is determined at least in part by flight performance and body size, which has important implications for forest structure and ecology.

P2.48 CRANE, E.; CHILDERS, D.; ROTHMAN, E.; GERSTNER, G.E.*; Univ. of Michigan; *geger@umich.edu*

Functional data analysis of mammalian masticatory jaw movements

Mammals are characterized by complex jaw movements associated with food ingestion and reduction. Despite the diversity of mammalian dentoskeletal forms, very few of the 5400+ identified mammalian species have been studied in terms of feeding kinematics, biomechanics and neuromotor control. One of our interests involves creating methods for quantifying oromandibular movements in ways that: (1) are minimally invasive for ethological reasons, (2) increase data analysis rates to expedite studies of additional species, (3) are rigorously quantitative and (4) allow statistically-legitimate comparative studies. Functional Data Analysis (FDA) is a set of sophisticated new methods that show great promise in these regards. Although FDA is gaining a foothold in human movement sciences, it is less well known among other disciplines and to our knowledge has only recently been applied to oral movement studies. One advantage of FDA lies in its treating time series data as functional observations, which offers the advantage of retaining information in continuous signals, e.g., masticatory jaw movements, by representing movements as functions of time rather than reducing the signal into discrete variables. Statistical analyses test hypotheses about the shape of movements, as opposed to traditional analyses based on landmarks, e.g., maximum gape, time of maximum velocity. We have been developing and testing FDA; here, we present FDA results, wherein we demonstrate: (1) automated jaw movement feature detection, e.g., gape cycles, transitions between fast and slow gape-cycle phases, etc., (2) extraction and functional rendering of gape cycles and (3) statistical tests to identify the location of significant differences in gape cycles between species.

P1.31 CREIGHTON, A.E.*; SINKIEWICZ, D.M.; WILCZYNSKI, W.; Georgia State University; *acreighton1@gsu.edu*

Steroid correlations in plasma, tissue and water samples

The study of steroid hormones and their mode of action is ubiquitous in all vertebrate and invertebrate organisms. The predominating theories indicate that sex steroid hormones are made primarily in the gonad and are released into plasma where they are free to pass through the plasma membrane of target tissues, and thus, levels of steroids in the tissues should reflect levels found in plasma. We chose to test this assumption in the green tree frog (*Hyla cinerea*), an animal in which reproductive behavior is seasonal and highly dependent on circulating sex steroid levels. We also collected samples to examine a non-invasive approach for steroid collection. Six frogs (3 male and 3 female) were placed in individual water baths for 30 minutes and euthanized immediately. Following decapitation plasma samples and tissue (brain, gonad, and liver) were collected and flash-frozen. Tissue samples were homogenized and steroid hormones extracted via C18 columns (Waters) from all tissue, plasma, and water samples. Extractions were measured using enzyme immunoassay kits (Cayman) for testosterone (T), and corticosterone (CORT). We found a strong, significant correlation between plasma and brain CORT (r^2=0.864, p=0.022) however; this was not seen with T (r^2=0.283, p=0.356). In the water vs. plasma samples we found a significant correlation in T (r^2=0.659, p=0.0497), which was not observed in CORT (r^2=0.205, p=0.3667). The significance of these results was not affected by adjusting for body mass. This suggests that plasma measures are a strong predictor of brain measures with respect to CORT, and water sample measures are a strong predictor of plasma measures with respect to T.

P2.17 CRICKENBERGER, S; Clemson University, Clemson, SC; *scricke@gmail.com*

Testing the predictive ability of niche-based models using a natural range retraction

A major goal of invasion ecology is to predict the range shifts and potential range limits of non-native species. Niche-based models are commonly used to achieve these goals. However, natural range shifts that enable the predictive ability of these models to be tested rarely present themselves. The barnacle *Megabalanus coccopoma* is native to shores extending from Baja California to Peru and has been introduced to the US Southeast, as well as a number of other locations worldwide. Prior to the cold winter of 2009/2010, its range in the US Southeast extended north to Cape Hatteras, NC with some peripheral, temporary populations as far north as Kitty Hawk, NC. During the winter of 2009/2010 the range of *M. coccopoma* shifted dramatically when all *M. coccopoma* north of Florida died. Subsequently, during the summer of 2010, new recruits appeared as far north as Tybee Island, Georgia; in the summer of 2011 recruits were found just south of Kitty Hawk, North Carolina. These data, along with data from surveys in the summer of 2012 and relevant environmental data, will be used to test the ability of two commonly used niche-based models, GARP and MAXENT, to predict the range shifts observed.

P3.98 CROFTS, SB; University of Washington; *croftss@uw.edu*

Effects of morphology on the function of crushing teeth

One of the diagnostic features of durophagous organisms are their teeth, which are generally described as low, robust, domes. A number of lineages of non-mammalian organisms include hard-prey specialists, and there is a wide diversity of tooth forms represented by these different groups. Teeth range from conical, to flat, and even to cupped shapes. The occlusal surface of a tooth may be smooth, or it may have force-concentrating projections. Are these different tooth shapes specialized for breaking different prey items? Why are some tooth-forms more common than others, and are there functional draw-backs to extreme forms? Or, are there trade-offs between tooth function and structural integrity? It has been proposed that the generalized molariform tooth shape associated with durophagy is an adaptation to either increased crushing efficiency, or increased resistance to breakage. To test the ability of different tooth shapes to crush prey items, we constructed three series of simplified tooth models that graded from one morphological extreme to another. We varied the degree of convexity/concavity of the occlusal surface, the height of a small conical stress concentrator, and the radius of a centrally located stress concentrator. In a materials testing system, we tested the ability of these tooth shapes to crush morphologically and compositionally identical prey items, in order to determine the relationships of the different morphologies. We compared these results to a previous study on the finite element analysis of these same tooth shapes to determine whether prey-breaking or the prevention of tooth breakage plays a more important role in the evolution of tooth shape.

P1.50 CRUZ, M.J.; SOURIAL, M.M.; WEIHRAUCH, D.*; University of Manitoba; *weihrauc@cc.umanitoba.ca*

Long term exposure to high environmental ammonia (HEA) impairs net ammonia secretion over the skin of the African Clawed Frog, Xenopus laevis

Ammonia excretion rates of the fully aquatic frog *Xenopus laevis* were determined to be 140± 3 nmol L^{-1} $gFW^{-1}hr^{-1}$. Skin tissues were investigated for their ammonia transport properties using a modified Ussing chamber and *in vivo*-like transepithelial osmotic gradients. Metabolic ammonia generated by the skin accounted to 24±0.2 nmol L^{-1} cm^{-2} h^{-1} (ventral skin) and 28 ±0.2 nmol L^{-1} cm^{-2} h^{-1} (dorsal skin) of which 57% and 51% were released towards the apical bath, respectively. A net ammonia efflux was produced by both skins, where reasonable ammonia net effluxes only occurred when the applied ammonia gradients were above ammonia levels measured in the plasma (0.364±0.033 mM). Quantitative mRNA-expression analysis revealed that Rhbg is highly expressed in kidney and skin tissues, but showed low expression levels in liver, nerve and muscle tissues. When compared to Rhbg, Rhcg showed 10 times lower relative expression levels in the skin, but 2.5 times higher expression levels in the kidney. When frogs were stressed for 7 days to HEA (1mM NH_4Cl) ammonia excretion rates and blood ammonia levels were similar to unstressed animals. Also skins of ammonia-stressed animals exhibited a net ammonia efflux, with greater ammonia net effluxes measured above blood ammonia concentrations. Interestingly, when exposed to HEA, both ventral and dorsal skins exhibited lower net ammonia efflux rates compared to control tissues.

P1.193 CUPP, JR., P. V.; Eastern Kentucky University; *paul.cupp@eku.edu*

Male green salamanders, Aneides aeneus, may help defend some nest sites

During an ongoing study of brooding behavior in female green salamanders, *Aneides aeneus*, six males (n=6)were found in crevices adjacent to brooding crevices or nest sites. The same males were in these crevices in subsequent visits, suggesting the possibility of being the paternal males. Outside the brooding period, these males were sometimes found in breeding crevices. Males were usually found near just one nest site. However, in one rock crevice subdivided into smaller crevices. the fortuitous arrangement of crevices allowed the male to occupy a posterior crevice just behind and between two narrow crevices where two females brooded eggs. This male was often present and apparently in position to aid in defense of both nest sites. Over a seven-year period, this male was present and young were usually produced successfully in both nest sites each year. In one year, another nest site was located close to the male. Thus, this male controlled three nest sites that resulted in about 60 hatchlings. In another instance, a male identified by the pattern of spots on the head was found in a crevice adjacent to a brooding female. Over a 10-year period, this same male was found in either an adjacent crevice or the breeding crevice. During this time, females successfully brooded eggs in the breeding crevice each year. Although only females may be seen brooding eggs in many crevices, these observations suggest that male *A. aeneus* may have a role in defense of some nest sites. Because male *A. aeneus* arrive at breeding crevices in late spring prior to females and are aggressive in maintaining territories where pairing and mating may occur, they have a considerable investment to protect. This is the first evidence of males associated with and possibly protecting nest sites for this species and possibly for the family Plethodontidae.

P1.94 CURTIS, Abigail A.*; LAI, George; VAN VALKENBURGH, Blaire; Univ. of California, Los Angeles; *abigailacurtis@gmail.com*

Frontal Sinus Morphology in Arctoid Carnivorans

Frontal sinuses are one of four mammalian paranasal sinuses that form when nasal epithelium escapes the nasal chamber and invades surrounding bones including the maxilla, sphenoid, ethmoid, and frontal. Sinuses appear to form where bone is mechanically unnecessary. Aquatic mammals are generally cited as lacking frontal sinuses, and it is presumed that they are lost due to negative effects of having air filled spaces during diving. To date, there has not been a quantitative study how sinus morphology varies with degree of aquatic lifestyle. Here we quantified frontal sinus anatomy in arctoid carnivorans including bears, seals, skunks, otters, raccoons, and weasels. Arctoids offer a number of independent acquisitions of aquatic behavior that range from fully terrestrial to almost exclusively aquatic, as well as a broad range of body sizes. We expect aquatic species will have no sinuses, and semi-aquatic species will exhibit relatively reduced sinuses relative to terrestrial species, reflecting their intermediate behavior. We used CT technology to construct volumetric models of frontal sinuses and quantified size and 3-dimensional shape using spherical harmonics. As expected, sinuses are absent in aquatic species and reduced in semi-aquatic species. Notably, the American badger and kinkajou (both terrestrial) lack sinuses. Aquatic species tend to have flatter skulls with enlarged, dorsally shifted orbits. The fossorial badger exhibits a similar trend in skull shape, whereas the frugivorous kinkajou has an extremely foreshortened snout. Thus we propose that the absence of sinuses in aquatic arctoids is not likely an adaptation for diving; rather it reflects skull shape changes that improve vision and streamlining for crypsis and/or swimming efficiency.

P2.83 DAGLEY, Brian*; MAGLIA, Anne; SHEARMAN, Rebecca; Framingham State University, National Science Foundation; *rshearman@framingham.edu*

Skeletal Development of Hyla chrysoscelis and the Skeletal Evolution of NA Hylids

Ossification sequence reflects developmental progress and may help elucidate associations between changes in timing of developmental events and adult morphology. North American (NA) hylids are a morphologically diverse group of tree frogs, which includes representatives of *Acris, Pseudacris,* and *Hyla.* A recent comparative developmental study of *Acris blanchardi* and *Pseudacris crucifer,* two small non-arboreal species, found that despite their similar size, *A. blanchardi* exhibited reduced ossification and miniaturization patterns while *P. crucifer* did not. We examined the skeletal developmental of *Hyla chrysoscelis* as a baseline for the "typical" arboreal NA tree frog, to which *A. blanchardi* and *P. crucifer* can be compared. In *H. chrysoscelis,* ossification of elements associated with the central nervous system occurs first, followed by major elements of the fore- and hind limbs (associated with terrestrial locomotion), then structural elements of the adult nose and face, and finally elements of the suspensorium and jaws (associated with terrestrial feeding). Although this pattern is consistent with *Acris* and *Pseudacris,* the timing of ossification of some elements relative to one another and to external developmental changes is unique. For example, the onset of ossification of the entire postcranium occurs relatively sooner in development in *H. chrysoscelis* than in *Acris* and *Pseudacris.* Herein, we detail the ossification pattern of *H. chrysoscelis,* compare it to that of *A. blanchardi, P. crucifer,* and *Hypsiboas lanciformis* (a South American hylid), and comment on the skeletal evolution of NA hylids.

P2.182 DANIEL, Nidun; CUNNINGHAM, Gregory*; St. John Fisher College; *gcunningham@sjfc.edu*

Stress hormone in White-throated sparrows (Zonotrichia albicollis) is not influenced by the cleanliness of a cotton bag

Bird banding stations are used throughout North America to trap and band birds, which allow researchers and government agencies to monitor populations, migration routes, health and a variety of other elements of avian physiology and biology. Birds are commonly trapped in mistnets, placed into a cotton bag, and brought to a research station where they are banded, weighed, measured and released. On some days, the number of birds caught may be so high that birds are left to hang in the bags for 10 – 20 minutes while other birds are processed. During this time in the bag the birds are undergoing a stress response, with their stress hormone levels (corticosterone; CORT) steadily increasing as a result. Given all of the negative effects of chronic stress, such as suppressing reproduction, nest desertion and inhibiting growth, banding labs should endeavor to decrease the stress of captive birds whenever they can. One way that CORT levels may be altered is by manipulating the microenvironment of the cotton bag. To that end, we monitored the stress response of White-throated sparrows (*Zonotrichia albicollis*) held for thirty minutes in either clean unused cotton bags or in comparable bags that had previously held at least 8 various passerines. For a variety of metrics used to assess CORT, there were no significant differences between the two groups; though both groups increased their CORT over time. Thus, from a stress perspective, a banding lab need not be concerned with whether or not a holding bag is feces free or has been excessively used. The possibility of transmitting disease such as Salmonella via feces, however, should not be ignored.

P2.173 DE BRUIJN, R; MERULLO, D*; WANG, L; CASH, J; ROMERO, LM; Tufts University; *robert.debruijn@tufts.edu*

Three weeks of daily, randomized exposure to rain, cold and food restriction do not elicit symptoms of chronic stress in molting European starlings

Repeated exposure to noxious stimuli causes chronic stress in animals, which is thought to reduce the ability of the animal to respond to additional stressors and potentially hampers survival. However molting birds appear to respond differently to chronic exposure to stressors. This study investigated heart rate and corticosterone responses of eight molting European starlings (*Sturnus vulgaris*) in response to a three week protocol, during which animals were exposed to 30 minutes of artificial rain or cold and a two hour food restriction period every day. Each of these stimuli elicits an acute stress response in the laboratory. Such weather related stressors are thought to be more relevant to molting birds, due to a higher protein demand and potentially less effective insulation as feathers are replaced. The order and application times of the stressors were randomized to prevent habituation and animals were exposed to three or four stressors per day. Weight increased from baseline throughout the chronic stress period, reducing back to baseline during the recovery period. No changes in daytime or nighttime basal heart rate were found before, during and after the chronic stress period. Birds responded to a standardized stressor with an increase in heart rate, which was the same throughout the experiment. No changes in baseline or stress-induced corticosterone levels were found. Neither corticosterone negative feedback nor maximum adrenal capacity changed over the course of the experiment. In conclusion, weather related stressors do not appear to cause chronic stress in molting European starlings.

P3.12 DE CASTRO, DM*; ZYLBERBERG, M; BRAZEAL, KR; HAHN, TP; University of California Davis; *dmdecastro@gmail.com*

Effects of various photoperiod treatments on the molt schedule of house finches.

Avian life history events are highly seasonal and dependent on their environment. Deviations in the environment can interfere with the timing of these events. For example, climactically mild years and increases in food availability may prolong breeding activity and delay the onset of molt in temperate zone songbirds. Given that molt schedule (the timing and rate of feather replacement) is dependent on photoperiod, a delay in the start of molt may affect the rate of feather re-growth. This in turn could affect trade-offs between molt and other biological functions and reduce individual feather quality. In this study, three groups of house finches (Carpadocus mexicanus) were exposed to photoperiods that rapidly increased from 15L to 18L (long day), followed a natural photoperiod (natural day), or rapidly decreased from 15L to 12L (short day). The short day group molted at a faster rate and greater intensity than the natural day group whereas the opposite was true for the long day group. As these results demonstrate, the rate of molt can be changed depending on time molt commences during the year. House Finches molting later molt faster due to decreasing day length and vice versa. Further research will investigate the influence of molt rate on factors of individual quality such as feather quality and immunocompetence.

P2.9 DE JESUS, Carrie E*; HOESE, William; California State University Fullerton; *cedejesus@pacbell.net*

Effects of anthropogenic noise on song sparrow song

Song sparrow (*Melospiza melodia*) males use songs for territorial defense and mate attraction. These acoustic signals may be masked by anthropogenic noise thereby reducing their effectiveness. Avian species reduce the effects of masking by changing when they sing to times with reduced noise, singing more frequently, singing louder, and shifting lower frequencies upward. Previous studies on song sparrows found that the minimum frequency was higher in males in noisy locations compared with males in quieter locations. We compared the songs of males singing in a high-noise location (adjacent to a 12 lane highway) with those of males in a low-noise location (undeveloped riparian habitat) in southern California to determine if all songtypes in a repertoire were similarly shifted in the noisy location. We hypothesized that song sparrows in noisy sites would have songs with higher minimum frequencies and narrower bandwidths compared to song sparrows in quieter sites. Repertoires from five males each in noisy and quiet sites were recorded during the spring of 2010 and 2011. Recordings were made with a Marantz PMD661 solid state recorder and Sennheiser condenser microphone. Ambient noise levels at each location were measured with a sound pressure level meter. We identified songtypes and measured the following characteristics from five songs from each songtype: minimum frequency, maximum frequency, and bandwidth. Sites varied with levels of anthropogenic noise: high 65 dBa (±SD 4.59), and low noise 45 dBa (±SD 5.01). Songs from the noisy site had a significantly higher minimum frequency than songs from the quiet site. There were no significant differences for maximum frequency or bandwidth between sites. Our findings provide additional evidence that individuals modify their vocal production in response to anthropogenic noise.

P3.177 DEMAS, A/D*; CLARK, A/J; College of Charleston; *amdemas@g.cofc.edu*

Mechanical properties of the skin of the Pacific hagfish, Epatretus stoutii

Hagfishes possess minimal tendinous connections between the skin and axial muscles that power locomotion, which gives their skin a loose-fitting appearance. This contrasts the tighter-fitting skin in lampreys, cartilaginous fishes, and bony fishes, which are due to numerous muscle-skin connections. Axial bending during swimming produces tensile stresses that must be accommodated by the skin, therefore we hypothesized that the loose-fitting skin of hagfish is less resistant to tensile stress in comparison to other fish species. We performed quasi-static uniaxial tensile tests to failure on various skin samples from five individual Pacific hagfish to determine skin strength (peak stress) and stiffness (resistance to deformation). Skin samples were obtained from dorsal and ventral surfaces of the body and tensile loads were applied in longitudinal and orthogonal directions. On the dorsal surface, the skin of the Pacific hagfish is anisotropic, being significantly stiffer in the longitudinal direction (47.1 MPa) than in the orthogonal direction (28.0 MPa). This pattern contrasts the anisotropy observed in other fishes, which possess skin that is stiffer orthogonally than longitudinally. Decreased resistance to deformation of hagfish skin in the orthogonal direction probably facilitates torsional movements characteristic to knotting. Furthermore, the tensile strength and stiffness of Pacific hagfish skin is comparable to that in terrestrial vertebrates and other fishes, including elongate species like the American eel, and fast-swimming species like skipjack tuna.

P2.90 DERRICKSON, E.M.*; COOK, M.; Loyola University Maryland; *ederrickson@loyola.edu*

Compensatory changes in assimilation capability in response to low protein diets in mice (Mus musculus)

The protein content of food directly impacts the growth and development of animals. Because low protein diets likely are encountered by omnivorous and herbivorous mammals, mice may have evolved adaptations that allow them to compensate for low protein, and thus moderate the impact of diet on fitness. We hypothesized that lactating mice on a low protein diet would demonstrate morphological and physiological changes in foregut compartments (stomach, small intestine) consistent with increased assimilation efficiency, and no changes in hindgut organs (cecum, colon). Mice were maintained on isocaloric diets containing low or optimal protein (10 or 20% respectively) during gestation and lactation, and sacrificed at 15-17 days of lactation. Wet and dry mass of organs and organ contents were obtained, and samples of small intestine were removed for enzyme assay and for fixation. Stomach wet mass and small intestine wet and dry mass each increased in mice on the low protein diet. No difference was seen in wet or dry mass of food in any compartment. Aminopeptidase activity/g tissue in the proximal, mid and distal regions of the small intestine did not differ between diet treatments. Small intestine diameter (but not length) was greater in mice on the low protein diet. These changes suggest that mice improve assimilation by increasing gastric secretion and increasing intestinal surface area for absorption of amino acids. We have no evidence that mice retain food preferentially in the foregut or increase aminopeptidase activity at the cellular level. We are measuring villus and crypt diameter along the intestine to determine what changes at the microscopic level account for the increased mass and diameter of the small intestine.

P1.123 DIAL, T.O.*; SANTANA, S.E.; EITING, T.P.; ALFARO, M.E.; University of California Los Angeles; *thomas.dial@ucla.edu*

How the bat got its stripes: roosting ecology and the evolution of pelage markings in bats

Although bats are not renowned for their diversity in color, multiple lineages have evolved striking facial and body pelage makings, including spots, stripes, neck bands and countershading. Researchers have hypothesized that these markings mainly evolved for crypsis, but this idea has never been tested in a quantitative and comparative context. We present the first large comparative study integrating data on roosting ecology (roost type and colony size) and pelage coloration patterns across bats, and explore the hypothesis that the evolution of bat pelage markings is associated with roosting ecologies that benefit from crypsis. We find that lineages that roost in the vegetation have evolved pelage markings, especially stripes and neck collars. These markings may function in crypsis through disruptive coloration and a type of anteroposterior countershading that might be unique to bats. We also demonstrate that lineages that live in larger colonies and are larger in size tend not to have some types of pelage markings. This result further suggests that the evolution of markings might be related to predation pressures, which would decrease in larger colonies due to the predator dilution effect and a lower number of potential predators in larger animals. Although social functions for pelage color patterns are also possible, our work provides strong support for the idea that roosting ecology has driven the evolution of pelage markings in bats.

P3.122 DIAZ, L*; LOPEZ-MARTINEZ, G; HAHN, D.A.; University of Florida; *dahahn@ufl.edu*

Do antioxidants mediate sexual selection after an extreme oxidative stressor in Drosophila melanogaster?

Almost all organisms are exposed to bouts of environmental stress. A wide variety of stressors from abiotic treats, like temperature and desiccation, to biotic threats, like pathogen infection and escape from predators, can induce oxidative stress. Resistance to oxidative stress has been associated with mating success in the context of sexual selection in numerous vertebrate taxa. Much of this work has focused on the role of diet-derived carotenoids in brightly colored birds and the role of endogenously produced antioxidant enzymes in sexual selection have received much less attention. Here we investigate the role of endogenous antioxidant enzymes on sexual selection in male *Drosophila melanogaster* flies that have been exposed to an extreme oxidative stressor, gamma irradiation. Using publicly available Gal4-UAS combinations we generate male flies with a range of antioxidant enzyme production and test the hypothesis that greater endogenous antioxidant capacity will be associated with greater mating success under stressful conditions.

P1.185 DIEDERICH, C.M.*; PECHENIK, J.A.; Tufts University; *casey.diederich@tufts.edu*

Intertidal and subtidal Crepidula fornicata experiencing drastically different thermal conditions have similar physiological tolerances

For sessile marine organisms, the intertidal zone is a physically stressful environment at low tide, and thus a less favorable place to live than the adjacent subtidal zone. However, intense subtidal predation and competition force some species to live intertidally; individuals of those species are rarely found subtidally, and thus few studies compare the physiological tolerances of intertidal and subtidal conspecifics. In New England, dense populations of the gastropod *Crepidula fornicata* live both subtidally and intertidally. We characterized the tissue temperatures that intertidal and subtidal individuals of *C. fornicata* experienced throughout the summer by deploying biomimetic temperature loggers among living *C. fornicata* at -1.0 and +0.4 meters MLLW. We then determined the thermal tolerances of adults, lab-reared juveniles, and field-collected embryos, and the temperatures at which juveniles experienced heart failure. Intertidal animals experienced temperatures as high as 42°C, about 15°C higher than those experienced by subtidal conspecifics. However, most animals from both environments died following a 3 hour laboratory exposure to only 35°C, suggesting that intertidal individuals are living very close to their thermal maximum. Both intertidal and subtidal animals at all life history stages had similar thermal tolerances and showed little variability in lethal temperature; intertidal animals showed a decrease in thermal tolerance over two years of sampling. Thus, subtidal *C. fornicata* seem pre-adapted to cope with the thermal stresses associated with life in the intertidal zone. It is unlikely that either population is undergoing directional selection for higher thermal tolerance.

P1.202 DO AMARAL, M. C.*; COSTANZO, J. P.; LEE, R. E. ; Miami University, Oxford, OH; *figueim@muohio.edu*

Seasonal variation in liver glycogen phosphorylase and cAMP-dependent protein kinase levels in Rana sylvatica

The wood frog, *Rana sylvatica*, is a terrestrially-hibernating, freeze-tolerant anuran. Liver glycogen has an important role in this species' winter survival, both as a source of energy and of cryoprotectant during freezing. In some anurans, the activity of liver glycogen phosphorylase (GP), the rate-limiting enzyme of glycogenolysis, increases during winter, and the liver glycogen stores increase as well. Moreover, in freeze-tolerant insects, cAMP-dependent protein kinase (PKA), the kinase that triggers glycogenolysis, shows seasonally high activity levels in winter. To understand liver glycogen metabolism and its regulation in *R. sylvatica* we measured seasonal changes in liver glycogen and in enzymes associated with glycogen metabolism. We sampled frogs housed under semi-natural conditions during fall, spring, summer and during simulated hibernation in the laboratory. Using Western blotting we measured the protein levels of both liver GP and of the catalytic subunit of PKAc, and liver glycogen. GP levels doubled from spring to winter and were accompanied by a significant increase in liver glycogen. To the contrary, PKAc protein levels significantly decreased from spring to winter. Carbohydrate metabolism has an important role in wood frog overwintering and distinct factors seem to be involved in the seasonal regulation of GP and PKAc protein levels in liver. Regulation of GP is likely controlled by factors related to glycogen metabolism; however, PKAc has a pleiotropic role in cells and our data suggest that cellular processes other than glycogen metabolism regulate its protein levels. Supported in part by NSF IOS1022788 and FCT SFRH/BD/63151/2009.

P1.199 DOELLING, A.R. *; WILLIAMS, J.B. ; Southern Illinois University Edwardsville, Southern Illinois University Edwardsville ; *adoelli@siue.edu*

Multiple freeze cycles induce oxidative stress and reduce survival in the freeze-tolerant goldenrod gall fly, Eurosta solidaginis

Most studies assess insect freeze tolerance by examining survival and/or parameters directly associated with extracellular ice formation immediately after a single, low temperature exposure. However, overwintering animals likely experience multiple freezing events and are potentially subject to a variety of stresses, such as the formation of reactive oxygen species as reperfusion of oxygen occurs post thaw. To determine if multiple freezing events reduce survival and influence factors associated with oxidative stress, we measured eclosion rates, levels of oxidative damage to macromolecules, and antioxidant capacity of larvae subjected to either 0 (control), 5, 10, 20, or 30 artificial diurnal freezes. Eclosion rates were similar for controls and animals experiencing only 5 freeze cycles (averaging 15%), but survival was reduced in groups subjected to 10, 20 or 30 freezing episodes (8%, 4%, and 2%, respectively). In contrast, oxidative damage to lipids (malondialdehyde levels) and protein (advanced oxidation protein product levels) were only higher in animals subjected to 30 freeze cycles (213.82±36.23 µmol TMOPng protein^{-1} and 25.06±2.39 mmol chloramine-Tµg protein^{-1}, respectively) compared to others which averaged 67.47±11.24 µmol TMOPng protein^{-1} and 11.60±1.21 mmol chloramine-Tµg protein^{-1}. Interestingly, no difference in antioxidant capacity (an animal's ability to mitigate reactive oxygen species), was observed between groups, with values ranging from 9.8-25.1 mmol troloxng protein^{-1}. In summary, the number of freezing events may dramatically increase oxidative stress and reduce survival in overwintering insects.

P1.92 DOHENY, Brenna M*; KOHNO, Satomi; MCCOY, Jessica A; GUILLETTE JR, Louis J; Medical University of South Carolina, OBGYN/Hollings Marine Laboratory; *doheny@musc.edu*

Signaling and Timing of Müllerian Duct Differentiation in the American Alligator

Perturbation of endocrine signaling during critical developmental windows has been implicated in decreased fertility and reproductive disorders. Using the "developmental origins of disease" paradigm, we examined the differentiation of the Müllerian duct into female reproductive tract structures. Müllerian duct development involves estrogen signaling, and is thus susceptible to disruption via environmental contaminants. The alligator is a useful model for studying reproductive system development, because sex determination is not genetic, but reliant on egg incubation temperature. To identify and characterize critical events in the differentiation of the alligator oviduct, we investigated pathways leading to sex reversal. Alligator eggs incubated at a temperature that produces 100% males (33.5 C) were treated with estradiol-17beta (E2) or 4,4',4''-(4-Propyl-[1H]-pyrazole-1,3,5-triyl)trisphenol (PPT), a specific agonist for estrogen receptor alpha (ERα), at a stage just prior to sex determination. In an initial study, E2 induced 100% sex reversal, indicated by Müllerian duct presence. PPT treatment induced sex reversal and Müllerian duct hyperplasia. Our current study examines the timing of signaling cascades by which increased ERα activity induces sex reversal. Müllerian duct tissue from different time points during sex determination was analyzed histologically, and by expression assays using quantitative RT-PCR for genes involved in temperature-dependent sex determination and expected to be regulated through ERα. The results of this study provide a model of normal ovarian and oviduct development, which is key to understanding developmental factors critical in the formation of a healthy reproductive system.

P3.121 DOUGLAS, M.J.*; HULSEY, C.D.; KECK, B.P.; RAKES, P.L.; SHUTE, J.R.; PETTY, M.A.; RUBLE, C.L.; University of Tennessee, Knoxville, Conservation Fisheries, Inc.; *mdougl11@utk.edu*

The evolutionary correlation of gene flow and pelagic larval duration in darters (Percidae: Etheostomatinae)

Similar to many marine fish species, many species of freshwater darters exhibit a pelagic larval stage during development before entering into the benthic lifestyle they maintain for the rest of their lives. Detailed observations of the characteristics and length of these stages are difficult to obtain in the wild. Therefore, inferring adaptive significance of this stage can be challenging. We compiled information gathered by Conservation Fisheries, Inc. located in Knoxville, TN on the duration of the pelagic larval stages of approximately 20 darter species. Using a recently published phylogeny and estimates of gene flow, we also examined the phylogenetically corrected correlation between larval duration and gene flow.

P2.94 DOWNS, C.J.*; WONE, B.; DONOVAN, E.R.; HAYES, J.P.; Univ.of Nevada, Reno; Ben-Gurion Univ. of the Negev, Israel, Univ. of Nevada, Reno; *downsc@gmail.com*

Selection on maximal metabolic rate in mice alters body mass but not body composition

Many life history traits, including growth rate, are often correlated with metabolic rate. Hence, selection of metabolic rate might cause correlated response in growth trajectories and final body mass and final body composition. We tested how selection on maximal aerobic metabolic rate (MMR) and basal metabolic rate (BMR) in laboratory mice (Mus musculus) affected growth trajectories, final body, mass, and body composition selected for mass-independent metabolic rates. As part of a larger experiment, three selection treatments were used: selection for high mass-independent MMR (high-MMR), selection for high mass-independent MMR and low mass-independent BMR (ANTAG), and no selection (i.e., randomly bred controls, CONT); each treatment had 4 replicate lines. After 7 generations of selection, MMR was greatest in high High-MMR mice and lowest in CONT mice; BMR was greatest in high-MMR mice and lowest in ANTAG mice. High-MMR mice were significantly heavier than CONT and ANTAG mice at weaning (21-days old) and at final body mass (19- to 21- weeks old). There were no overall differences in mass-independent body composition (i.e., fat mass, ash-free lean mass, ash mass, and water mass). This suggests a proportional increase of each component of body composition with the absolute increase in mass. At the level of selection treatment, our results agree with previous work that body mass was positively associated with BMR and MMR. However, at the level of selection treatment, there were no relationships between body composition and either BMR or MMR.

P2.164 DRISCOLL, S.C.*; CRINO, O.L.; BREUNER, C.W.; University of Montana; *stephanie.driscoll@umontana.edu*

The forgetful finch: Does developmental stress affect cognitive ability in zebra finches?

Developmental stress decreases song learning and associative learning in many passerines. The majority of studies have focused on the effects of nutritional stress (i.e. restricted food); however, few studies have examined the direct effects of glucocorticoids on learning. Using the zebra finch (*Taeniopygia guttata*) as a model system, we examined how developmental stress affects adult cognitive function. We fed nestlings corticosterone (the dominant avian glucocorticoid) dissolved in peanut oil for 16 days during the nestling period (12- 28 days post-hatch). During this same period matched siblings received peanut oil. After reaching adulthood (60 days post-hatch), we measured cognitive function using an established foraging paradigm. Finches that solve the foraging paradigm in the fewest trials are considered superior learners. We found that finches exposed to CORT during development solve the foraging paradigm in fewer trials compared to control-treated siblings. This suggests that developmental stress has sustained effects on cognitive function into adulthood in zebra finches.

P2.77 DUCHMAN, Bryce J.; WIENS, Darrell J.*; University of Northern Iowa; *wiens@uni.edu*

Effects of Hypergravity on Xenopus Embryo Growth and Cardiac Hypertrophy

All life on earth has developed and evolved in a unity gravity (1G) environment. Any deviation below or above 1G could affect animal development, a period when much change occurs and sensitivity is high. We imposed simulated hypergravity through centrifugation and analyzed the effects on the overall body length and cardiac growth of Xenopus laevis embryos. We predicted that increased contractile force would be required from the heart to adequately circulate blood, dispersing nutrients, and that this would inhibit growth and possibly induce a state of hypertrophy. Embryos reaching gastrulation stage were exposed to a 7G or 1G (control) field via centrifugation for 96 hours. We then recorded behavior, mortality and took body length measurements. We found no significant differences in behavior or mortality, however, body length was significantly reduced by an average of 6.8% in the 7G group. We then fixed, embedded, sectioned and stained embryos in order to investigate the dimensions of cardiac tissue and of the cardiac region of the body using image analysis software. We found the 7G group had a significantly reduced average body cross-sectional area (-18%) and yet a significantly larger ventricular cross-sectional area (+36%) when compared to the 1G group. The average ratio of ventricle cross-sectional area to average body cross-sectional area was significantly higher in the 7G group when compared to the 1G. From these data, we conclude that hypergravity has a significant inhibitory impact on the Xenopus laevis embryo growth and causes a significant increase in ventricle size.

P1.53 DUKA, A.*; AHEARN, G.A.; U. of North Florida, Jacksonville; *gahearn@unf.edu*

Comparative sugar transport by crustacean hepatopancreas and intestine

Crustacean hepatopancreas and intestine are both sites of nutrient absorption. Glucose is transported in both organs by Na-dependent cotransport, while Na-dependent D-fructose influx has also been described for the hepatopancreas. In neither organ have the details of ion dependent sugar transport been elucidated and it is still unclear as to whether the two sugars are independently transported by two distinct cotransporter carrier systems. In this study lobster (Homarus americanus) hepatopancreas brush border membrane vesicles (BBMV) were used to characterize, in detail, the Na-dependency of both 3H-D-glucose and 3H-D-fructose influxes, while in vitro perfused intestines were employed to determine the nature of cation-dependent sugar transport in this organ. Over the sodium concentration range of 0-100 mM, both 3H-D-glucose and 3H-D-fructose influxes (0.1 mM; 1 min uptakes) by hepatopancreatic BBMV were hyperbolic functions of [Na], exhibiting Km values of 2.30 +/- 0.59 mM (glucose) and 2.58 +/- 0.95 mM (fructose). Both sugars displayed significant ($p < 0.01$) Na-dependent and Na-independent uptake processes. Transepithelial 0.025 mM 3H-D-glucose and 3H-D-fructose fluxes across lobster intestine over a luminal sodium concentration range of 1 – 50 mM were hyperbolic functions of luminal [Na+], displaying Km values of 6.05 +/- 0.99 mM (glucose) and 10.58 +/- 1.65 mM (fructose). As with hepatopancreatic sugar transport, transepithelial intestinal sugar transport exhibited both significant ($p < 0.01$) Na-dependent and Na-independent processes. Similar sodium dependency of glucose and fructose transport in both gut organs suggests that they may be transported by carrier processes with physiological properties considerably different than those of mammalian transporters.

P3.174 DUNBAR, MA*; DAVENPORT, IR; Xavier University of Louisiana, New Orleans; *idavenpo@xula.edu*

Follicle Cell Processes in the Squaliformes, dogfish sharks

We have recently described a novel set of structures found within the chondrichthyan ovarian follicle. These actin-based, tube-like structures that we have called Follicle Cell Processes (FCP), are not seen in any other vertebrate so far described and may well be unique to the chondrichthyan fishes. These tube-like structures appear to connect the follicle cells directly to the oocyte during oogenesis. We have suggested they serve two purposes: 1) to allow for the passage of large quantities of metabolites to the developing oocyte, and 2) to physically support large egg cells upon ovulation. We have observed these structures in many stages of egg development, in several carcharhinid sharks. Here we describe the presence of FCP during various stages of oogenesis in a different order of sharks, namely the squaliformes, dogfish sharks.

P1.42 DUNHAM, LA*; WILCZYNSKI, W; Georgia State University, Atlanta; *ldunham2@student.gsu.edu*

Influence of AVT on corticosterone and aggression in lizards

Arginine vasotocin (AVT) is a potent regulator of social behavior in a wide variety of species, but little is known about its role in reptilian behavior. In mammals, AVT release increases corticosterone (CORT) secretion, and changes in circulating CORT levels are associated with changes in aggression. We set out to determine if AVT and CORT interact to influence behavior in the green anole lizard (*Anolis carolinensis*). Male anoles were pretreated with vehicle (VEH) or a CORT synthesis inhibitor (metyrapone, MET) followed by treatment with VEH or AVT 30 minutes later. As expected, pretreatment with MET followed by VEH significantly reduced plasma CORT (t=3.04, p=0.005). Treatment with AVT significantly increased CORT (t=8.30, p<0.001) even when pretreated with MET (within AVT treatment, CORT levels did not differ significantly between MET and VEH pretreatment; t=1.16, p=0.138), indicating that AVT can influence CORT by stimulating its release rather than inducing new CORT synthesis. A 30 minute aggression test was given and the number of displays quantified. To examine temporal differences in behavior due to metabolism of treatments, we separated the 30 min behavior test into three 10-minute segments. There were no significant differences in behavior between groups during the first and second time segments. In the final trial segment, a two way ANOVA revealed that AVT significantly reduced aggressive response, regardless of the presence of a CORT synthesis inhibitor (F=5.57, p=0.024). Treatment with MET did not affect behavior in any trial segment. Moreover, we found no significant correlation between CORT and overall behavior (r=-0.137, p=0.433). The results suggest that AVT influences both aggression and CORT in reptiles, but that the behavior change may be independent of the effect on CORT.

P1.74 DUONG, Nhi*; DAVIDOWITZ, Goggy; University of Arizona; *nhiduong@email.arizona.edu*

The Effects of Food Availability on the Workforce of a Social Insect: Response of Worker Production in Bumble Bee (Bombus impatiens) Colonies When Food Availability is Manipulated

Animals range in a continuum from solitary living to social living. Characteristic of highly social animals is their division of labor, where individuals divide both reproductive and work efforts. Such highly social organisms include naked mole rats, termites, ants, and bees. Sterile workers make up most of a social group's population size, and work is divided amongst them based primarily on dominance, age, or size. In a morphological division of labor, workers vary tremendously in their size. For instance, workers within bumble bee colonies can vary up to 10 times in body mass- five times more than in other social insects. Because division of labor affects colony fitness in social insects, worker size variation within colonies could affect fitness in colonies that have a morphological division of labor. Thus, it is important to know how ecologically relevant variables, such as food availability, impacts worker size variation. In our study, we manipulated food availability in bumble bee (*Bombus impatiens*) colonies such that they had 'unlimited' or 'limited' access to food. We recorded the following data: body size of all emerged workers, worker size variation within colonies, and colony fitness. We discuss the effects of our food availability manipulations on our colonies.

P3.146 DUQUE, Juan F.; FREUDENBERGER, Kelly; YAGER, David D.*; Univ. Maryland, College Park; *ddyager@umd.edu*

Multimodal Integration in Praying Mantis Audition: Visual Information Modulates the Descending Ultrasound-evoked CNS Responses of Parasphendale agrionina

Many male praying mantises fly at night, probably seeking pheromone-producing females. Most species have an ultrasound-sensitive ear in the metathorax that allows detection and successful evasion of the dominant nocturnal predator, echolocating bats. Auditory information carried by at least two auditory interneurons reaches the head by 12-13 ms. after the stimulus, and the evasive response begins ca. 50 ms. later. We asked whether visual input affects the descending neural response during the animal's night. Under conditions of complete darkness or moderate light, we recorded the robust, multiunit descending responses in the lateral half of a prothoracic connective using a suction electrode. All measured parameters differed significantly after 15 min. in the dark versus after 15 min. in light. Responses in the light had, on average, a 15% shorter latency (26 vs. 31 ms.), a 59% shorter duration (274 vs. 457 ms.), and 33% fewer total spikes/stimulus (60 vs. 91). In addition, there was an average of 7.6 recognizable units in the light response vs. 9.4 in the dark. To eliminate the possibility that the differences were due solely to the novelty of a bright light during the night, we repeated the recordings in the animal's daytime when bright light is normal. The patterns of response in the day were the same as at night, although for both light and dark conditions the latencies were shorter, spike numbers higher, and durations longer suggesting a circadian component. Thus, visual input strongly affects descending auditory responses. Because in the dark we saw greater numbers of spikes but longer latencies, the overall change is probably not a simple threshold shift.

P3.67 EASSON, Cole/G*; THACKER, Robert/W; OLSON, Julie/B; SLATTERY, Marc; WILLETT, Kristie/W; GOCHFELD, Deborah/J; University of Mississippi, University of Alabama at Birmingham, University of Alabama; *cgeasson@olemiss.edu*

Effects of Nutrient Enrichment on Competition between the algae Microdictyon marinum and the sponge Aplysina cauliformis

Coral reefs are impacted by runoff from local population centers, including nutrients from fertilizers and sewage. Previous studies have documented that increasing the nutrient load on a coral reef can lead to a phase shift from a coral-dominated to an algal-dominated system. While many species are affected by increased algal cover, one of the more important species found on Bahamian reefs is the rope sponge *Aplysina cauliformis*. At our study site in the Exuma Cays, Bahamas, 28% of *A. cauliformis* are in direct contact with the alga *Microdictyon marinum*. The primary goal of this study was to understand the effects of direct contact between these two species, and assess how this interaction is affected by elevated nutrient levels. In field experiments, sponges and algae were subjected to enhanced nutrient levels separately and in contact with one another in order to examine the impacts of competition and eutrophication on a number of physiological factors. The results show that nutrients positively affected the sponge's chlorophyll concentration, but algal contact resulted in negative effects to the sponge. Nutrients had a positive effect on the algae in all experimental treatments. Understanding the effects of nutrients on interactions between reef species will help us to better understand coral reef population changes in the face of anthropogenic impacts.

P1.34 EBERSBACHER, H.E.*; FURIMSKY, M.; Westminster College - PA; *ebersbhe@wclive.westminster.edu*

The Effects of Deer Antler Velvet on Caudal Fin Regeneration in Zebrafish

Deer antler velvet has recently been in the news concerning its use by professional athletes in injury recovery and performance enhancement. This product is a natural source for the growth factors IGF1 and IGF2, and other substances such as type II collagen, glycosaminoglycans and chondroitin sulfate, all of which contribute to the belief that it assists with joint problems, aging, rheumatoid arthritis, strength, bone injury, and other clinical recoveries. The aim of this study was to examine the effects of deer antler velvet powder on caudal fin regeneration in adult zebrafish. Based on its bone fracture healing properties, we predict that exposure to deer antler velvet will have a positive effect on fin regeneration rate. Following light clove oil anesthesia, caudal fins were amputated and fish allowed to recover before being placed in experimental conditions. Fish were placed in either regular system water (control) or in system water containing 450 mg of dissolved deer antler velvet powder. Following completion of fin regeneration, fish were fixed and stained for neuromast cells to determine whether treatment also affected regeneration of the lateral line system. The results of this study will be presented.

P1.63 ECHLIN, ML*; MACLEA, KS; MYKLES, DL; Colorado State Univ.; *moriahe@rams.colostate.edu*

Cloning and Characterization of a Novel Transforming Growth Factor-β in Crustaceans

The molting gland, or Y-organ (YO), of decapod crustaceans transitions through four physiological states (basal, activated, committed, and repressed) during the molt cycle. We hypothesize that a TGF-&beta-like factor is required for the YO to transition from the activated to the committed state during premolt. TGF-β is an autocrine factor that controls cell proliferation and differentiation in mammals. In YO, TGF-β may alter molt-inhibiting hormone (MIH) and metazoan Target of Rapamycin (mTOR) signaling pathways to stimulate ecdysteroid synthesis. The only members of the TGF-β superfamily that have been characterized in crustaceans are cDNAs encoding myostatin (Mstn). A BLAST search of the GenBank database identified an expressed sequence tag (EST; 1.7 kb; accession #CN854252) of a TGF-β factor distinct from Mstn in the American lobster, *Homarus americanus*. The EST was obtained from a library constructed from mixed tissues at Mount Desert Island Biological Lab by David Towle and Chris Smith and was fully sequenced. The deduced amino acid sequence has 52-75% identity and 73-85% similarity to the mature peptide domain of TGF-&beta-like factors in other arthropods. Furthermore, a sequence alignment shows highly conserved regions in the mature peptide domain, including the 7 cysteines involved in intra- and inter-molecular disulfide bridges. We will use 5' rapid amplification of cDNA ends (RACE) to extend the lobster sequence and polymerase chain reaction (PCR) and RACE to clone the ortholog from the blackback land crab, *Gecarcinus lateralis*. A goal is to quantify the effects of molting on the expression of TGF-β in the YO using quantitative PCR. Supported by NSF (IOS-0745224).

P1.39 EDMONDS, K.E.; Indiana University Southeast; *kedmonds@ius.edu*

Hormonal and Metabolic Regulation of Compensatory Testicular Hypertrophy in the Marsh Rice Rat (Oryzomys palustris)

Compensatory testicular hypertrophy (CTH) is a phenomenon in which the surgical removal of one testis results in a significant increase in the size of the remaining testis relative to control animals. CTH was examined in juvenile male rice rats to determine if its regulation is subject to hormonal and metabolic manipulation. Juvenile males housed on 14L:10D were weaned at 3 weeks of age and sham unilaterally castrated (sham ULC) or ULC. Rice rats were implanted subcutaneously with 15 mm capsules that were empty (E; control) or contained estradiol (E2), dihydrotestosterone (DHT), or corticosterone (C). At 8 weeks of age, pups were weighed and sacrificed. The right testis, seminal vesicles (SV), right epididymis, spleen, and Harderian glands (HG) were removed and weighed. Significant CTH occurred in E, DHT, and C males. E2 dramatically inhibited body mass, the HG, and all reproductive development. Interestingly, E2 increased spleen mass. DHT also increased SV and HG mass. To examine whether CTH could be stimulated on a short photoperiod, animals were transferred from 14L:10D to 13L:11D at weaning and sham ULC or ULC and chronically provided sulpiride (a dopamine antagonist hypothesized to elevate endogenous prolactin levels) in the drinking water. There was a significant effect of sulpiride on the right testis in ULC males, suggesting that CTH can be altered in males housed on a short photoperiod. Other endpoints measured were not dramatically affected. Lastly, in ULC males injected daily with 2-deoxy-D-glucose (2-DG), an inhibitor of intracellular glucose utilization, CTH was inhibited at three weeks post-surgery. The only other endpoint significantly affected was the spleen which was reduced in size in 2-DG animals. Taken together, these results show that CTH is dependent upon the hormonal and metabolic environment in rice rats. (Supported by the Indiana Academy of Science)

P1.29 EDWARDS, Thea M.*; MORGAN, Howard E.; Louisiana Tech University; *tedwards@latech.edu*

Effects of acid rain on parsley phytoestrogen content and development.

Phytoestrogens are a diverse group of small molecules made by plants to ward off disease and pests, attract symbionts and pollinators, and regulate growth and reproduction. As their name suggests, phytoestrogens are pharmaceutically interesting because they bind estrogen receptors or otherwise interact with estrogenic signaling cascades in animals. In fact, much more is known about the nutraceutical uses of phytoestrogens than their roles in plants. This study is part of a larger research program to understand how plants use phytoestrogens to regulate their own physiology, and to assess how phytoestrogen content changes in plants as they respond to environmental cues. We exposed parsley plants to simulated acid rain and control treatments (pH = 4.5, 5.6, 6.8) from germination through seed production to determine if environmental pH affects phytoestrogen content in parsley. Like soybeans and clover, we have previously shown that parsley stimulates a strong estrogenic response in a yeast reporter gene system expressing human ESR1 and ESR2. We report on developmental changes in estrogenicity of parsley across pH treatments. Acid rain is a significant global environmental concern. We use our findings to predict how the effects of acid rain on plants might be mediated by phytoestrogens.

P1.150 EISNER PRYOR, Leah/J*; CASTO, Joseph/M; Illinois State University ; *ljeisne@ilstu.edu*

Chronic Mite Infestation and its Effects on Nest Success, Immunity and Development in European Starling Nestlings

We experimentally assessed the effects of chronic haematophagous mite infestation on nest success, egg spottiness, growth, and immune function in European Starling nestlings. We did this by spraying half the nests with the common agricultural insecticide permethrin to reduce ectoparasite number and inoculating the other half of the nests with approximately 200 adult northern fowl mites during incubation. We measured innate immunity by performing bactericidal assays on days 10 and 15 post hatch. We analyzed cell mediated immunity by measuring lymphocyte proliferation in response to lipopolysaccharide and concanavalin A at 17 days post hatch and we measured wing length, tarsus length, and mass to assess growth. We found a significant effect of mite infestation on nest success. Significantly more nests failed before hatch in the mite-enhanced group. We also found a significant treatment effect on egg spottiness. Post-treatment, eggs in mite-enhanced nests were significantly more spotted than eggs in permethrin treated nests. There was no effect of treatment on growth. We found a significant effect of mite load on innate immunity. Nestling bactericidal ability was significantly lower in mite-enhanced nests at day 10 but significantly higher at day 15. We also found a significant effect of day on innate immunity, in that nestlings on day 15 had significantly higher bactericidal ability than nestlings on day 10 in both treatment groups. We found no effect of treatment on lymphocyte proliferation. Further comparison to lymphocyte proliferation in adult starlings should allow us to determine whether nestlings have generally reduced proliferative ability or are capable of producing adult-like proliferation in response to the mitogens tested.

P1.33 ELLENS, E.R.*; KITTILSON, J.D.; SOWER, S.A.; SHERIDAN, M.A.; North Dakota St. Univ., Fargo; *elizabeth.ellens@my.ndsu.edu*

Evolutionary Origin and Divergence of the Growth Hormone/Prolactin/Somtolactin Receptor Family: Insights from Studies in Sea Lamprey

In this study, we sought to clarify the evolutionary origin and divergence of the growth hormone receptor (GHR)/prolactin receptor (PRLR)/somatolactin receptor (SLR) family by identifying the ancestral precursor(s) from the liver of sea lamprey, one of the extant groups of the oldest lineage of vertebrates, Agnatha. By using a multi-phased PCR-based approach, we isolated, cloned, and sequenced a single full-length cDNA that encodes a protein that shares amino acid identity with GHRs, PRLRs, and SLRs previously characterized from teleost fish. Expression of the GHR/PRLR/SLR-like transcript was widespread among tissues of the lamprey, including brain, pituitary, heart, liver, and skeletal muscle, which is consistent with the broad physiological roles of GH-family peptides. Phylogenetic analysis suggests that the sea lamprey GHR/PRLR/SLR mRNA derives from an ancestral gene that diverged to give rise to distinct GHRs, PRLRs, and SLRs over the course vertebrate evolution. (Supported by NSF grant IOS09200116 to M.A.S. and IOS0849569 to S.A.S.)

P1.178 ELLERBY, D.J.; HITCHCOCK, A.C.*; Wellesley College; *ahitchco@wellesley.edu*

Use of preferred escape trajectories in Bluegill sunfish (Lepomis macrochirus)

The escape response of a fish must be both rapid and unpredictable to avoid predation. Movement directed away from the predator would seem ideal; however, a fixed escape strategy would allow predators to predict a prey animal's movements. Conversely, a random strategy would lead to some escape responses being towards the predator, an unsuccessful solution. Large data sets that allow clear resolution of escape trajectory distributions and an assessment of individual variability in escape strategy are not currently available for vertebrates. Individual bluegill sunfish (*Lepomis macrochirus*) were startled 60 times by a stimulus directed towards the head and their escape trajectory was recorded via high speed camera. The resulting trajectory distribution was multimodal. Similar preferred escape trajectories were found across individuals, occurring at approximately 85o and 140o from their initial orientation. An additional peak at very low angles occurred in some individuals, and some fish expressed "sidedness," with a preference for either right or left turns. The presence of common peak trajectories suggests that fish choose from a set of preferred angles of escape relative to the direction of the threat, keeping their response unpredictable but also nonrandom. This may keep the variability necessary to confuse predators while reducing the pool of potential choices, allowing a faster response.

P1.209 ENZOR, Laura A.*; PLACE, Sean P.; University of South Carolina; *enzorl@email.sc.edu*

High Latitude Oceans in a High CO2 World: Comparative Analysis of the Metabolic Response of Antarctic Notothenioids to a Multi-Stressor Scenario

For Notothenioid fishes of the Southern Ocean, evolution in extremely stable, cold waters has resulted in several physiological adaptations that likely come with a high metabolic cost. For instance, production of antifreeze glycoproteins for freeze avoidance, or the constant expression of the inducible heat shock protein, Hsp70, in response to reduced protein folding efficiency, necessitate the reallocation of precious energy expenditures away from growth and reproduction. Additionally, these fish have adapted to their cold environment by increasing mitochondrial density, utilizing lipids as a primary energy source, thereby eliminating the need for a swim bladder, as well as lowering enzyme activation temperatures. Thus, in the face of increasing global climate change, the metabolic cost of maintaining cellular homeostasis in these stenothermal fish may be significantly impacted. While the effects of thermal stress on teleost metabolic rates have been well documented, there is little to no data on the effects of potential synergistic stressors. We have begun a comparative study to identify changes in cellular energetics that may result from predicted changes to ocean environments. We have used intermittent aquatic respirometry of whole animals to compare the basal metabolic response of several Nothenioid species to the combined effects of increasing water temperatures and decreasing ocean pH levels. In addition, we measured the oxygen utilization of isolated hepatocytes in the presence and absence of inhibitors in an effort to identify changes in energy allocation under this multi-stressor scenario.

P1.181 ERNST, D.A.*; LOHMANN, K.J.; University of North Carolina at Chapel Hill; *dernst@live.unc.edu*
Undersea Orientation Mechanisms of Horseshoe Crabs
During the high tides of spring, the American horseshoe crab (*Limulus polyphemus*) can be found in large mating aggregations along low-energy sandy beaches ranging from the east coast of Maine to the Yucatan Peninsula. Little is known, however, about the sensory cues and navigational strategies used by horseshoe crabs to locate suitable nesting beaches. Sexually mature crabs typically spend most of the year in deeper estuarine waters or on the continental shelf and migrate toward shore to nest during a limited period of each spring. Although wave surge and seafloor slope might potentially be used in finding the beach once crabs have arrived in close proximity to the shore, the deeper wintering grounds are likely devoid of these cues. Furthermore, *Limulus* has been frequently captured at depths where little or no light penetrates and many populations thrive in highly turbid estuarine habitats, greatly reducing the efficacy of visual landmarks as navigational guideposts. In principle, several non-visual environmental cues might guide horseshoe crabs from deep water to their nesting beaches, including auditory cues, depth cues, chemical signals, and the Earth's magnetic field. Potential cues and navigational strategies that may function in the onshore migration will be discussed.

P2.107 ESSNER, JR., R.L.*; PATEL, R.; REILLY, S.M.; Southern Illinois University Edwardsville, Ohio University; *ressner@siue.edu*
Ontogeny of Body Shape and Diet in Freshwater Drum (Aplodinotus grunniens)
Ontogenetic changes in body shape were studied in Freshwater Drum *Aplodinotus grunniens*, using geometric morphometrics. We examined a single cross-sectional sample of juveniles, sub-adults and adults collected from the Ohio River near Racine, OH. Eleven landmarks on lateral profiles of fish were digitized and body shape was compared using relative warp analysis. Significant allometric growth was identified between four relative warp axes and centroid size. Several of the shape changes characterizing growth in *A. grunniens* appear to be functionally related to feeding. Gut content analysis was consistent with other research that found a dietary shift from soft-bodied prey (e.g., copepods, chironomids) in smaller individuals to hard-bodied prey (e.g., fish) in larger individuals. Key shape changes that correspond to a shift in diet to larger and harder prey types include a more anteriorly positioned mouth, more expansive gape and increased body depth.

P1.223 FAHERTY, S.L.*; YODER, A.D.; Duke University; *sheena.faherty@duke.edu*
Assessing gene expression profiles during seasonal thermoregulation in a hibernating primate, Cheirogaleus medius
In most species, obesity is considered detrimental to health, however in some hibernating mammals, the endogenous circannual cycle includes seasonal periods of obese and lean states. At present, a significant knowledge gap exists in our understanding of the molecular mechanisms that allow hibernators to survive the physiological changes associated with hibernation, in particular, genes governing seasonal weight gain and loss. Real-time RT-PCR (qRT-PCR) has become a widely used method to assess gene expression profiles in white adipose tissue (WAT). However, in order to remove nonspecific variation leading to quantification errors, normalization to stably expressed endogenous reference genes is crucial. There exists no prior context for endogenous reference genes in WAT of the hibernating primate, *Cheirogaleus medius*. In this study, we aim to identify and validate candidate reference genes suitable for gene expression studies using subcutaneous WAT from *C. medius* throughout the circannual cycle. This study provides the critical first step in gene expression studies investigating the coordinated and predictable changes in expression profiles during seasonal weight gain and loss in a hibernating primate.

P3.184 FEILICH, KL*; GERRY, SP; ELLERBY, DJ; Wellesley College; *dellerby@wellesley.edu*
Modulation of leech muscle performance by serotonin
The obliquely striated muscle in the leech body wall has a broad functional repertoire; it provides power for both locomotion and suction feeding. Increased serotonin (5-HT) levels promote these behaviors and also affect muscle mechanical performance. During isometric contractions 5-HT enhances active force production and reduces resting muscle tone. 5-HT may therefore increase net work output during the cyclical contractions associated with locomotion and feeding. Body wall longitudinal strains were measured by sonomicrometry during swimming, crawling and feeding. The resulting strain patterns were applied to longitudinal strips of body wall muscle in vitro using an ergometer and the timing and duration of stimulation selected to maximize net work output. The presence of 5-HT significantly increased net work output during simulated swimming, crawling, and feeding relative to the saline control condition. Without 5-HT the muscle strips could not achieve a net positive work output during simulated swimming. The behavioral and mechanical effects of serotonin are clearly complementary: promoting particular behaviors and enhancing muscle performance during those behaviors.

P3.59 FELDER, M.R.*; VRANA, P.B.; SZALAI, G.; SHORTER, K.; LEWANDOWSKI, A.; University of South Carolina; *felder@biol.sc.edu*

Development of Resources for Peromyscus Laboratory Research

Peromyscines are among the most common and speciose of North American mammals. The Peromyscus maniculatus species complex is particularly wide-spread and varied. These characteristics along with their relative longevity and their adaptability to colony conditions makes this group well suited for studies of natural genetic variation. The Peromyscus Genetic Stock Center (PGSC) maintains multiple species stocks derived from natural populations as well as numerous variants within the P.m. species complex. To further their usefulness as a mammalian model system, the PGSC is developing further resources, including: 1) a medium density genetic map covering the entire genome (currently ~350 markers), 2) ESTs from multiple tissues and developmental timepoints, and 3) greater assisted reproductive technologies such as the ability to transfer and cryopreserve embryos. These resources are being generated using the PGSC P. maniculatus bairdii BW stock and the P. polionotus subgriseus PO stock (http://stkctr.biol.sc.edu/index.html). Further, our NHGRI accepted proposal for sequencing of four Peromyscus genomes is underway (http://www.genome.gov/10002154). The BW sequencing is complete; assembly and annotation is underway. Most of the genomic data is already available (http://www.ncbi.nlm.nih.gov/genomeprj/53865). Sequencing of the PO and three other Peromyscus genomes has also been completed. Here we will present overviews of progress in all these areas.

P3.105 FELLER, Kathryn D*; CRONIN, Thomas W.; Kathryn D. Feller UMBC; *kfeller1@umbc.edu*

The spectral sensitivity of stomatopod larvae

Adult stomatopods possess exceedingly complex visual systems with unique structural adaptations, unusual spectral filters, and a myriad of expressed visual pigments. Larval visual systems of these marine crustaceans, by comparison, are much simpler in both their structure and visual pigment expression. Previous research suggests that stomatopod larvae possess compound eyes typical of many pelagic zoea, with transparent apposition optics and a single, spectrally distinct visual pigment class. The physiological function of stomatopod larval eyes and their transition into the complex structures seen in adults, however, are largely unknown. It also remains unclear as to whether larval and adult stomatopods express separate suites of visual pigments, or if larval pigments are retained through adulthood. Preliminary research on the larval and adult stages of the gonodactyloid species, *“”Gonodactylaceus mutatus “”, supports the presence of a larval visual pigment that retains its expression in the adult eye. In lysiosquilloid and squilloid species, however, data suggest unique suites of visual pigments for each life phase. Despite these conflicting results, we hypothesize that separate sets of visual pigments are expressed during the larval and adult stages. This hypothesis would account for both these preliminary results and the unique developmental process observed in stomatopod eyes. During the final, metamorphic molt of stomatopod larvae the larval retinas degenerate while the adult retinas form as separate structures medially adjacent to the prexisting larval material, resulting in two retinas within a single eye for a brief period. Here we report new data regarding visual pigment absorption in single receptors of stomatopod larvae measured by microspectrophotometry. These data deepen our understanding of larval visual ecology and suggest further approaches for investigating the peculiar development of stomatopod eyes.*

P2.104 FELLMANN, C.D.*; YOUNG, J.W.; Ashland University, Northeastern Ohio Medical University; *cfellman@ashland.edu*

Limb growth, locomotor development, and life history in lagomorphs

Young mammals must often navigate in the same niche as adults despite a number of growth-related limits to locomotor performance. As such, juveniles are expected to exhibit compensatory mechanisms that allow them to offset such limitations, increasing their chance of reaching sexual maturity. In a set of classic studies, Carrier (1983, 1995) found that in young hares, limb joint mechanical advantage and long bone cross-sectional dimensions scale with negative allometry, whereas bone mineral density increases with age. Together, these “compensatory” growth trajectories facilitate increased force output during jumping, allowing juvenile hares to achieve adult-like escape velocities at just 30% of adult mass. Here, we tested whether similar trends could be found among cottontail rabbits, a less precocial group of Lagomorphs. Cottontail rabbits leave the nest at three weeks, rather than at birth as in hares, and use darting locomotor maneuvers, rather than sprinting, to evade predators. Using microCT and 3D morphometrics, we documented ontogenetic changes in bone geometry, density, and limb joint mechanical advantage. Our results indicate that, like jackrabbits, 1) immature rabbits have significantly lower limb bone mineral density, 2) increased humeral and femoral bending strength, and 3) increased mechanical advantage at the elbow, knee, and ankle. These results show that immature rabbits, like the jackrabbits in Carrier’s studies, exhibit patterns of post-cranial growth which likely facilitate predator evasion early in ontogeny, suggesting that ontogenetic compensation for growth-related limits on locomotor performance may be common across the Lagomorpha. Research supported by NEOMED.

P1.103 FEO, Teresa J*; PRUM, Richard O; Yale University; *teresa.feo@yale.edu*

A revised model of feather shape development

Feathers come in a wide range of shape and size ranging from a few millimeters to over a meter. This diversity of form allows birds to perform an equally diverse set of functions important in all major aspects of avian biology. However, due to the branched nature of a feather, it is not readily obvious how structural changes in feathers create the diversity of observed shapes. Previous studies concerning feather shapes have relied on a morphogenic model to describe the differences between shapes, but the efficacy of this model was never tested using real feathers. Using the concepts of theoretical morphology and our current understanding of feather development, we have constructed a revised morphogenic model to describe the development of feather shape. This model simulates the growth of a feather using 7 developmental parameters such as growth rate and branch angle. Next, we studied real feathers during their development from a variety of species. With these feathers we were able to directly measure values for the developmental parameters and test the efficacy of the revised model in predicting the resulting feather shape. A realistic model of feather morpogenesis allows for variation in feathers shapes to be described in terms of differences in the underlying developmental process. Our model will be a valuable tool for understanding the evolution and development of feather diversity.

P1.46 FERGUSON, S.F.*; REICHARD, D.G.; ROSVALL, K.A.; WHITTAKER, D.J.; KETTERSON, E.D.; College of Wooster, Ohio, Indiana University, Bloomington, Michigan State University, East Lansing; *sferguson12@wooster.edu*

Behavioral and physiological responses to simulated territorial intrusions of short- and long- range song in male dark-eyed juncos (Junco hyemalis)

Social interactions between conspecifics, such as auditory communication, can have profound impacts on the behavior and physiology of an organism. In songbirds, communication is heavily reliant on song, which can be broadly classified based on differences in amplitude: (1) low amplitude short-range song (SRS), used in close-proximity aggression and courtship displays, and (2) high amplitude long-range song (LRS), important in territory maintenance and mate attraction. SRS and LRS can also differ substantially in structure and complexity and can elicit very different behavioral responses from territorial males. However, whether these song classes differentially affect the physiology of male receivers remains unknown. Thus, we presented free-living male dark-eyed juncos (*Junco hyemalis*) with simulated territorial intrusions consisting of 10 min of LRS or SRS playback and recorded their behavioral response. Then, 15 minutes after playback ended, we captured each male and collected plasma to measure post-intrusion testosterone (T) levels and assay results are pending. Males spent significantly more time near the speaker and flew significantly less during SRS playback than during LRS playback, indicating a more aggressive response to the SRS intrusion. Differences in both the behavioral and hormonal responses to these two song classes will be discussed in the terms of the perceived threat and function of each song class as well as within the context of the Challenge Hypothesis.

P3.117 FERNANDES, D.A.O.; PODOLSKY, R.D.*; College of Charleston; *podolskyr@cofc.edu*

Effects of ocean acidification on growth, development, and calcification of gastropod embryos: does encapsulation matter?

Increases in atmospheric CO2 have brought rapid declines in oceanic pH and calcium carbonate saturation levels. Because calcification rate depends on these physical factors, acidification has raised concerns about the future health of calcifying organisms. In addition to altering calcification, low pH can also cause physiological stress and reduce growth. These effects may be especially critical during development, as many organisms lay down protective calcified structures before metamorphosis. Larval shell formation in marine molluscs, for example, is negatively affected by low pH, though such effects have not been studied in encapsulated embryos, where intracapsular fluids might buffer against certain environmental effects. We examined the effects of acidification on growth, development, and larval shell formation in the intertidal mud snail Nassarius obsoletus, which develops in intertidal environments that are expected to be strongly influenced by future pH change. Encapsulated embryos were reared in seawater under atmospheric conditions matching 1x-, 2x-, and 4x–current CO2 concentrations. The inorganic content of hatchlings, largely reflecting shell deposition, declined with increasing pCO2, most dramatically between the 1x and 2x treatments. Organic content, however, was unaffected by the same pH changes, indicating that tissue growth was not similarly inhibited. Hatchling shell length and development rate both declined in parallel with inorganic content. These results suggest that growth and development in encapsulated embryos can be differentially sensitive to acidification. In addition, studies that use shell size as a proxy for growth could underestimate the rate of tissue growth under conditions where calcification is compromised.

P1.35 FERNANDEZ, W.L.*; ELMUTI, L.F.; KONKLE, M.E.; NATHAN, B.P.; MENZE, M.A.; Eastern Illinois University, Dept. Biol. Sci., Charleston, IL, Eastern Illinois University, Dept. Chem., Charleston, IL; *mmenze@eiu.edu*

Effects of Estrogen on Mitochondrial Function in ApoE-deficient Mice

ApoE genotype is the major risk factor in a variety of neurological diseases, such as Alzheimer's disease (AD) and Parkinson's disease. Estrogen deficiency is also considered to be a contributing factor in these diseases. One mechanism whereby estrogen can play a role in these diseases is by modulating mitochondrial function. In this study we examined the effects of estrogen on mitochondrial function in apoE-deficient/knockout and wild-type mice. To accomplish this, we measured mitochondrial respiration in purified synaptosomes from the forebrain of 4 - 12 month C57BL/6J mice. Routine respiration of permeabilized synaptosomes in presence of 5 mM pyruvate, 2 mM malate, and 10 mM glutamate at 37 °C was 0.67 ± 0.11 pmol $O_2 \bullet s^{-1} \bullet 10^{-1}$ mg protein. The fold increase in oxygen flux (respiratory control ratio - RCR) after addition of 2 mM ADP of 9.67 ± 0.48 demonstrated well coupled mitochondria (n = 21, ±SE). The RCR values between synaptosomes isolated from apoE knockout (n = 19) and wild-type mice were similar. Treatment of synaptosomes with 10 µM 4-hydroxynonenal (HNE), a reactive electrophile produced during oxidative stress, lead to a significant drop in the RCR values in both the apoE knockout (5.13 ± 1.26) (n = 11, ±SE) and wild-type mice (4.91 ± 1.75) (n = 5, ±SE). Pre-incubation of synaptosomes with 100 nM estrogen prior to the addition of HNE did not ameliorate these reductions in RCR values. These results suggest that (1) apoE deficiency in mice does not have an effect on mitochondrial RCR and (2) estrogen pre-treatment was unable to rescue oxidative stress induced by HNE. Further studies are needed to explain the role of estrogen and apoE on mitochondria function in neurological disorders (Supported by: CFR-EIU-2011).

P2.6 FERNANDEZ, D.; SMITH, G.T.*; Georgia State University, Indiana University; *getsmith@indiana.edu*

Blocking Gonadal Steroid Receptors Affects Sexually Dimorphic Communication Signals in a Weakly Electric Fish

Brown ghost knifefish (*Apteronotus leptorhynchus*) continuously produce weak electric organ discharges (EODs) for electrolocation and communication. During courtship and aggression, these fish transiently modulate EOD frequency (EODf) and EOD amplitude to produce signals known as chirps. EODf and chirping are sexually dimorphic and steroid-sensitive. Males have higher EODf and chirp more often than females. Androgen treatment masculinizes EODf and chirping in females, and estrogen treatment feminizes EODf in males (Schaefer and Zakon 1996; Dunlap et al. 1999). We examined the effects of blocking androgen and estrogen receptors to further test the hypothesis that sex differences in EODf and chirping are regulated by these hormones. Adult males and females in reproductive condition were housed in water that contained the androgen receptor blocker flutamide (0.5 mg/L), the estrogen receptor blocker tamoxifen (0.1 mg/L), or vehicle (ethanol, 0.0025%) for three weeks. Before and after treatment, EODs and chirps were recorded by using playbacks of simulated conspecific EODs. Flutamide lowered (feminized) EODf in males, but not in females. Tamoxifen increased (masculinized) EODf in both sexes. Neither flutamide nor tamoxifen significantly affected chirp rate. Our results suggest that activational effects of androgens and estrogens contribute to sex differences in EODf, but that sex differences in chirping might be regulated by other mechanisms (e.g., organizational effects of hormones or non-steroidal mechanisms). Supported by NSF IOS 0950721.

P1.122 FINKLER, M.S.; Indiana Univ. Kokomo; *mfinkler@iuk.edu*
Dimorphism on the Inside: Differences in Visceral Organ Mass between Male and Female Spring Peepers (Pseudacris crucifer).
Studies of sexual dimorphism rarely consider differences in the size of internal structures, although dimorphisms in internal anatomy may exist even when the external morphologies of males and females are similar. In this study I examined differences in the masses of the heart, liver, and kidneys between male and female Spring Peepers *(Pseudacris crucifer)* early in their reproductive season. Both heart mass and liver mass were significantly greater in males that in females, and increased more acutely with body size in males than in females. In contrast, there was no difference in kidney mass between males and females. These findings highlight sex-related differences in somatic organ size that have heretofore received little consideration in investigations of the evolution of sexual dimorphism. Notably, the relatively larger size of the heart and liver in males reflects differences in activity and energy expenditure between males and females during the breeding season.

P3.63 FIORE, Cara L*; LABRIE, Micheline; LESSER, Michael P; University of New Hampshire; *clfiore@gmail.com*
Pumping Activity and Nitrogen Cycling in the Giant Barrel Sponge, Xestospongia muta
The giant barrel sponge, *Xestospongia muta*, is one of the most prominent coral reef sponges in the Caribbean and its large size and high abundance provides habitat for a large number of macrofauna. Additionally, many sponges, including *X. muta*, are known to harbor various symbiotic microbes, which can influence sponge metabolism and the cycling of inorganic nitrogen, a limiting nutrient in tropical waters. Processes such as nitrogen fixation, nitrification and denitrification have been documented in a number of sponges and while nitrification has been documented in *X. muta*, it is not known whether other nitrogen transformations occur in this sponge. This study utilized stable isotopic techniques and nutrient analysis to assess which nitrogen transformations maybe occurring in this sponge. Sponges from three Caribbean locations were examined, and the flux of nitrogen to the surrounding reef was determined based on pumping activity and measurement of ambient and excurrent concentrations of inorganic nitrogen. Cyanobacterial and non-cyanobacterial *nif*H gene sequences were recovered in addition to archaeal *amo*A genes. Data from these experiments also suggests that anammox bacteria may be operating anaerobically in microhabitats within the sponge. Our data show the potential for nitrogen fixation, which may be an important source of 'new' nitrogen to the sponge and the reef given the large numbers of this species on coral reefs and high concentration of bacteria in their tissues. Future work will include investigating the molecular genetics of nitrogen cycling in *X. muta* under different environmental conditions.

P3.58 FISCHER, AHL*; TULIN, S; SMITH, J; MBL, Woods Hole; *afischer@mbl.edu*
Gene Regulatory Networks in Nematostella: Old Questions - New Approaches
The phylogenetic position of the starlet sea anemone, *Nematostella vectensis*, offers a unique window into fundamental developmental programs, such as axis specification, gastrulation, germ layer specification and embryonic patterning. *Nematostella* is exceptionally tractable for studying developmental Gene Regulatory Networks (GRNs). The *Nematostella* genome is sequenced and annotated, transgenesis and RNAi are established tools and it is easy to culture and to induce gametogenesis. Five specific technologies will put *Nematostella* at the forefront of molecular developmental studies: (1) rapid identification of differential gene expression by RNA-seq; (2) large scale, quantitative perturbation analysis using the Nanostring nCounter; (3) rapid profiling of spatial expression patterns using a novel method, TRIP-seq (Translating Ribosome Immunoprecipitation followed by deep sequencing), and employing BAC recombinants; (4) real-time spatial readout of gene expression using BAC reporter constructs, and thus permitting rapid cis-regulatory analysis; (5) global identification of cis-acting elements through a modified application of ChIP-seq methods. This set of quantitative and high-throughput techniques puts the goal of defining GRNs for complex systems within reach, even in emerging model systems. We seek to determine the complete GRN of early *Nematostella* development in a faster and more inclusive manner than previously known. The obtained results will then be compared to known interactions in other organisms to gain a deeper understanding about evolutionary changes of the developmental program across metazoans.

P3.6 FISHER, L.*; OWENS, D.; GODFREY, M.; College of Charleston, North Carolina Division of Environment and Natural Resources; *lrfisher22@gmail.com*
Predicting impacts of global climate change on the Northwest Atlantic Loggerhead sea turtle (Caretta caretta) population: Locomotor responses of hatchlings to differing incubation temperatures
Sea turtles have a temperature-based sex determination system. For the Atlantic loggerhead sea turtle (*Caretta caretta*), a major concern of rapid climate change is that increasing sand temperatures on nesting beaches are female-skewing the hatchling sex ratio. Apparent population-wide female-biased hatchling sex ratios contrast with observations of juvenile populations, where sex ratios have remained constantly female-biased at about 2 to 1 over the past 30 years. It has been suggested that some unknown factor is affecting loggerhead survival resulting in an unexplained differential loss of ~60% of female hatchlings per year. The principle theory to explain this hatchling mortality is that incubation temperature affects traits that influence survival. Previous studies on hatchling performance have not tested the upper or lower limits of incubation temperature, and fitness consequences remain untested or unconfirmed. In this study, laboratory experiments will be conducted to test for an effect of incubation temperature on performance of loggerhead hatchlings. The initial hatchling dispersal period will be simulated in a controlled laboratory setting, and performance and locomotor variables will be tested over a 24-hour period. Differences in performance that may be seen from hatchlings incubated at high temperatures are important in light of increased sand temperatures, and could indicate increased mortality from incubation temperature effects. Preliminary performance data will be presented. By conducting controlled laboratory experiments on hatchlings, the results will support or refute incubation temperature as a significant variable affecting loggerhead hatchling survival.

P3.62 FLAMMANG, B.E.*; ALBEN, S.; LAUDER, G.V.; Harvard University, Georgia Institute of Technology; *bflammang@post.harvard.edu*

Vortex perturbation of fish hovering

The pectoral fins of most fishes are flexible and deformable and their overall shape changes during a fin beat. While whole pectoral fins have been the subject of locomotor studies, there are few data on the kinematics and flexibility of single fin rays during swimming. In addition, nothing is known about the effect of fluid perturbations on the kinematics of fin rays of fish during normal swimming. We examined the curvature of the longest pectoral fin ray (third from dorsal edge) during steady swimming, hovering behavior and during a vortex perturbation provided during the fin beat. It was observed that during normal hovering behavior, a wave of curvature passed from base to tip and then tip to base of the fin ray during the course of one fin beat. The maximum curvature of the fin ray during normal hovering was 0.29 cm^{-1} in the proximal half of the fin ray and 0.54 cm^{-1} in the distal half of the fin ray. Perturbation of bluegill sunfish was accomplished by shooting vortices at the pectoral fin during hovering behavior. Kinematic analysis showed that the pectoral fin rays yielded substantially to the force of the vortex at the point of impact (maximum curvature = 1.13 cm^{-1}), but that the rest of the fin ray did not deform (maximum curvature = 0.24 cm^{-1}). We have also simulated the fin-vortex interaction using a computational fluid model which represents a 2D cross section of the fin and vortex ring. In the model, the fin is mainly repulsed by the vortex, but the distal edge curls towards it during the interaction. Comparison of the vortex impact on a fish fin with that of the model simulation suggests that structural properties of the fish fin ray may inherently dampen the effects of fluid perturbations.

P2.61 FLORES, E.B.*; BYRUM, C.A.; University of Miami, College of Charleston; *byrumc@cofc.edu*

Expression of myoregulatory factors in the sea urchin Lytechinus variegatus

Although much has been learned about the molecular interactions that regulate early formation of endomesoderm in the sea urchin embryo, much less is known about the mechanisms regulating the specification and differentiation of endodermal and mesodermal cells that form later in development. Our research focuses on the processes responsible for formation of one subgroup of late mesoderm; muscle. The phylogenetic position of our subject, the echinoderm *Lytechinus variegatus*, makes it an attractive model for studying the evolution of muscle formation in metazoans. As a basal deuterostome, *L. variegatus* provides a valuable intermediate between the vertebrate phyla and more pleisiomorphic groups such as the Cnidaria. Using reverse transcriptase PCR and wholemount *in situ* hybridization, we have evaluated the expression of several genes known to participate in the regulation of myogenesis or in the differentiation of muscle in numerous metazoan groups. Embryos cultured at 22˚C were evaluated every two hours from the late mesenchyme blastula stage (16 hours postfertilization) to the late pluteus stage (46 hours postfertilization at 22˚C). This preliminary work provides an important foundation for future functional studies in the formation of muscle in basal deuterostomes.

P2.22 FOCKLER, Shadow L*; HELMUTH, Brian; Univ. of South Carolina, Columbia; *focklers@email.sc.edu*

Modelling in the waves: Significance of wave splash to the survival of intertidal organisms

The body temperature of intertidal animals during aerial exposure at low tide can have significant impacts on their survival and physiological performance. Thus, understanding the potential impacts of changes in both aerial and submerged body temperature are important considerations for predicting the likely impacts of climate change on intertidal communities. Understanding the role of wave splash is key not only for predicting these impacts in areas of different wave exposure, but also for applied applications such as understanding the potential impacts of physical structures such as breakwaters and wave energy farms. A biophysical heat budget model was used to conduct a sensitivity analysis of the effects of environmental factors including wave splash on the aerial body temperature of the mussel *Mytilus californianus*. Results of the model were compared against *in situ* measurements using environmental inputs from either a local weather station or from reanalyzed large scale data (National Center for Environmental Prediction Climate Forecast System Reanalysis). Results indicate that the model successfully predicts aerial body temperatures to within approximately 2.8°C (local weather station) to 3.3°C (CFSR), and that at least at the site tested (Bodega Bay, CA), animal temperatures are surprisingly insensitive to changes in the nearshore wave climate.

P2.168 FOLTZ, Sarah L.*; DAVIS, Jason E.; GREENE, Virginia W.; LAING, Brenton T.; TALLANT, James A.; MOORE, Ignacio T.; Virginia Tech, Radford University; *sarahf8@vt.edu*

Aggression, neophobia and corticosterone in relation to urbanization in song sparrows (Melospiza melodia)

Continued growth of urban and suburban areas permanently changes habitats and disrupts native species. Although some native animals are able to inhabit urbanized areas, previous studies have shown that urban living can be related to changes in stress hormone levels and in behaviors such as conspecific aggression and neophobia (fear of novel objects). Here we compare corticosterone (the major avian stress hormone), conspecific aggression, and neophobia in male song sparrows (*Melospiza melodia*) across suburban and rural habitats in southwestern Virginia. Behaviors were measured using modified simulated territorial intrusions in which we introduced a novel or control object while playing recorded conspecific male song on the focal bird's territory. We found a significant positive correlation between urbanization and aggression. In addition, all birds exhibited reduced aggression in the novel test, and the magnitude of this reduction was the same across groups. Thus, while suburban birds responded more aggressively than rural birds to both novel and control tests, we found no difference in neophobia between suburban and rural birds. No relationship was found between corticosterone and either behavior or urbanization. We conclude that either urban living increases conspecific aggression in song sparrows or aggressive individuals are better able to colonize urbanized habitats.

P1.13 FONTANELLA, EL*; ABGRALL, MJ; TARASKA, NG; LEBLANC, L; TREMBLAY, E; BOETTGER, SA; West Chester University of Pennsylvania, University of New Brunswick, Kouchibouguac National Parkia, Kouchibouguac National Park; *ef633454@wcupa.edu*
Disseminated neoplasia and clam populations in a Canadian National Park – Kouchibouguac National Park
Kouchibouguac National Park of Canada (KNPC), situated along the Northumberland Strait in South Eastern New Brunswick, encompasses an area of 238 km2 and allows both commercial and recreational softshell clam (*Mya arenaria*) harvesting. Clam populations at 18 different sites of known sediment composition in KNPC were evaluated according to clam densities, sizes and development of a commonly occurring blood disease, disseminated neoplasia (DN). Fully neoplastic, and therefore fatally ill animals collected from KNPC in 2011 are found at frequencies between 0-27.85%, while animals without neoplasic cells were detected at frequencies of up to 89.09%. This indicates a continued increase in neoplasia frequencies compared to 2009 and 2010. A number of environmental stressors could influence the severity and the spread of DN in the Park, making this increase of particular interest to ecologists and the commercial fishing industry. Our results, which are some of the few continuous, long term documentations on neoplasia, indicate that populations of *Mya arenaria* in a confined body of water are impacted by DN.

P3.137 FONTANELLA, J.E.*; FISH, F.E.; BARCHI, E.I.; CAMPBELL-MALONE, R.; NICHOLS, R.H.; BENESKI, J.T.; West Chester Univ., PA, Johns Hopkins Univ., Baltimore, MD, Univ. of Rhode Island, Kingston; *jf650930@wcupa.edu*
Batoid out of hell: Hydrodynamic geometry of rays related to swimming mode
Batoid fishes possess depressed bodies and greatly expanded pectoral fins to form a broad planform. The pectoral fins are used for thrust generation by undulation or oscillation. Undulatory locomotion is performed by benthic species, whereas more derived, pelagic rays use the oscillatory mode. To examine morphological differences between the two locomotor extremes, planform geometry was measured from digital images on 106 batoids. A clear distinction between oscillators and undulators was observed with respect to pectoral fin shape and aspect ratio (AR=pectoral fin span^2/fin area). Oscillatory rays had fin shapes that were elongate and wing-like and an AR >2.7. Undulatory rays had fins that were round or rhomboidal in shape with AR <2.7. The three-dimensional geometry was obtained from CT scans. Measurements along the semispan of each pectoral fin showed that undulatory rays had thinner fins relative to both chord length and position of maximum thickness compared to oscillatory rays. The thickness of the fins decreased steadily for undulatory rays, whereas thickness relative to chord remained essentially steady for oscillatory rays. Because of the flattened venter of undulatory rays, the pectoral fins showed cambering along the entire span. Oscillatory rays had fins with a symmetrical profile, but showed cambering in the central body. Analysis of the two- and three-dimensional geometry of batoids indicates that the morphology of these fishes is associated with habitat and phylogeny. These differences in fin shape may determine levels of swimming performance within Batoidea.

P1.152 FORSMAN, A.M.*; PAITZ, R.T.; Cornell University, Illinois State University; *amf226@cornell.edu*
Geographic variation in maternal effects across the breeding range of the tree swallow (Tachycineta bicolor)
During the process of egg-formation, hormones and immune compounds accumulate in the developing yolk and subsequently influence offspring development. Maternally derived steroids such as testosterone have been shown to influence offspring growth, behavior, and immune function while maternally derived antibodies (MAb's) confer passive immunity to neonates with effects on growth and immune function. MAb's neutralize many foreign antigens without the need for costly endogenous immune responses that would divert resources away from growth. Levels of these yolk substances vary with maternal experience, which has led to the hypothesis that females may utilize these substances to adjust offspring development to prevailing conditions. Understanding how levels of yolk steroids and MAb's vary with maternal environment is critical to interpreting the evolutionary consequences of such maternal effects. In this study we investigated two potential factors that likely exert pressure upon these maternal effects: pace-of-life and antigenic diversity in the environment. We quantified levels of yolk androgens and antibodies (IgY) in eggs collected from across the breeding range of the North American tree swallow. The resulting latitudinal gradient captures fast pace-of-life birds in the north and slow paced birds in the south. We predicted that fast paced birds would lay eggs with higher levels of androgens and perhaps MAb's than slow paced birds, but that MAb levels may also be influenced by antigenic pressure, which we assumed to be higher at lower latitudes. By investigating how levels of yolk androgens and MAb's vary across an environmental gradient, we can begin to understand how these substances may be utilized to influence offspring development in a context-dependent manner.

P1.70 FOX, Alicia M*; SCHREY, Aaron W; MCCOY, Earl D; MUSHINSKY, Henry W; University of South Florida; *amfox@mail.usf.edu*
Parentage Analysis of the Florida Sand Skink, Plestiodon reynoldsi , following relocation on the Lake Wales Ridge in Central Florida
As a consequence of a fossorial lifestyle, there is a lack of information regarding the mating system of the threatened Florida Sand Skink, *Plestiodon reynoldsi* , which occurs in xeric habitat on the central ridges of Florida. Multiple forms of land development and mining have occurred on Florida's central ridges and one of our study locations near Davenport, Florida on the Lake Wales Ridge is scheduled to be mined for sand. As a result of the sand mining, all individuals captured at this site were relocated in the spring and summer of 2007 to a site on the northern end of Lake Wales Ridge. Individuals moved to the relocation site were placed in 20m X 20m enclosures that contained multiple pitfall arrays and had various shade and ground cover treatments. Twenty individuals were placed into each enclosure with recapture efforts beginning in 2008. While our relocation site provided opportunity for multiple studies, such as survivorship and habitat preference, the purpose of this study is to examine reproductive success in *P. reynoldsi* . A total of 63 juveniles, resulting from mating presumed to have occurred between 2008 and 2010, was captured from 13 enclosures. Genotypes were determined at multiple microsatellite loci for all individuals originally captured at our Davenport location and for all juveniles captured at the relocation site. A parentage analysis was done to determine parents of juveniles in each enclosure and reproductive success of both males and females. This study is a first step in understanding the genetic mating system of the Florida Sand Skink that can be used in the conservation and management of this species.

P3.118 FRAZIER, M.R.; DILLON, M.E.*; U.S. EPA, Western Ecology Division, Newport, OR, University of Wyoming, Laramie; *Michael.Dillon@uwyo.edu*

Allometric scaling of development time in insects

Development time is a fundamental life-history trait with broad organismal, ecological, and evolutionary implications. Insects dominate the terrestrial biosphere, and their ecological and economic importance has prompted the collection of a great deal of developmental data for many species. Despite this abundance of data, there have been few synthetic efforts to characterize how insect development time scales with body size. As such, insects provide an ideal opportunity to test some historical allometric scaling assumptions. We gathered literature estimates of egg to adult development time as a function of temperature for 357 insect species from 16 insect orders. From these data, we estimated minimum development time (regardless of the temperature at which it occurred) and body size (from the literature or via personal communication) for each species. Preliminary analyses suggest that development time scales with body mass to the 0.16, excluding the historically assumed 1/4 power scaling. Further, the scaling exponent is invariant among insect orders but the intercept varies significantly, such that some insects develop more quickly at the same body size. These initial results suggest that life history and macroecological models that assume 1/4 power scaling of development time will tend to overestimate the costs of delaying development to obtain larger body sizes.

P3.110 FRITZ, R.M; GEORGE, S.B.*; Georgia Southern University; *georges@georgiasouthern.edu*

Low salinity decreases juvenile production in the sea urchin Lytechinus variegatus (Echinodermata:echinoidea)

Due to current changes in climate and weather patterns, echinoderm larvae may be exposed to prolonged periods of low salinity along the East coast. In a series of experiments, the effects of prolonged exposure to low salinity on *Lytechinus variegatus* larval mortality, development and the number and size of juveniles produced were analyzed. Prolonged exposure to 25‰ seawater significantly increased larval mortality and prolonged development. Larvae exposed to 25‰ seawater throughout development, and those transferred from 25‰ to 32‰ seawater after 40 days at the lower salinity, failed to metamorphose. Exposure of eight-arm larvae to 28‰ and 25‰ seawater increased the time to metamorphosis to 44 and 49 days after fertilization respectively and significantly decreased the number of juveniles produced (57 and 18 respectively). In comparison, larvae exposed to 32‰ seawater throughout development began to metamorphose 35 days after fertilization. Two hundred and thirty-three juveniles were produced from this latter treatment. Overall, prolonged exposure to low salinity negatively affected *Lytechinus variegatus* larvae by increasing larval mortality, prolonging development, delaying metamorphosis, and decreasing the number of juveniles produced.

P3.10 FUDICKAR, A. M.*; PARTECKE, J.; Max Planck Institute for Ornithology; *afudickar@orn.mpg.de*

Pre migratory activity in free living migratory and sedentary European blackbirds Turdus merula

Seasonal migration by songbirds is accomplished by the integration of a suite of highly specialized physiological and behavioral traits. A common behavior among migratory songbirds includes a transition from diurnal to nocturnal activity around the time of migration. Partial migration, when only a fraction of a breeding population is migratory, is an intermediate stage between obligate migratory and sedentary life histories. Thus, the occurrence of both migratory and sedentary individuals breeding in the same population provides researchers with a model system to study the evolution of migration. Using automated radio telemetry we compared the pre migratory activity of migratory and sedentary free living European blackbirds *Turdus merula* in a single breeding population in southwestern Germany. By comparing the seasonal transitions of migratory and sedentary individuals, we hope to provide insight into the physiological and behavioral transitions adaptive to a migratory life history.

P3.64 FUESS, L.E.*; SHEDLOCK, A.M.; WHAM, F.C.; DUSTAN, P.; College of Charleston, Pennsylvania State University; *lefuess@g.cofc.edu*

A molecular assay for the cause of bleaching in the temperate Atlantic coral species Occulina arbuscula

The causation of bleaching of the temperate scleractinain coral, *Oculina arbuscula* is being investigated over the course of seasonal warming off Charleston, South Carolina from June to October. Reports of coral bleaching on the wreck of the Freddy Day were confirmed during the summers of 2009 and 2011. Previous data suggests that the seasonal bleaching has decreased the total coral coverage of the reef, however the cause of bleaching is still unknown. Additionally past research has indicated that due to the temperature range of the site, adaptive bleaching of symbiotic zooxanthellae is not occurring. Data collected for site temperature shows a positive correlation between increasing temperatures and bleaching events. Additionally, other species of *Oculina* have been documented to bleach in the presence of high temperatures due to infection by *Vibrio shiloi*. We are employing PCR-based species-specific DNA sequence analysis in order to distinguish between thermal stress and bacterial infection and to determine the actual cause of bleaching on the reef. DNA samples are extracted from coral samples taken off of the research site during periods of known bleaching. PCR primers specific to *Vibrio shiloi* 16rDNA sequences are used to amplify any DNA present from the target pathogen in mixed environmental samples, then products are sequenced to confirm taxonomic identification of pathogens. Molecular genetic results will be discussed in relation to pinpointing the exact cause and infectious nature of bleaching and can provide a more predictive framework for understanding the present and future status of this reef and those like it in temperate Atlantic coast zones.

P1.155 FUQUA, RD*; MONROY, JA; NISHIKAWA, KC; Northern Arizona University; *rdf2@nau.edu*

Force enhancement of soleus muscles from mdm mice

When muscles are stretched actively, tension increases and settles at a steady state that is well above isometric force. The mechanism underlying this behavior, termed force enhancement, remains poorly understood. In this study, we tested the "winding filament" hypothesis (WFH), which accounts for force enhancement of muscle. The WFH states that the protein titin binds to the thin filaments upon Ca^{2+} influx, thereby increasing titin-based stiffness. As muscle force increases, titin stiffness continues to increase as it winds on the thin filament with each cross-bridge stroke. During active stretch, the work done in elongating titin is stored as elastic potential energy resulting in force enhancement. We used mice with the *mdm* mutation, a deletion in the N2A region of titin, to elucidate the role of titin during active stretch. We stretched whole soleus muscles stimulated submaximally in two solutions, Kreb's and dantrolene, which decreases intracellular calcium. By comparing the force responses in these solutions, we were able to isolate the effects of intracellular Ca^{2+} on force enhancement. We found that wild-type mice showed a large decrease in force following stretch in dantrolene, suggesting that the observed increase in stiffness upon activation is in fact Ca^{2+}-dependent. In contrast, in both solutions the magnitudes of passive and active forces following stretch did not differ in *mdm* mutant mice. Similar to our results for elastic recoil, these data suggest (1) that upon activation in wild-type muscles, N2A titin binds to thin filaments, which decreases the length and increases the stiffness of titin; and (2) that N2A binding is absent in *mdm* mutants. These results are consistent with the "winding filament" hypothesis and may help to elucidate the mechanism for force enhancement with stretch. Supported by NSF IOS-1025806.

P3.147 GANS , Elizabeth*; WILLIS, Katie L; BIERMAN, Hillary; CARR, Catherine; Univ. of Maryland, College Park; *elizabethsgans@gmail.com*

The interaural canal of the barn owl, Tyto alba

The interaural canal of birds allows for phase interaction on both sides of the tympanum, thus increasing the effective separation of the ears to produce larger interaural delays than would be predicted from the head width (Calford and Piddington, 1988). The canal, however, appears ineffective at frequencies above about 4 kHz. At lower frequencies, however, ipsilateral and contralateral inputs interact at the tympanum (Moiseff and Konishi, 1981). We have therefore measured the extent of the middle ear cavity and associated sinuses in the barn owl, *Tyto alba*. We used microMRI (7T) scans of the barn owl head with a resolution of 195µm3 per voxel. Image stacks were constructed in 3-D using Neurolucida (Microbrightfield) by tracing the cavities and measuring their volumes. The interaural canals on each side had a diameter of about 1.8 mm as they exited the middle ear cavity, and formed large ventrally directed tubes which were united in the expansive rostral tympanic recess. This recess was about 1.5 cm in rostrocaudal extent. Our measurements were consistent with those from the great horned owl (Witmer et al, 2008), and also consistent with recordings of large interaural delays at low best frequencies in the barn owl (Koppl and Carr, 2004).

P3.7 GANTZ, JD*; SHEAFOR, BA; Miami University, University of Mount Union; *gantzjd@gmail.com*

Behavioral Thermoregulation and its Role in Decreasing Morbidity and Mortality Associated with Chytridiomycosis

Chytridiomycosis, an amphibian disease caused by the chytrid fungus *Batrachochytrium dendrobatitis*, has been implicated as a cause for contemporary precipitous declines in amphibian populations worldwide. Temperature has been shown to be a prominent factor in viability and virility of *B. dendrobatitis*. Temperatures above 28° C inhibit growth and can be lethal to the fungus while temperatures between 6 and 23° C appear to increase its fecundity. Amphibians which have significant thermoregulatory control due to the thermal variability of their microhabitat, such as tree frogs (genus: Hyla), may be capable of overcoming infection through basking behavior modification and increased exposure to elevated temperatures. In order to test such responses, two species, gray tree frogs, *Hyla versicolor*, and green tree frogs *Hyla cinerea* (*H. versicolor*, n = 9; *H. cinerea*, n = 11), were selected. Frogs were housed in a 1.83 meter long clear acrylic tube within which a temperature gradient, from 14° C to 35° C, was established, in two separate treatments, uninfected and infected. A non-contact, infra-red thermometer was utilized to record body temperatures six times a day for 5 d. A significant difference between the basking temperatures of the two species existed prior to infection regimes (*H. versicolor*, mean: 28.0° C, standard deviation: 2.8; *H. cinerea*, mean: 28.7° C, standard deviation: 2.5). Data collected following the infection regimes was incomplete, as the organisms never displayed definitive signs of infection. In spite of this, the investigation may still provide greater understanding of the mechanisms by which some amphibian species avoid population declines due to chytridiomycosis.

P3.51 GARLAND, Michael A*; ELDER, Holland; HURT, David A; STILLMAN, Jonathon H; TOMANEK, Lars; California Polytechnic State Univ., San Luis Obispo, Romberg Tiburon Center, SFSU, Romberg Tiburon Center, SFSU; *mgarland@calpoly.edu*

The proteomic response to acute heat stress after acclimation to fluctuating temperatures in the eurythermal porcelain crab, Petrolisthes cinctipes

The porcelain crab *Petrolisthes cinctipes* inhabits the high intertidal along the Pacific coast between British Columbia and central California and is an emerging model organism to study the effects of environmental stress. In its habitat it experiences not only variability in average temperature but also variability in temperature fluctuations. To investigate the effect of temperature fluctuations, we characterized the heat shock response at 30°C for 6 h by acclimating individuals to three different acclimation treatments: 10°C, 10-20°C (4 h), and 10-30°C (4 h) on a daily basis for one month. We dissected claw muscle and separated proteins by 2D gel electrophoresis. Differences in protein expression patterns were identified based on a two-way ANOVA. We detected a total of 477 protein spots of which 67 showed an interaction effect between acclimation and heat stress. There were 80 and 135 proteins which showed a main effect for acclimation and heat stress, respectively. Proteins changing significantly were digested with trypsin, prepared for tandem mass spectrometry (MALDI TOF/TOF), and identified based on an expressed sequence tag library (Porcelain Crab Array Database). Several arginine kinase isoforms were up-regulated following heat shock without prior temperature fluctuations, but were not up-regulated following acclimation with fluctuations. Additionally, several energy metabolism enzymes were up-regulated following heat shock, but only when individuals were exposed to the 10-30°C acclimation. The results suggest that previous temperature fluctuations affect the acute heat shock response.

P1.83A GARREHY, C.A.*; BENOWITZ-FREDERICKS, Z.M.; SWEENEY, K.; Bucknell University; *cag025@bucknell.edu*

Interactions between yolk testosterone levels and post-hatch food availability in male chickens: Early indicators of sexual maturation

C. Garrehy K. Sweeney Z.M. Benowitz-Fredericks Bucknell University Both maternal androgen deposition and post-hatch environmental conditions have the potential to alter avian fitness. However, the phenotypic changes induced by the interactions between both maternal androgens and the post-hatch environment have yet to be investigated. We hypothesized that domestic chickens (*Gallus gallus*) with high yolk androgen exposure in a favorable post-hatch environment may experience greater fitness benefits than chickens with low-yolk androgen levels, but might suffer greater fitness costs in a challenging post-hatch environment. In particular, rates of sexual maturation might be accelerated by high yolk androgens under favorable conditions; this would be reflected in circulating androgen levels and increased expression of androgen-dependent secondary sexual characteristics. We investigated this interaction by manipulating yolk testosterone levels and post-hatch food availability. Unincubated chicken eggs were injected with 5 ng of testosterone dissolved in 50 µL of sesame oil (“T”) or 50 µL of sesame oil (“C”). On day 7 post-hatch, 30 T males and 20 C males were evenly distributed into diet cohorts of either 70% qualitative food restriction or food ad libitum. Diet lasted 14 days, then comb size was measured, and the reflectance spectrum of the comb was determined with a spectrophotometer. We found evidence for an interaction between diet and yolk treatment in regards to its influence on male comb coloration—specifically red chroma. We conclude that maternal effects and post-hatch environment may interact to generate a complex array of fitness consequences.

P3.114 GENOVESE, C.B.*; MORAN, A.L.; Clemson University; *cgenove@clemson.edu*

Magnitude of specific dynamic action response in larvae of the sea urchin Lytechinus variegatus

Specific dynamic action (SDA) is defined as an increase in the metabolic response of an organism following a meal. Typically, an individual’s metabolic rate will increase rapidly, peak, and then slowly return to pre-feeding levels. SDA has been attributed to an array of physical processes necessary to obtain, digest, absorb, and assimilate food. Evidence of the response has been documented in a variety of species, both vertebrate and invertebrate, with the percent increase ranging from as low as 25% to over 600% in some studies. Given that the metabolic capacity of an individual is limited, such a response may have a critical impact on the energy budget of an organism, as the energy allotted to SDA may reduce the energy available for other aerobic activities. A majority of studies on specific dynamic action have focused on adult organisms, and little research has been performed on larval stages. Planktonic larval populations determine the success of the adult population; however, relative to adult stages, few studies have attempted to describe their metabolic response to food. This study focused on the larvae of the sea urchin *Lytechinus variegatus*; a marine invertebrate with a broad distribution and planktotrophic, feeding larvae. Using a µBOD method to measure oxygen consumption, postprandial metabolic rates were characterized to determine the magnitude of the SDA response in the larvae. Rates were measured for 24 hours post-feeding, during which the larvae approximately doubled their pre-feeding rates. Further studies on how meal size and composition affect the response, as well as the effects of environmental conditions, will aid in our understanding of the physiological and ecological significance of the SDA response in the life histories of marine invertebrate larvae.

P2.59 GEORGE, R; HUTCHINS, E; ECKALBAR, WL; KUSUMI, K; RAWLS, JA; WILSON-RAWLS, J*; Arizona State University; *Jeanne.Wilson-Rawls@asu.edu*

Isolation of Anolis carolinensis satellite cells and examination of their differentiation potential.

The anole lizards are the closest vertebrates to humans that demonstrate the ability to regenerate cartilage, muscle and nervous tissue. We wanted to investigate whether the muscle from these lizards had satellite cells, an adult stem cell population responsible for the repair and growth of skeletal muscle, and if these cells were multipotent. We have isolated a cell population from *A. carolinensis* muscle and demonstrated that they will differentiate into multinucleated myotubes that express the muscle structural protein myosin heavy chain. Further, RT-PCR analysis of these cells demonstrated that they express genes that are consistent with satellite cells derived from mammals. Subsequent experiments demonstrated that these cells can be induced to differentiate into cartilage and bone without the need for exogenous factors such as bone morphogenic proteins being added to the culture medium. RT-PCR analysis of these cells demonstrated the expression of bone and cartilage specific genes.

P1.154 GEORGE, NT; SALCEDO, MK*; WILLIAMS, CD; IRVING, TC; DANIEL, TL; Univ. of Washington, Seattle, Ill. Inst. of Technology, Chicago; *salcem@uw.edu*

Myofilament lattice spacing increases as muscles shorten

Under constant volume muscle contraction myofilament overlap increases and muscle expands radially. While myofilament overlap is considered a major factor in force generation, considerably less is known about the role of myofilament expansion accompanying shortening during contraction. Recent theoretical evidence suggests that the spacing between filaments will indeed be an important determinant of force generation at any level of filament overlap, however, there are scant data that show the extent to which filament overlap changes in intact muscles. To address this issue we performed work loops on intact *Manduca sexta* flight muscles while simultaneously measuring myofilament spacing, force, and length using time resolved small angle x-ray diffraction imaging. Muscles were stimulated at 25 Hz and held at a temperature of 35C while simultaneously measuring length and force. Five x-ray images were taken during each wingbeat cycle for 100 contractions. These images were averaged over all cycles, and lattice spacing was measured for each phase. During work loops with a 6% strain cycle, lattice expansion changes by 2.77 ± 0.839%. Thus we do not reject the constant volume assumption, which would predict a 2.4% change in radial dimension for a 6% longitudinal strain. Taken together these data suggest that lattice expansion during muscle shortening is a critical component of muscle force generation.

P2.150 GEORGI, Justin A; Arizona College of Osteopathic Medicine, Midwestern University; *jgeorgi@midwestern.edu*
Natural Orientation of the Lateral Semicircular Canal in Alligator mississippiensis
Head orientation is useful for the study of extant vertebrates and the reconstruction of life history in fossils. The organs of rotational balance, the semicircular ducts, are fixed in bony canals of the skull and are integral to many systems, including stable vision. Previous researchers have postulated that the semicircular ducts are tightly linked to head orientation and that the lateral duct should approximate earth horizontal. Studies in many mammalian models support this conclusion, but data for non-mammals are restricted to only pigeon and slider turtle. This study investigates the lateral semicircular canal in *Alligator missisippiensis*. Using 3D motion capture, the orientation of the head during terrestrial locomotion was recorded for five specimens ranging in size from 0.89 to 1.39 m. Using CT imaging it is shown there is no ontogenetic variation in the orientation of the lateral canal relative to an external skull plane. Thus, the orientation of the lateral canals can be tracked relative to the motion capture landmarks. Four of the five subjects maintained a mean lateral canal orientation of 5.3° - 8.4° above the horizontal anteriorly. This is consistent with the values reported for the turtle (3° - 4°) and the pigeon (10°). One subject's mean orientation was higher: 15.6° evidence points to intraspecific display and this is not considered normal position. These results continue to support the hypothesis of general correlation between lateral semicircular canal orientation and earth horizontal during typical behaviors. The addition of alligator data to the non-mammalian groups not only reinforces the general nature of this trend, but also provides stronger support for the numerous studies that seek to use this method to reconstruct head orientation in fossil archosaurs.

P2.120 GERRINGER, M.E.*; FRIEDMAN, J.; DRAZEN, J.C.; YANCEY, P.H.; Whitman College, Walla Walla, Univ. of Hawai'i, Honolulu; *yancey@whitman.edu*
Proximate chemistry of buoyant gel tissues in benthopelagic and benthic deep-sea fishes
It has long been known that the muscles of some deep-sea animals have high water and low protein contents, hypothesized to be an adaptation to low food availability or reduced intensity of visual predator-prey interactions. Some mesopelagic fishes also have a gelatinous layer beneath the skin and/or around the spine, hypothesized to be a buoyancy adaptation. Several demersal species also have similar layers, though their composition and function have not yet been fully described. This study characterized these layers in seven species from Monterey Bay Canyon (1,000 to 3,000 m): 4 benthopelagic (*Bothrocara brunneum, Careproctus melanurus, Careproctus cypselurus, Spectrunculus grandis*), 2 benthic (flatfishes *Embassichthys bathybius, Microstomus pacificus*), and a new species of eelpout *Pachycara* n sp. A (habitat uncertain). We determined osmolalities and tissue buoyancies and conducted proximate chemistry analyses for contents of water, sodium, potassium, protein, carbohydrate, lipid and organic osmolytes including trimethylamine oxide (TMAO). We found that gel in all species had high water content, 94.8-98.7%. Sodium, potassium and TMAO concentrations were similar to plasma (rather than muscle) of similar species. Protein (average 0.5%), carbohydrate (average 0.6%) and lipid contents were low in all species. All gel tissues floated in cold seawater while muscle tissues sank for all but the new eelpout species, in which both gel and muscle floated. These results are consistent with the buoyancy hypothesis. Lift may benefit flatfishes during burst swimming. The composition may also be a way to increase body size with low energy costs. The low nutritive content of this tissue may have commercial implications for the fishing industry.

P3.136 GERRY, S.P.*; ROBBINS, A.; ELLERBY, D.J.; Fairfield University, Wellesley College; *sgerry@fairfield.edu*
Variation in Fast Start Performance of Bluegill Ecomorphs
Bluegill sunfish (*Lepomis macrochirus*) from Lake Waban, MA exhibit variation in their morphology and swimming performance based on habitat. Pelagic ecomorphs have a relatively streamlined, fusiform body shape that correlates with greater steady-state swimming speed and energy economy. In contrast, littoral bluegill have deeper bodies with fins located farther from their center of mass to enhance maneuverability among the vegetation. Deeper body shapes have been associated with increased fast start performance in order to escape predators and capture prey. We hypothesized that the littoral ecomorphs would exhibit greater fast start performance compared to pelagic fish. A total of 27 bluegill (16 littoral, 11 pelagic) were caught by hook-and-line and their fast start performance analyzed from high-speed video recordings. Body shape appears to be a poor predictor of fast-start performance in these ecomorphs. Contrary to our expectations, pelagic bluegill have a higher peak velocity (ANOVA, $p = 0.002$), peak acceleration (ANOVA, $p = 0.008$) and angular velocity (ANOVA, $p = 0.001$) compared to littoral bluegill. Pelagic ecomorphs living among larger predators and foraging on mobile prey in the open water may be exposed to selection pressures that favor increased fast start performance. Future studies of fast-start performance in juvenile bluegill may provide a greater understanding of how these fish diverge in form and function to become either a pelagic or littoral ecomorph.

P2.117 GERSON, A.R.*; GUGLIELMO, C.G.; Advanced Facility for Avian Research, Dept. of Biology, University of Western Ontario; *agerson2@uwo.ca*
Changes in Body composition and the metabolic response to high and low evaporative water loss during short duration flights in the American Robin (Turdus migratorius)
During avian flight both lipids and protein are catabolized, resulting in significant reductions in fat stores, muscle mass, and organ sizes over the course of an endurance flight. We have recently shown that the rate of protein catabolism in flight is an adaptive metabolic strategy to provision water. In an attempt to more fully understand the effect of water loss on the metabolic response during the early stages of flight, American robins were flown in a climatic wind tunnel under high and low humidity conditions for up to 1.5 h. Body composition was measured using quantitative magnetic resonance body composition analysis before and after flights, and blood was taken before and immediately after flight to measure plasma metabolite levels. Flight duration ranged from 17 - 92 minutes. There were significant reductions in mass, lean mass, and fat mass with flight duration, but there were no significant differences between humidity regimes on this short time scale. Plasma ß-Hydroxybutyrate and non-esterified fatty acids increased and glucose decreased during flight, irrespective of flight duration or humidity regime. Plasma triglycerides, glycerol, and phospholipids were not different from rest. Our findings agree with previous studies of the metabolic response to flight, and despite dramatic effects of ambient conditions on rates of lean mass catabolism during long duration flights, plasma metabolites of birds flown for short duration remained unaffected by ambient conditions experienced during flight.

P1.225 GIARRA, Matthew N. *; VLACHOS, Pavlos P. ; SOCHA, John J. ; Virginia Polytechnic Institute and State University; *mgiarra@vt.edu*

Visualization of hemolymph flow in the heart of a cockroach

Insects pump hemolymph (blood) through their bodies using an open circulatory system consisting of numerous pumps that are not interconnected by vascular tissue. One major and highly conserved element in the circulatory system is the dorsal vessel (or heart), which is a long, axially-oriented muscular tube that produces peristaltic-like contractions along its length and pumps hemolymph between the posterior and anterior ends of the animal. Many species of insects exhibit periodic heartbeat reversals, wherein the directions of both the contractile waves in the heart and of the flow of hemolymph alternate between anterograde (anterior to posterior) and retrograde (posterior to anterior). The physical mechanism by which these wave-like contractions produce directional flow, as well as details of the flow kinematics in and around the heart, are unknown. Here, we experimentally measured the flow of hemolymph within the heart of a living cockroach (Periplaneta americana) to gain insight regarding the heart's pumping capacity. Hemolymph flow in the heart was observed via the injection of fluorescent dye and fluorescent particles into the pericardial sinus. Digital videos of the dye and particle motions were analyzed, and the Reynolds number of the flow was estimated to be of order 1. These preliminary results serve as a starting point for more sophisticated experiments in the future, including 2-D and 3-D in vivo measurements of the velocity fields comprising the hemolymph flow.

P3.102 GIDMARK, NJ*; TARRANT, JC; KONOW, N; BRAINERD, EL; Brown University; *njg@brown.edu*

Bite force limitation by the length-tension relationship of skeletal muscle in three cyprinid fish species

The force production of a muscle varies based on its instantaneous length; therefore jaw position, specifically jaw gape, should impact bite force. Such changes in muscle length can alter bite force either statically, based on prey size, or dynamically, based on jaw kinematics during chewing. We used XROMM, an *in-vivo* skeletal imaging technique, to quantify 6-degree-of-freedom movements of the pharyngeal jaws and neurocranium *in-vivo* for three cyprinid fish species. We mapped the origins and insertions of five representative fibers within the main pharyngeal jaw adductor, which we used as a proxy for whole muscle length. Following *in-vivo* experiments, we combined XROMM *in-situ* with a muscle stimulation protocol to determine the tetanic length-tension relationship for the same muscle in the same set of individuals. The adductor muscles of all species examined operated at short lengths (on the ascending limb of the length-tension curve) during *in-vivo* food processing, resulting in submaximal bite forces. The ranges of operating lengths corresponded to 55-73 percent of maximum force in black carp (*Mylopharyngodon piceus*, a molluscivore, feeding on small manufactured food pellets), 62-79 percent of maximum force in common carp (*Cyprinus carpio*, an omnivore, feeding on small manufactured food pellets), and 18-100 percent of maximum force in grass carp (*Ctenopharyngodon idella*, an herbivore, feeding on thin blades of grass). The wider range of *in-vivo* jaw adductor operating lengths in grass carp is caused by greater jaw motion and muscle strain during chewing. The consistent operation of these adductor muscles at lengths shorter than would be optimal for force production is surprising, and may be related to maintenance of muscle stability at the level of the sarcomere.

P1.186 GILCHRIST, Sandra L; New College of Florida, Sarasota; *gilchrist@ncf.edu*

A Seven Year Study of Shell Use by Coenobita clypeatus(/i)> on Cayos Cochinos Mejor, Bay Islands, Honduras

Adult land hermit crabs, *Coenobita clypeatus* (J.C. Fabricius 1787), must find shells or other abdominal coverings throughout their lives. Shells can come from fresh water, marine or terrestrial sources. Fresh water is also a critical resource for these crabs, allowing them to regulate temperature as well as maintain hemolymph balance. Some authors have noted that these hermit crabs find shells along beaches near wrack lines while others indicate that shell collection areas such as tree holes and beneath fallen trees provide shell resources. A seven year study of shell cycling and fresh water access on Cayos Cochinos Mejor supports the notion that crabs frequent shell collection areas close to fresh water sources. Introduced shells farther from fresh water access are not located as quickly. Crabs at collection sites exchange shells even when there is an excess of new shells available. Mark/recapture studies reveal that the mean size of the crabs did not change over the sampling period despite the addition of several thousand large shells over the seven years. There were fluctuations in shell crowding during each sampling season, but not a significant change across seasons. Crabs visiting collection areas near fresh water had a mean larger size as well as a wider size range than sites farther from fresh water. Shells were retained in the system for at least 5 years, though the quality of the shell declined over time. This study was permitted by DIGIPESCA through the generosity of the Honduran Government.

P1.136 GIRARDO, D.O.*; CITARELLA, M.R.; KOHN, A.B.; MOROZ , L.L.; Whitney Lab for Marine Bioscience, University of Florida, St Augustine, FL, Whitney Laboratory for Marine Bioscience Dept of Neuroscience, Univ. of Florida, Florida; *abkohn@msn.com*

Automatic Transcriptome Analysis and Quest for Signaling Molecules In Basal Metazoans

Ctenophores and sponges are one of the most basally branched lineages of Metazoa. Their unique organization, development, cellular structures and simpler behaviors make them useful for understanding the origins and evolution of nervous systems. We hypothesize that secretory peptides can be the earliest intercellular signaling molecules. The 1st step in our analysis, we developed an automated transcriptome analysis pipeline fully integrated with a signaling peptide prediction system. Our pipeline is a “zero-click” analysis package for transforming sets of raw reads from next-generation sequencing platforms into a fully assembled, annotated, quantified, and visualized transcriptome project with minimal manual operation. The zero-click pipeline greatly reduces the complexity and time requirements of working with next-generation sequencing data by integrating a number of publicly-available software packages, including MIRA, Newbler, mpiBLAST, annot8r, and a suite of neuropeptide prediction programs, into a completely autonomous system. The pipeline actively monitors a relational database of jobs created by our next-generation sequencing platforms (including 454 and Ion Torrent), selects projects for analysis, submits raw reads for assembly, transforms intermediate files, and uploads the resulting assembly and annotation data without any work on the part of researchers. In the work presented here, this has allowed our lab to transform raw sequence data into a fully functional transcriptome database complete with predicted signaling molecules, within one to two days.

P2.54 GOODARZI, Athena*; MEKDARA, Prasong j.; SOLTANI, Ana; BERG, Otto; GOTO, Joy J; MULLER, Ulrike K.; Cal. State Univ. Fresno; *agoodarzi@csufresno.edu*

Quantifying the Locomotory Capabilities of Drosophila through a Novel Lenticular Arena

As toxicological screenings become widespread because of legislation requiring environmental impact studies and risk assessment to human health, Drosophila (fruit flies) have become the invertebrate model organism of choice. Drosophila are also an important model organism for mutational and genetic analysis. Screening assays have been developed to assess mortality, reproduction, or behavioral competence. In this study, we developed a new assay to assess locomotor competence. We developed a circular walking arena with a lenticular floor and a flat cover, so the slope of the floor increases gradually from the center to the edge of the arena. The arena is 75 mm in diameter and 7 mm high. Drosophila are negatively geotactic – they climb as high as possible. We tested whether our arena can detect subtle differences in walking ability by treating adult Drosophila with an environmental neurotoxin that is known to cause Parkinson's like symptoms in humans. This neurotoxin is a glutamate-agonist, which should cause insect muscles to contract involuntarily. We therefore expect this toxin to cause loss of fine motor control in fruit flies. We quantify the climbing ability of 40 flies (10 control, 30 treated with three different doses) for 10 minutes per day over three consecutive days. We use custom-made software (Ctrax), student-developed MATLAB routines and manual behavioral scoring to track the flies in the arenas. Our experiments show that the lenticular arena not only detects a loss in climbing ability, like the tap-down assay. But it also enabled us to show that BMAA causes an increase in activity levels despite the loss of motor ability. So the lenticular arena allowed us to detect more complex effects of the neurotoxin than the tapdown.

P1.68 GOOTE, P.C.*; BERGMAN, D.A.; Grand Valley State University; *gootep@mail.gvsu.edu*

Using Crayfish to Control Zebra Mussel Populations

The expansion of zebra mussel distribution into inland waterways of North America has created significant abiotic and biotic challenges. Zebra mussels foul a wide array of submerged substrates including rock surfaces, plants, native bivalves, dock walls, and watercraft. Fouling of water intake pipes and associated installations can severely impair water delivery to hydroelectric, municipal and industrial users making proactive or reactive control measures necessary. Mussels increase water clarity by removing suspended clay, silt, bacteria, phytoplankton, and small zooplankton. This focuses nutrients into the bottom of lakes away from much of the food chain and also causes increases in cyanobacterial toxins due to increased growth of blue-green algae. However, mussels are exploited by a host of predators, most notably waterfowl, fish, and crayfish. They can return some of the nutrients to the food chain, but unfortunately even with predation much of the nutrients remain at the bottoms of lakes. We have tested one crayfish species (Orconectes propinquus) for feeding responses when given an opportunity to interact with zebra mussels (5 consecutive days). Crayfish did ingest zebra mussels and males ate more than females. Moreover, all crayfish selected smaller zebra mussels as a preferential prey item.

P2.39 GOPINATH, A.*; ELDER, J.F.; RING, B.C; BECHLER, D.L.; Valdosta State University, Valdosta, Georgia; *agopinath@valdosta.edu*

Relationship between cnr1 gene variation and behavioral differences among Kryptolebias marmoratus laboratory isogenic lines

The endocannabinoid system (ECS) is composed of molecules that include endogenous cannabinoids (endocannabinoids), cannabinoid receptors and the enzymes that regulate the concentration of endocannabionoids. In human beings and other vertebrate models the Endocannabinoid system is implicated in the regulation of several bodily functions from appetite regulation to processing rewards. The cnr1 gene encodes the CB1 receptor (Cannabinoid receptor 1) which is an integral part of this system. Polymorphism in the cnr1 gene (Cannabinoid receptor 1 gene) in humans is associated with substance addiction, depression, anorexia and several other disorders. *Kryptolebias marmoratus* (kmar) are self fertilizing hermaphrodites that produce clonal progeny. This study aims to sequence the cnr1 gene in four isogenic lines of kmar and correlate polymorphism to behavioral differences. Since the dynamics of the ECS is yet to be fully characterized in any organism, a significant result could help provide the spark to encourage study of the ECS in this simple vertebrate.

P3.202 GOUIN, N*; BERTIN, A; BORQUEZ, J; SAMPERTEGUI, S; RUIZ, V; FIGUEROA, R; CEAZA, La Serena, Chile, Universidad de La Serena, Chile, Universidad de ConcepciÃ³n, Chile, Universidad de ConcepciÃ³n, Chile, Centro EULA, ConcepciÃ³n, Chile; *nicolas.gouin@ceaza.cl*

Contrasting influence of spatial and ecological factors on genetic diversity and morphological differentiation of two freshwater invertebrate species

Population differentiation results from the combination of evolutionary, ecological and stochastic processes. While lotic organisms are usually distributed along environmental gradients, they may show species-specific responses to the environment depending on their ecological requirements. Here, we investigate the effects of spatial and ecological processes on genetic diversity (mitochondrial DNA; COI gene) and morphological differentiation among populations of two freshwater invertebrates, *Chilina dombeyana* (CD) and *Aquarius chilensis* (AC), in a Chilean watershed. Both species show interpopulation genetic and morphological differentiation ($p<0.001$), with a higher genetic structure in CD (FSC=0.39) than in AC (FSC=0.17). Isolation by distance was detected for both morphological and genetic data in CD, but not in AC. In both species, morphological variation was influenced mainly by habitat and water characteristics. While significant correlations between nucleotide diversity and indices of water and riparian habitat quality were detected in both species, the direction and magnitude of the correlations were different between them (r=-0.40 and -0.41, respectively, for CD and r=0.51 and 0.66, respectively, in AC). These results suggest that these two species are influenced by different environmental factors and that AC may be more sensitive to local water quality. Consistent with this view, we also found that sites where AC shows the highest levels of genetic diversity also harbor higher macroinvertebrate diversity. Future studies are necessary to elucidate the ecological mechanisms underlying these observations.

P3.101 GRABENSTEIN, Callie J.*; HULSEY, C. Darrin; Univ. of Tennessee, Knoxville; *cgrabens@utk.edu*
Many-to-one Mapping in Catastomid Fish Jaws: Multiple ways to be a sucker!
Many-to-one mapping is a ubiquitous feature of organismal design and has been examined extensively in the jaws of fishes. To detail an example of many-to-one mapping in Ostariophysan fishes, we examined the jaw protrusion mechanism of 35 species in the family Catastomidae, commonly called North American Suckers, and tested for many-to-one mapping in the elements underlying jaw protrusion. We quantified the lengths of the kinethmoid-vomerine ligament, the kinethmoid, premaxilla-kinethmoid ligament, and length of the premaxilla as well as jaw protrusion. Using a published phylogeny of Catastomids, we highlight several examples of many-to-one mapping in how these elements contribute to jaw protrusion.

P3.134 GREEN, MH*; CURET, OM; PATANKAR, NA; HALE, ME; Univ. Chicago, Northwestern Univ.; *mhgreen@uchicago.edu*
Kinematics and fluid dynamics of pectoral fin movement in larval zebrafish.
Larval zebrafish rhythmically beat their pectoral fins during many behaviors including low speed swimming, prey tracking and hovering; however, very little is known about the functions of larval pectoral fin movements. We used high-speed video imaging to track the movement of the pectoral fins during slow forward swimming. We observed large bending along the span of the fin during abduction. During adduction the fin remained rigid along its span. We placed drops of dye in the water to image the movement of fluid by the fins. Dye-marked fluid was transported by fin beats from a position rostral and lateral to the fin base to a position caudal to the fin base near the body surface. Dye-marked fluid appeared to be stretched, folded and pushed backwards by fin beats. We used computational fluid dynamics to analyze the fluid dynamics of normal fin movement, and to test the effects of removing bending from the fin motion. For normal fin beats, we found a qualitative match between simulated fluid movement and fluid movement observed during dye imaging experiments. Patterns of stretching and folding of fluid by the fin were found to correspond to Lagrangian coherent structures (LCS) in the fin wake. When bending was removed from fin motion, fins were less effective at transporting fluid to the body surface, and the LCS in the fin wake were disrupted. Our data suggest that the pectoral fins are effective in transporting distant fluid to the body surface and mixing fluid near the body surface, and that bending along the span of the fin during abduction is essential for transport and mixing.

P1.93 GREEN, P.*; PANG, B.; VAN VALKENBURGH, B.; University of California, Los Angeles; University of Massachusetts, Amherst, University of California, Los Angeles; *patrick.greener@gmail.com*
RESPIRATORY AND OLFACTORY TURBINATE SIZE IN CANID AND ARCTOID CARNIVORANS
It is widely assumed that dogs (Family Canidae) have an exceptional sense of smell, however there is little comparative evidence to support this claim. We used 3D visualization of CT scans to measure the bony surface areas of olfactory (OSA), respiratory (RSA) and, combining these, total (TSA) turbinates in skulls of 10 species of canids as well as 12 previously studied, terrestrial species of the Superfamily Arctoidea (Ursidae, Mustelidae, Mephitidae, Procyonidae). We examined scaling relationships and asked if ecological variables such as diet and home range size correlate with olfactory ability, as shown by ratios of OSA and RSA. After phylogenetic correction, we found that canids show greater positive allometry in TSA relative to arctoids, as a result of positive allometry in OSA and isometry in RSA. Canids also have a greater proportion of their turbinate area devoted to olfaction than respiration, suggesting that canids have enhanced olfactory ability relative to most arctoids. Interestingly, two arctoid species, the wolverine (*Gulo gulo*) and polar bear (*Ursus maritimus*) are similar to canids in having enlarged olfactory turbinates. An expanded olfactory region in both these species and the larger canids is associated with hypercarnivory as opposed to omnivory. We suggest that this reflects selection for greater olfactory ability in large, meat-eating species in response to their dependence on widely dispersed, relatively sparse resources (large vertebrate prey). Future research will use histology and flow visualization to more deeply investigate nasal chamber structure and function in mammals.

P3.142 GREETER, Jeremy SM*; HEDRICK, Tyson L; University of North Carolina at Chapel Hill; *jgreeter@live.unc.edu*
Sideslipping Maneuvers in Free-Flying Hawkmoths
Pilots envy the ability of some flying insects to dart in any direction with seeming ease. Recent research revealed some of the biological and mechanical rules that govern these maneuvers in insects both large and small. These studies include investigations of yaw rotations in *Drosophila* and hawkmoths (Dickinson *et al.*, doi:10.1126/science.284.5422.1954, Hedrick *et al.*, doi:10.1126/science.1168431), and the pitch stability of hovering insects (Sun & Wang, doi:10.1242/jeb.00457). Many birds, bats, and insects can also produce lateral or sideslip maneuvers, which we investigate here in the hawkmoth *Manduca sexta*. To elicit lateral movements, we oscillated a low-intensity light source above moths in a dark flight chamber, rather than training moths to follow flowers as in earlier experiments. This eliminated the unknown effects of an unfurled proboscis on flight mechanics and prevented it from mechanically coupling the moth to the moving target. We used high-speed infrared videography and 3D reconstruction to measure angular and translational kinematics of the moths and their wings in flight. We observed that hawkmoths use roll to create accelerations in the lateral plane during sideslip direction reversals. These roll-based sideslips differ from sideslips reported in *D. melanogaster* (Ristroph *et al.*, doi:10.1242/jeb.025502), which initiate lateral accelerations by changing the relative timing of flips in the long-axis wing rotation angles of their left and right wings. Preliminary findings suggest hawkmoths initiate the roll maneuver that creates their lateral acceleration *via* stroke amplitude asymmetry. A potential reason for this diversity of sideslip maneuvers is the higher Reynolds number of hawkmoth flight and the shift towards downstroke-dominated force production in these larger fliers.

P3.181 GROSS, Vladimir*; HOCHBERG, Rick; ATHERTON, Sarah; University of Massachusetts, Lowell; *Vladimir_Gross@student.uml.edu*

A comparison of tardigrade muscular organization between species with different body form and habitat

Tardigrades (aka water bears) are microscopic, eight-legged, barrel-shaped invertebrates that dwell in permanently or temporarily wet environments. Tardigrades were first described over 200 years ago and to this day are characterized primarily by their external morphology. At present, most tardigrade research is focused on cryptobiosis and tardigrade relationships to arthropods, onychophorans and various "aschelminth" taxa. However, morphological studies intending to gain insight into the structure of organ systems or their utility in understanding intra-phyletic relationships are relatively rare. In this study, the muscular system of an intertidal marine tardigrade, *Batillipes pennaki* (Heterotardigrada, Arthrotardigrada), is compared to that of a semi-terrestrial species in an attempt to understand how this relatively conserved organ system may vary with body form and habitat. The study was performed using fluorescent labeled phalloidin and confocal laser scanning microscopy (CLSM) to create a 3D reconstruction of the muscular system of each species. Characters of the muscular system were then mapped onto a phylogeny of the Tarigrada – using newly generated molecular sequences - to view evolutionary trends in the architecture of the tardigrade muscular system. Because of a lower degree of variability compared to external characters, internal morphology of organ systems such as the musculature may be a more useful tool for gaining insight into the evolutionary history and intra-phyletic relationships of tardigrades.

P1.162 GROVE, TJ*; FORT, TJ; Valdosta State University; *tjgrove@valdosta.edu*

Functional Characterization of Calsequestrin from the Eurythermal Killifish, Fundulus similis

Calsequestrin (CSQ) is a calcium-binding protein in sarcoplasmic reticulum (SR) that undergoes dramatic conformational changes, changing from a random coil at low Ca^{2+} levels in SR during muscle contraction to highly ordered polymer chains under high Ca^{2+} concentrations during muscle relaxation. We are interested in understanding the mechanisms by which this structurally dynamic protein is able to undergo conformational changes and remain functional in organisms that experience variable physiological temperatures. To this end, we are currently characterizing the function of CSQ from fast twitch muscle of the longnose killifish, *Fundulus similis*. Using a fluorometric assay to monitor the intrinsic fluorescence of conserved tryptophans, preliminary data indicate the dissociation constant (K_d) of CSQ from *F. similis* is 544 ± 40 µM at 25°C in the presence of 0.1M KCl and 270 ± 16 µM at 25°C in the absence of KCl. In addition, Ca^{2+}-induced polymerization and precipitation of CSQ aggregates at 25°C in the presence of 0.1M KCl was measured using a turbidity assay. The Ca^{2+} concentration at which half maximal precipitation of polymers occurred was 1.72 ± 0.13 mM. Experiments are ongoing to examine the effects of temperature on the calcium-binding ability of CSQ in this eurythermal fish species. This work is supported by National Science Foundation grant IOS-0817805.

P2.76 GRUCHALLA, K.L.*; RHEN, T.E.; University of North Dakota; *kathryn.gruchalla@email.und.edu*

Development of the Hypothalamus and Pituitary Gland in the Snapping Turtle, Chelydra serpentina

The hypothalamus and pituitary gland regulate the endocrine system in all vertebrates in order to maintain homeostasis. Development of the hypothalamic-pituitary axis has been well-studied in mammals and birds, however documentation in reptiles is lacking. Previous studies have shown the hypothalamus originates early in development from the diencephalon, later differentiating into distinct nuclei. The brain begins as a bipotential organ that will develop either a masculine or feminine phenotype; sex steroids produced by the developing gonads are implicated in establishing sexual dimorphisms. Proper organization of the hypothalamus during early development is important later in life for control of gonadal function as well as activation of sex-appropriate reproductive behavior. The snapping turtle displays temperature-dependent sex determination, which makes it a useful model species to study the development of sexual dimorphisms because it allows for the control of sex. The pituitary gland develops concomitantly, originating from two separate tissues: the anterior pituitary gland arises from oral ectoderm, whereas neural ectoderm forms the posterior lobe. This study aims to establish a developmental record of the hypothalamus and pituitary gland in the snapping turtle and determine areas of sexual dimorphism in both regions. Throughout development we employed a morphological analysis and stereology, an unbiased method to evaluate potential differences in cell number and hypothalamic nuclear volume. This record will act as a starting point for further studies involving hypothalamus and pituitary gland development and characterization of sexual dimorphisms in these regions.

P3.68 GUINEA, M/L; Charles Darwin University; *michael.guinea@cdu.edu.au*

Dwindling Sea Snakes at Ashmore Reef: Searching for the "Elephant in the Room"

At least 17 species of sea snakes are recorded from reefs, lagoons and channels at Ashmore Reef on Australia's Sahul Shelf. Three species are regionally endemic (*Aipysurus foliosquama*, *A. apraefrontalis* and *A. fuscus*) with another two species also endemic to Australia. Surveys to 1998 indicated a stable population of 6 to 17 snakes per hectare of reef flat at low tide and from 1 to 3 snakes per hectare on the sand flats at high tide, but from 30 to 70 snakes per hectare in the lagoons at low tide. Tagging studies over three years estimated from 94 and 192 Turtle-headed Sea Snakes (*Emydocephalus annulatus*) used a single coral head 30 meters in diameter. Spawning events by Damselfish (*Chromis*) attracted feeding aggregations of Turtle-headed Sea Snakes. The reef was prolifically abundant with new individual sea snakes swimming into view each minute. By 2008 Ashmore Reef supported less than 1 sea snake for 10 hectares, regardless of habitat, with only three snakes seen in three weeks of survey. Sea snake populations on neighboring reefs, at 30 to 250 nautical miles distant, appeared unaffected. The cause of this decline at Ashmore Reef remains unknown. Possible, but unsubstantiated, causes include: changes in sea level with erosion of reef flats and increased sedimentation in lagoons; changes in water temperature over the expansive reef flat; changes to rainfall patterns; altered management regimes due to increased surveillance of border security; changes to fishing practices by artisanal Indonesian fishers; increased frequency and closer proximity of seismic surveys and gas well construction by petroleum companies. Sea snakes are the marine equivalent of the miner's canary for reef health. Yet the cause of their decline in numbers and species at Ashmore Reef remains the "elephant in the room" until examined afresh.

P2.51 GUO, M*; HEDRICK, TL; Univ. of North Carolina at Chapel Hill; *minghuig@email.unc.edu*

3D Image Correlation based reconstruction of fluid locomotor surfaces

The wings and fins of a wide variety of swimming and flying animals are characterized by large, time varying deformations. These deformations arise from a variety of sources, including inertial effects, aeroelastic or fluid-structure interactions, or even active deformation controlled by the animal. Characterization of these deformations is vital to ongoing work on the fluid dynamics of animal locomotion, but presents a substantial challenge due to the large deformations, highly three dimensional nature of many animal movements, and difficulty of perfectly positioning a moving animal within experimental apparatus. Here we address these difficulties by adapting stereo digital image correlation techniques to rapidly extract time-deforming wing meshes from hovering hawkmoths. Our approach uses two closely positioned and stereo-calibrated high-speed cameras. The close alignment and resulting similar images from the two cameras facilitate automatic detection of dense matching feature sets among the two cameras. These feature pairs are then reconstructed in 3D using the camera calibration relationships and the resulting 3D point cloud smoothed and resampled over a regular grid with a thin plate spline function. We then trim the grid to overall wing shape outlines determined from contour based image segmentation with manual correction. The resulting wing grid points may then be meshed using a variety of surface meshing algorithms. Local velocity vectors are determined by an analogous operation from frame to frame on calibrated cameras. Additional camera pairs may be added as needed to measure deformations along complete locomotor cycles. We demonstrate operation of this technique on hawkmoth wings and plan to make the software implementation freely available for application to similar problems.

P1.114 GUSSEKLOO, S.W.S.*; GROSSE, I.R.; BERTHAUME, M.; DUMONT, E.R.; Wageningen University, University of Massachusetts, Amherst; *sander.gussekloo@wur.nl*

finite element modeling suggests functional divergence in the skulls of palaeognathous and neognathous birds

The basal bifurcation in the phylogeny of modern birds is between ostrich-like birds (ratites and tinamous; Palaeognathae) and all other birds (Neognathae). Most differences between the Palaeognathae and Neognathae lie in the reduction or loss of the ability to fly, but the crania of palaeognaths are also more robust and more fenestrated than those of neognathous birds. The specific morphology of the palaeognath cranium has been attributed to neoteny, but recent studies suggest that it must have functional significance. Within the avialan lineage the cranium becomes increasingly fenestrated leading to a reduced number of lateral elements. This trend is more pronounced in palaeognaths than in neognaths. To test how fenestration affects cranial function, we made a finite element model of a neognath (chicken) skull and in two analyses applied experimentally validated forces and displacements to it. We then removed the lateral bars, which are lacking in palaeognaths, and applied the same forces and movements. When the lateral bars were present, we found lower stress concentrations in the maxilla during beak opening, suggesting that lateral bars serve to reinforce the beak. The presence of the lateral bars during beak closing also appears to reinforce cranium as well as increase in beak reaction (bite) force. These results suggest that differences in the degree of fenestration in the skulls of palaeognathous and neognathous birds have functional consequences that may have played a role in the divergence of the two lineages.

P1.99 GUTZWILLER, S.G.*; O'CONNOR, P.M.; SU, A.; The Ohio State University, Ohio University, Cleveland State University; *gutzwiller.5@osu.edu*

Postcranial Pneumaticity and Bone Structure in Two Clades of Neognath Birds

Some living birds exhibit postcranial skeletal pneumaticity, aeration of the postcranial skeleton by the pulmonary air sacs. The extent of pneumaticity can vary, ranging from taxa that are completely apneumatic to those with air filling most of the postcranial skeleton. This project examined the influence of skeletal pneumatization on bone structural parameters in a size- and locomotor-diverse (e.g., diving vs. soaring) assemblage of neognath birds (charadriiforms and pelecaniforms). Results for pelecaniforms suggest that specialized dive foragers (e.g., the apneumatic anhinga) tend to have thicker cortical bone and a higher trabecular bone volume fraction. Conversely, *Pelecanus occidentalis*, the taxon with pneumatic vertebrae, the largest body size, and specializations for soaring flight, exhibits thinner cortical bone and a lower trabecular bone volume fraction. Such patterns in bone structural parameters are here interpreted to pertain to decreased buoyancy in birds specialized in dive foraging and decreased skeletal density in birds of larger body size, particularly those with specialized flight behaviors. The potential to differentially pneumatize the postcranial skeleton and alter bone structure may have played a role in relaxing constraints on body size evolution and/or habitat exploitation during the course of avian evolution. Notably, no patterns were observed within charadriiforms, indicating that the relationship between pneumaticity and bone structure is variable among different clades of birds.

P3.179 HABEGGER, M.L*; MOTTA, P.J; MULLINS, G; STOKES, M.J; WINTERS, D; University of South Florida; *mhabegge@mail.usf.edu*

Feeding biomechanics in billfish: Inferring the role of the rostrum from a mechanical standpoint

Billfishes are a group of large pelagic predators that are characterized by the elongation of both premaxillary bones forming the bill or rostrum. Besides the relevance of this structure, from which the group's name is derived, its biological role is still controversial. Therefore, the goal of this study is to investigate the biomechanical role of the bill for feeding. Our main hypothesis suggests that if the bill is designed for striking its prey during feeding, there should be a homogenous distribution of stress along the structure. By using beam theory as our primary model and from the application of strain gauges along the bill, mechanical testing were performed in two individuals of *Xiphias gladius* , at two different planes. Mechanical parameters including stress, strain, Young's modulus, flexural stiffness, second moment of area were then estimated. Additionally, histological samples were obtained to characterize the components of the rostrum. Preliminary results show that the second moment of area increases towards the base of the bill, stress values along the bill varied from 2.2 - 1.7 Nmm2 and Young's modulus varied from 6.4 to 16.5 GPa from the base to the tip of the bill. Histology revealed acellular bone as the main component of the rostrum, however hyaline cartilage and adipose tissue were also present at its base. Statistical analysis showed no significant differences among stresses along the bill, confirming our hypothesis The distribution and values of the mechanical parameters are discussed with regards to the feeding behavior of this species.

P1.173 HADJISOLOMOU, S.P.*; GRASSO, F.W.; The Graduate Center of the City University of New York; *shadjisolomou@gc.cuny.edu*

Chromatophore control mechanisms underlying crypsis in the European cuttlefish, Sepia officinalis.

Cephalopods control light reflected off their skin for crypsis and communication. Muscle-effected dilation and contraction of chromatophores allow for sub-second changes in skin reflectance to match benthic substrata or for signaling to conspecifics or predators. These behaviors are modulated by visual input from the optic lobes. From the optic lobes, the bilateral, interconnected lateral basal lobe and anterior and posterior chromatophore lobe networks contribute to motor programs that control the state of chromatophores. While the anatomical arrangement of the neuro-muscular components and the sensory contributions of the visual system have been documented, the organizing mechanisms that control body patterns have received less attention. We recorded high speed (100 Hz) video of changes in skin reflectance from a European cuttlefish, *Sepia officinalis* (Linnaeus, 1758) following brief (100 microsecond duration) intense light flashes presented to the eyes. This stimulus was adequate to trigger chromatophore responses, producing spatial gradients of contrast across the mantle. These responses were slow to be triggered, initiating with a delay of 130 milliseconds. Time-spectral analyses of the responses from individual mantle regions of skin (< 0.25 mm^2) provide evidence for several processes, which involved brief dilation followed by gradual contraction of the chromatophores. These processes resulted in differential intensities of reflected light off the skin. The responses could be long, lasting up to 4 seconds. The long duration of these responses may reflect the persistence of a sensory trace of our intense flash input. The responses also suggest potential opponent processes at work, consistent with a system that adapts to ambient light level, which changes in the natural environment.

P3.11 HAHN, T. P.*; HAIMAN, A. N.; BRAZEAL, K. R.; DE CASTRO, D. M.; GENDI, K. M.; BOMZE, L. M.; WATTS, H. E.; Univ. of California, Davis, California State Univ. East Bay, Loyola Marymount Univ.; *tphahn@ucdavis.edu*

Evolution of photorefractoriness in the Cardueline finches.

Photorefractoriness in birds is defined as reproductive insensitivity to the stimulatory effects of long days. It is characterized by spontaneous termination of reproductive competence despite continued long days, and complete unresponsiveness even to constant light once the gonads have collapsed. Among songbirds, taxa that breed on temporally opportunistic schedules (e.g., crossbills, zebra finches) tend to lack refractoriness, whereas seasonally-breeding taxa consistently display refractoriness as part of their annual cycles. Within the Cardueline tribe of finches (Fringillidae), the only taxa that have been found to lack refractoriness are the crossbills (*Loxia* spp.), a group of archetypal temporal opportunists that specialize on unpredictably-distributed seeds of conifers. This study extended existing among-species comparisons of photorefractoriness by testing for photorefractoriness in two relatively basally-derived cardueline lineages, genus *Leucosticte* (rosy-finches) and genus *Coccothraustes* (hawfinches/evening grosbeaks). Both gray-crowned rosy-finches (*L. tephrocotis*) and evening grosbeaks (*C. vespertinus*) collapsed the gonads spontaneously when held on constant long days after the summer solstice, consistent with the hypothesis that photorefractoriness is the ancestral trait within the cardueline finches. This finding lends further support to the inference that the absence of photorefractoriness in the crossbills represents a recently-evolved adaptation facilitating temporal reproductive flexibility.

P2.8 HAIMAN, Aaron/N.K.*; GENDI, Kirollos/M.; HAHN, Thomas/P.; Univ. of California, Davis; *anhaiman@ucdavis.edu*

Variation in Flight Calls and Responsiveness among Individuals and Types in the Evening Grosbeak (Coccothraustes vespertinus)

The Evening Grosbeak (*Coccothraustes vespertinus*) is a nomadic species that ranges across North America. This species has been in decline in recent years, and the taxonomic status of its subspecies is uncertain. Five distinct variants, or types, in flight calls produced by individuals in different geographic areas have been observed. The specific acoustic variations that occur in the flight call, and the possibility that this species can use this vocalization to identify other members of the species to group or individual levels, has not been explored. Here we quantify variation in 240 flight calls of 24 individuals representing three western types (Type 1, Type 2, and Type 4). Our goal was to illustrate a possible mechanism by which individual and group membership could be determined using the acoustic parameters of the flight calls. Analyses of variation (ANOVA) and coefficients of variation (CV) show that the flight calls vary both between individuals of the same type and between types. Variation between types is more consistent across acoustic parameters than variation between individuals of the same type. To determine if these birds do discriminate between flight calls types, a playback experiment was conducted. Type 1 individuals were presented with recordings of their own flight call type and a foreign flight call type and levels of responsiveness were compared. Variation in vocalizations can allow identification at different group levels. The different activity rate of observed birds to recordings of different flight call types suggest that these birds can distinguish between flight calls types. These results could have significant influence on flock assemblage and mate selection, and so contribute to speciation in nomadic species.

P1.44 HANAUER, RACHEL E.*; KETTERSON, ELLEN D.; Indiana University; *rhanauer@indiana.edu*

Corticosterone, immune function, and behavior in free-living dark-eyed juncos

Pleiotropic effects of hormones can lead to integration of traits, potentially causing trade-offs that limit an organism's adaptive responses to different environments. Previous studies in birds have found that the steroid hormone corticosterone affects multiple traits, including immune function and exploratory behavior, but it is unknown to what extent shared mediation by circulating corticosterone leads to correlation between these traits. If shared hormonal mediation leads to correlations between immune function and other hormone-mediated traits, then a mechanism exists for parasite selection on immune function to lead to changes in many other traits. I tested for correlations between corticosterone, constitutive immune function, and exploratory behavior in free-living dark-eyed juncos, *Junco hyemalis*. Baseline and elevated plasma corticosterone were assessed by taking blood samples from birds within three minutes of capture and again one hour later. Blood was also collected to measure bacteria-killing ability and hemagglutination. Exploratory boldness was assayed after holding the bird in captivity overnight. Infections by five types of parasites were also evaluated. These data will examine whether exploratory boldness and immune function covary, and if this covariation can be attributed to plasma corticosterone. By measuring the degree to which immune function is correlated with a hormone-mediated behavioral trait, these data will help address the plausibility of common hormonal mediation as a mechanism for the large-scale associations observed between parasite prevalence, life history, and behavior.

P1.126 HANCOCK, Jennifer A.*; BIKNEVICIUS, Audrone R.; Marietta College, Marietta, Ohio, Ohio University Heritage College of Osteopathic Medicine, Athens, Ohio; *jah006@marietta.edu*

The evolution of retinal morphology in birds

Retinal morphology is highly variable in extant birds, ranging from the afoveate retina of the Oilbird (*Steatornis caripensis*) to the bifoveate retina of the Common Flamingo (*Phoenicopterus roseus*). In order to understand the distribution and evolution of avian retinal morphology, we collected known data on retinal features in 165 species of birds. Specifically, we recorded the number and location of the area centralis (a region of increased retinal cell density) and foveae (a depression within the area centralis) for each species. Configurations of the area centralis include: circular in shape and located in either the nasal or temporal retina; circular in shape and located in both the nasal and temporal retinal fields; a horizontal band that extends across the retina; and absent. The number of foveae similarly ranges from 0 to 2 per eye, and, when present, they may be located in the nasal, temporal or both retinal fields. These data were then mapped onto a phylogeny in order to reconstruct the evolution of retinal characters. The ancestral character state for birds was found to be a nasal unifoveate retina with a band-shaped area, and from this nine other retinal patterns evolved. The evolution of these retinal patterns appears complex, involving retentions of the primitive condition, directional changes toward different configurations and reversals.

P1.10 HANSELMANN, R*; JOLLES, AE; Oregon State University; *hanselmr@onid.orst.edu*

How intensive forest management affects disease in wildlife: Patterns of Sin Nombre virus infection and gastrointestinal parasitism in wild deer mice (Peromyscus maniculatus).

Ecosystems are increasingly being eroded by anthropogenic disturbances, including habitat fragmentation, ecosystem simplification, and toxic exposures from agricultural activities. One important ecosystem service that may suffer from such environmental disruption is the abatement of disease in organisms inhabiting said communities. This can occur through altered species composition of an ecological community or by affecting the physiology of the organisms inhabiting the disturbed ecosystem. However, the ultimate effects of such disturbance on the dynamics of disease harbored within a host community are variable and poorly described. Wild deer mice (*Peromyscus maniculatus*) are major carriers of zoonotic pathogens. In North America, these include Sin Nombre virus (SNV), the causative agent of Hantavirus Pulmonary Syndrome, a fatal respiratory disease in people. Frequently, deer mice are also infected with gastrointestinal (GI) parasites, including various helminths and protozoa. Here, we examine the patterns of different endemic infections in *P. maniculatus* populations inhabiting forestry plots of varying management intensities: 40-50 year old stands, recently clearcut sites that were not further managed (control), and recently clearcut forests that were also heavily treated with herbicides. Considering the potentially negative impacts intensive forest management is likely to exert on wildlife host physiology, we hypothesized that deer mice inhabiting intensively managed sites are more likely to carry pathogens when compared to animals found on control plots, or in older stands. Interestingly, both SNV and GI parasite prevalence differs among deer mice inhabiting the three plot types, but prevalence patterns are not consistent for the different infections.

P3.34 HANSON, KM*; MCELROY, EJ; College of Charleston; *khanson27@gmail.com*

Anthropogenic Impacts on Herpetofaunal Diversity and Community Structure on a Developed Barrier Island in South Carolina

Reptiles and amphibians are integral parts of myriad ecosystems, but their well-documented population declines pose a serious threat to the integrity of these systems. Habitat loss and alternation, as a result of human development, are seen as the main causes of biodiversity loss throughout the world. Few areas are more affected by human development than barrier islands, where a finite amount of land is clearly defined and, on small temporal scales, plant and animal populations are isolated. Despite the abundance of barrier islands and herpetofauna in the southeast, no previous study has investigated whether human development alters herpetofaunal diversity or community structure on these islands. We tested this hypothesis by collecting herpetofauna community data on Kiawah Island, South Carolina, a private island that has been developed continuously from west to east over the past 35 years. This directional development has resulted in a gradient of developmental density across the island. We found that the east end of the island, with low developmental density, harbors the greatest number of species in the highest densities. In fact, this area accounted for more than 50% of all animals caught during the study. The remaining areas (high and moderate development) were similar in number of species and individuals caught. This suggests alternate explanations for the patterns of herpetofaunal diversity observed during this study. Additional data such as the development history of each area and other habitat characteristics would help enlighten the reasons for the similarities in herpetofaunal diversity between the high and moderate areas, but not the low area.

P1.58 HARDY, KM*; BURNETT, KG; BURNETT, LE; Cal Poly State Univ - San Luis Obispo; Medical Univ of South Carolina, College of Charleston; *kmhardy@calpoly.edu*

The effect of hypercapnic hypoxia and bacterial infection on protein synthesis rates in the Pacific whiteleg shrimp, Litopenaeus vannamei

Estuarine species frequently encounter areas of low dissolved O_2 (hypoxia; H) and high CO_2 (hypercapnia; HH). Exposure to low O_2 results in a downregulation of metabolic rate that serves to decrease ATP utilization and O_2 demand. This depression is facilitated by a reduction in protein synthesis, which can be responsible for up to 60% of total basal metabolism. We have previously observed a decrease in the relative mRNA levels of genes involved in protein synthesis during H and HH in the Pacific whiteleg shrimp, *Litopenaeus vannamei*. In the present study, we aimed to confirm that this hypoxia-induced metabolic downregulation is accompanied by a decrease in protein synthesis. Metabolic depression has also been observed in other decapods in response to bacterial challenge, leading us to hypothesize that protein synthesis may also be reduced during infection. Here we examined the effects of H, HH and bacterial infection (*Vibrio campbellii*) on tissue-specific [muscle and hepatopancreas (Hp)] total protein synthesis rates (K_s) in L. vannamei, as determined by the rate of tissue incorporation of radiolabeled [^{3}H]-phenylalanine. We observed a significant decrease in K_s in muscle after 24h exposure to both H and HH, and in Hp after 4 and 24h exposure to HH. Thus, in Hp tissue the combined stress of H and hypercapnia exacerbated their effect on K_s. Bacterial infection (24h), however, had no significant effect on K_s in either tissue. These results suggest that marine crustaceans reduce metabolic demand during environmental hypercapnic hypoxia by reducing global protein synthesis, whereas this mechanism does not seem to facilitate decreased metabolic rates associated with infection.

P1.20 HARPER, B.T.*; JARVIS, T.A.; BUTLER, B.; RICE, L.; RYAN, S.; BIELMYER, G.K.; Valdosta State University, Waterford Institute of Technology; *btharper@valdosta.edu*

Metal Accumulation from Dietary Exposure in the Sea Urchin, Strongylocentrotus droebachiensis

Heavy metal contamination is an increasing problem in aquatic environments, mainly due to anthropogenic inputs. Environmental regulations are developed using toxicity data of waterborne metal exposures and less research has focused on dietary metal exposure. However, recently the importance of the dietary exposure route has been demonstrated, particularly in assessing sub-lethal toxicity in invertebrates. This research investigated the accumulation and effects of dietary metals in a macro invertebrate. The seaweed species *Ulva lactuca* and *Enteromorpha prolifera* readily uptake metals, are widely distributed, and are often used as bioindicators of pollution in ecological studies. Additionally, these species serve as vital components in aquatic food chains. *U. lactuca* and *E. prolifera* were concurrently exposed to five metals (Cu, Ni, Pb, Cd, and Zn) and then fed to the sea urchin *Strongylocentrotus droebachiensis* for a period of two weeks. Body mass, test length, and total length were measured, the sea urchins were dissected and their organs (esophagus, stomach, intestine, gonads, and rectum) were digested and analyzed for metals. The results demonstrated that metal accumulation varied between seaweed species and among metals. All of the metals accumulated within at least one organ of *S. droebachiensis*, with Cu being most significant. In general, there were higher levels of metals within the sea urchins fed *E. prolifera* as compared to those fed *U. lactuca*. These results indicate that *E. prolifera* may accumulate metals in a more bioavailable form than within *U. lactuca*. In this study no significant differences in body length, growth, or coelomic fluid ion concentration were detected.

P3.151 HARRISON, A*; KEMPLER, K.E.; DUGGER, JR., D; BATTELLE, B-A.; Whitney Lab., Univ.of Florida, St. Augustine and Spelman College, Atlanta, GA, Whitney Lab., Univ. of Florida, St. Augustine, Dept. of Ophthalmology, Univ. of Florida, Gainesville; *battelle@whitney.ufl.edu*

UV opsin is expressed in Limulus lateral, median and ventral eyes and is coexpressed with a visible light sensitive opsin

The horseshoe crab *Limulus polyphemus* (Lp) has three types of eyes, lateral (LE), median (ME) and rudimentary. The latter consist of clusters of giant and somewhat smaller photoreceptors. Sensitivity to UV light was thought restricted to MEs. We recently cloned a predicted UV-sensitive opsin from *Limulus* (LpUVops). Surprisingly, the clone originated from a cDNA library prepared from the ventral rudimentary eye (VE). Using gene specific primers, we detected the transcript for this LpUVops also in cDNA libraries from LE and ME. A monoclonal antibody specific for the C-terminus of LpUVops applied to fixed, frozen sections of each of the eyes, revealed LpUVops-like immunoreactivity in some but not all rhabdomeres of the ME, in rhabdomeres of smaller but not giant VE photoreceptors, and perhaps most surprisingly, in the membrane of the eccentric cell dendrite in LE. Eccentric cells have been considered a type of second order neuron in *Limulus* LE and ME because they are electrically coupled to photoreceptors, generate action potentials in response to photoreceptor depolarization and project to the brain. We also applied immunocytochemistry to test whether LpUVops is coexpressed with either of the visible light sensitive Lp opsins previously characterized, Ops1-2 or 5. So far, we have detected coexpression LpUVops with Ops5 in VE and ME photoreceptors. Our studies show LpUVops is expressed in all *Limulus* eyes, that *Limulus* VE contains two biochemically distinct populations of photoreceptors and that photoreceptors in ME and VE coexpress UV- and visible light-sensitive opsins. They also suggest that LE eccentric cells may be UV sensitive photoreceptors.

P3.119 HART, M.W.*; POPOVIC, I.; EMLET, R.B.; Simon Fraser Univ., Univ. of Oregon; *mwhart@sfu.ca*

Population genetics of Heliocidaris sea urchins with benthic fertilization and brooded development

Evolutionary changes in reproduction and development can affect rates of population divergence and speciation through both adaptive (e.g., sexual selection on gamete recognition proteins) and selectively neutral (e.g., genetic drift due to limited dispersal and gene flow) mechanisms of differentiation. We compared these two effects of life history differences among echinometrid sea urchins, and found that the evolution of benthic fertilization and development has a stronger effect on neutral population differentiation than on adaptive divergence of gamete recognition. *Heliocidaris bajulus* has benthic fertilization of large yolky eggs and brooded development of nonfeeding offspring tethered to the mother’s spines, and is closely related to the model organism *H. erythrogramma*. Compared to *H. erythrogramma* (with planktonic fertilization and dispersal of yolky lecithotrophic larvae), *H. bajulus* has strong population differentiation caused by low gene flow. This difference is consistent with the different modes of dispersal in the two species (and the loss of planktonic larval dispersal). In contrast, *H. bajulus* has slow rates of codon evolution of the sperm acrosomal protein-coding locus for bindin that are similar to rates in *H. tuberculata* and other echinometrids with small eggs and feeding larvae, and slower than previously reported fast bindin evolution in *H. erythrogramma*. This difference is not consistent with previous interpretations of fast bindin evolution in *H. erythrogramma*, which was provisionally ascribed to the evolution of large eggs that make large sperm targets at fertilization (with high risk of polyspermy), a trait shared in common with *H. bajulus* that evolved recently in their common ancestor. In this case fast bindin evolution may be linked to ecological differences that affect the risk of polyspermy rather than to differences in gamete traits.

P3.125 HART, Mary K; University of Kentucky; *mkhart0@yahoo.com*

Allometry of sex allocation for a simultaneous hermaphrodite: a contrast of patterns at high and low densities

Recent studies have demonstrated that sex allocation patterns among populations and social groups vary continuously with differences in density and sperm competition. That is, greater density is positively correlated with sperm-competitive behavior and proportional male allocation in a simultaneous hermaphrodite, both within and among populations. In addition, proportional sex allocation is determined through a combination of reproductive investments in ovarian and testicular gonadal tissue relative to body size. In the present study, I examine whether the patterns of allometry associated with measures of sex allocation (proportional male allocation) are consistent over time for populations at high and low density. Populations of Serranus tortugarum in the Bocas del Toro, Panama region have been repeatedly sub-sampled across the representative size range from 2004-2007. These yearly sub-samples (n = 50-150 individuals each) can be divided based on high (N=6) and low reef densities (N=7). This study compiles a large dataset of allometric patterns in reproductive investments with size from individuals of a representative size range for the population. I predict that for the low density populations, I will see a consistently greater investment in ovarian tissue with size and for high density populations, I will see a consistently greater investment in testicular tissue with size.

P3.149 HASPEL, G*; SCHWARTZ, A; SOARES, D; NINDS, Univ of Maryland College Park; *daphne.soares@gmail.com*
Unique mechanosensory adaptation to extreme environments in cavefish.
Extant cavefishes can be viewed as replicate experiments in adaptation to an extreme environment. Various surface dwelling fishes have independently invaded caves throughout evolutionary time. Thus, the existence of independently derived cave forms provides a unique opportunity to examine parallel evolution and convergence because cavefish species belong to a diverse palette of families. All cavefish ancestors had to outmaneuver and adapt to the harsh constraints imposed by the extreme environment of caves and their perpetual darkness. As a result a suite of specific troglobitic phenotypes have independently emerged. Here we studied the cavefish Astroblepid pholeter which is endemic to a single cave on Ecuador (Jumandy 77°47'33"W 0°52'30"S). Our results show that this fish species is of special interest because it appears to be the first teleost to have no neuromasts. We were not able to detect the presence of neuromasts using neither DASPEI, nor scanning electron micrography, nor serial thin sectioning of the skin. Instead, we found that A. pholeter dorsal skin is covered with novel putative sensory organs that are unique in morphology, respond electorphysiologically to mechanosensory stimuli and influence rheotaxic behavior.

P1.82 HAWKINS, MB*; FERZLI, M; OVERMAN, E; SHEA, D; North Carolina State University; *beth_hawkins@ncsu.edu*
A Studio Lab for the Undergraduate Biology Curriculum: Using a Comparative Endocrinology Model to Recruit Future Scientists.
Students in the **Research PackTrack** program are investigating the structural and functional evolution of the three estrogen receptors (ERs) found in a teleost fish, *Micropogonias undulatus*. This well-characterized neuroendocrine model introduces students to the value of scientific inquiry through a comparative, evolutionary approach. The goal is help undergraduate science majors develop an appreciation for the authentic practice of scientific research. Opportunities for undergraduate research are limited, and students who do find projects in laboratories are often unprepared. The Research PackTrack Program addresses these problems in part via a three credit-hour course for sophomores that offers hands–on experience in a working research laboratory. This course allows for hypothesis-driven authentic research projects rather than standardized laboratory exercises. Lab times are highly flexible, vary from week to week, and depend on individual progress of the students. Students use a robust experimental protocol, *in vitro* bacterial expression of the ER and subsequent competitive binding assays, to test their novel hypotheses about the effects of site-directed gene mutations on ER-ligand interactions. Since estrogens play a critical role in a broad range of physiological processes and disease states, students are able to pursue a line of inquiry that particularly interests them. CURE survey results suggest that students in the program have an increased interest in science and scientific research. This “studio lab” approach encourages first semester sophomores to think creatively and to apply and reinforce the concepts they learn in traditional classrooms.

P3.160 HAZARD, L.C.*; SIERRA, J.; TERODEMOS, H.; CARO, L.; Montclair State University, NJ; *hazardl@mail.montclair.edu*
Limited sensitivity to aldosterone in salt glands of two lizard species with minimal variation in cation secretion
Many lizards use nasal salt glands to supplement renal excretion of excess dietary sodium and/or potassium (coupled with chloride). In some species, cation secretion is flexible, and varies depending on the dietary input; the sodium:potassium ratio is modified by aldosterone, a sodium-conserving hormone. However, other species have more limited ability to vary the cations secreted. *Uromastyx dispar* (an herbivore) secretes nearly 100% potassium, and *Eumeces schneideri* (an insectivore) secretes ~40-60% potassium, regardless of cation load incurred. We hypothesized that the salt glands of these two species would therefore be relatively insensitive to aldosterone. Individuals of both species were given either sodium chloride or potassium chloride loads daily for four days, in conjunction with aldosterone, spironolactone (an aldosterone blocker) or ethanol (vehicle control). Salt gland, urinary, and fecal sodium and potassium output were measured. In *U. dispar*, aldosterone had no effect on rates of sodium and potassium secretion or on the sodium:potassium ratio; however, spironolactone resulted in a slight increase in sodium secretion consistent with the expected effects of blocking aldosterone. Results were more complex for *E. schneideri*; in NaCl-treated animals spironolactone increased sodium secretion, but in KCl-treated animals aldosterone appeared to both increase sodium secretion and decrease potassium secretion. These contradictory responses suggest that the roles of aldosterone and other osmoregulatory hormones in regulating lizard salt glands may be more complex than previously thought, and that other regulatory pathways and interactions with other excretory routes may be involved.

P3.128 HEINIGER, J*; VAN UITREGT, V; WILSON, Robbie; The University of Queensland; *r.wilson@uq.edu.au*
Death after Sex in the Australian Bush: determinants of survival and reproduction in males of the world's largest semelparous mammal
The northern quoll (*Dasyurus hallucatus*) is a medium-sized (approx. 1 kg) predatory marsupial previously common across the entire top-end of Australia. This species is the largest known semelparous mammal in the world, which means mating is highly synchronous, males live for only one year, and males undergo total die-offs soon after the mating season. Such population-wide male die-offs are presumably due to the physiological stress of procuring copulations and the intense fighting among males. A small proportion of females will survive to produce a second litter, but there are no documented cases of survival to a third breeding season. The young are born after a short gestation period and then carried in a rudimentary pouch for approximately 60-70 days. Females will then leave young in dens while they forage, returning to suckle until young are independent at 4 – 5 months. Both sexes are solitary throughout the year with a home range averaging 35 ha for females and approximately 100 ha for males during the breeding season but varies greatly between individuals. During out study, we will be investigating the morphological and performance determinants of both survival to reproductive-age and fecundity among males of this species on Groote Eylandt, an Indigenous-managed island off the coast of the Northern Territory. Northern quolls are still highly abundant on this island and this population offers a unique opportunity to understand the evolution of this extreme mating system and the role physical performance plays in the reproductive success of males.

P3.20 HEINRICH, EC*; MCHENRY, MJ; BRADLEY, TJ; Univ. of California, Irvine; *eheinric@uci.edu*
Spiracular activity and respiratory airflow in the Madagascar hissing cockroach (Gromphadorhina portentosa)
Using simultaneous dual-camera video recordings, flow-through respirometry, flow visualization, and gas microanalysis, we have examined spiracular function and respiratory air flow patterns in the Madagascar hissing cockroach (*Gromphadorhina portentosa*). Synchronized video recordings of individual spiracles demonstrate that all abdominal spiracles (5-9) open and close together. The fourth spiracles are used for hissing, and are otherwise closed at all times. It is more difficult to determine if the thoracic spiracles are open or closed using external visual inspection. Synchronized video and flow through respirometry have been used to provide insight into how spiracular control contributes to different patterns of CO_2 release. At different times, roaches appear to exhibit classic discontinuous respiration, continuous respiration with all spiracles open or continuous respiration with active ventilatory movements, during which the spiracles open and close in time with abdominal pumping. On the basis of neurological data, a previous model suggested that spiracular activity promotes unidirectional airflow through the insect. Using airflow visualization methods we show that during periods of active ventilation, airflow proceeds from the anterior to the posterior end of the insect. These results demonstrate the complexity of respiratory control in insects, in which the respiratory pattern responds to metabolic rate, gas composition, and activity level. This work was supported by the following grants from the National Science Foundation: IOS-0920683 (TJB) and IOS-0952344 (MJM).

P3.86 HELM, R.R.*; DUNN, C.W.; Brown University ; *Rebecca_Helm@brown.edu*
A phylogenetic synthesis of medusa development
In complex life cycles, a diversity of asexual developmental mechanisms are necessary to give rise to different life cycles stages. Understanding the evolution of asexual development in complex life cycles is critical to understanding the evolution of complex life cycles themselves. In Medusozoa, a group of cnidarians that includes "true jellyfish", the canonical complex life cycle consists of a sexually produced polyp that asexually produces a medusa (jellyfish), which produce gametes. Medusa development has been studied since the mid-19th century, and recent advances in phylogenetics have resulted in robust evolutionary hypotheses for relationships among a diversity of medusozoans. However, the medusa development literature has yet to be broadly synthesized in a phylogenetic framework. I place previous observations on medusa development into a contemporary phylogenetic context, and discuss the possible evolutionary conservation or convergence of these differences, with possible implications for life cycle evolution.

P3.165 HELMEY-HARTMAN, W.L.*; MILLER, C.W.; University of Florida, Gainesville; *wlhelmey@ufl.edu*
Effects of environmental variation on courtship in the harlequin bug, Murgantia histrionica
Although environmental variation is ubiquitous, few studies have examined the ways in which sexual selection varies across environments. For herbivorous insects, host plant availability is a major and persistent source of environmental variation that may affect sexual selection. This experiment was designed to determine the effects of natal and current host plant on courtship and mating behavior of the harlequin bug, *Murgantia histrionica* (Hemiptera: Pentatomidae). This insect feeds on a variety of crops that often shift in availability throughout the year. We reared insects in separate containers with either mustard or broccoli for food. Virgin adults of similar ages were later paired in behavioral trials to include all combinations of natal plant and testing plant contexts. Behavior was analyzed to detect any effects of host plant. Observed differences may result from varying nutritional quality of the host plants or phenotypic plasticity in mate-recognition signals based upon natal or testing host plant. These differences may provide a mechanism for sympatric speciation or result in adaptive change that maximizes the success of this species in a heterogeneous environment.

P2.192 HELMSMÜLLER, D.; WEFSTAEDT, P.; NOLTE, I.; SCHILLING, N.*; Small Animal Clinic, University of Veterinary Medicine Hannover, Institute of Systematic Zoology and Evolutionary Biology, Friedrich-Schiller-University; *nadja.schilling@tiho-hannover.de*
Kinematic, kinetic and electromyographic analysis of the locomotor ontogeny of the Beagle
Juveniles must perform in the same environment as adults while their body undergoes continuing changes in body size and proportions and their musculoskeletal system progressively matures. To better understand how young altricial mammals cope with these changes and analyze which locomotor parameters change during ontogeny, we studied the locomotor development in dogs. We used six male Beagle siblings in this longitudinal study and collected data every week to two weeks starting at the age of 9 weeks. Kinematic, kinetic and electromyographic data were collected synchronously while the puppies walked and trotted on an instrumented treadmill. Each gait was performed at the same Froude number throughout ontogeny to circumvent locomotor differences due to body size. Additionally, morphometric data were collected to capture the development of body and limb proportions. Confirming previous results, the typical mammalian intralimb re-proportioning was observed, i.e., distal segments decreased while proximal segments increased in relative length. Epaxial muscle activity was nearly adult-like in its timing by the age of 9 weeks. Likely connected with the changes in body proportions, the relationship of the peak vertical forces between the fore- and hindlimbs shifted from the forelimb supporting a relatively greater proportion of body mass in the puppies in comparison to adults. The results of this study increase our understanding of the dog's locomotor ontogeny in particular and of mammals in general.

P3.19 HENRY, A.F.*; DEAROLF, J.L.; Hendrix College, Conway, AR; *henryaf@hendrix.edu*
Determining the existence of a sphincter in the caval region of Stenella spp.

Sphincters of the vena cava have been found in the diaphragms of deep diving seals and some cetaceans (whales, dolphins, and porpoises). These sphincters produce safe, elastic aneurysms that help maintain diastolic blood pressure and prevent fluid accumulation during deep dives. Sphincters are characterized by large percentages of slow-twitch fibers, which provide prolonged contractions and do not fatigue quickly, aspects that sphincter muscles must have in order to function properly. Thus, the purpose of this experiment is to determine if striped and spotted dolphins, *Stenella* spp., possess a sphincter in the caval region of their diaphragms. To determine if there is a sphincter present, the percentage of slow-twitch fibers in the costal region of the diaphragm was compared to the percentage in the caval region, by cutting sections from these regions of striped and spotted dolphin diaphragms in a cryostat and staining them for their myosin ATPase activity. The stained sections were then imaged, and slow- and fast-twitch fibers were identified in each image and counted. Slow-twitch fibers are also known to contain more myoglobin than fast-twitch fibers. Thus, if the caval region has a larger proportion of slow-twitch fibers than the costal region, it should also have a higher myoglobin concentration. To test this hypothesis, myoglobin analyses were also performed on samples from the costal and caval regions of *Stenella* spp. diaphragms, and the average myoglobin concentrations in these regions were compared. If the diaphragms of striped and spotted dolphins are found to have a sphincter, then these findings will demonstrate that caval sphincters are common adaptations for deep diving in marine mammals.

P3.100 HENSON, C.B.*; FRANCIS, JR., A.W.; Armstrong Atlantic State Univ., Savannah, GA; *ch3866@stu.armstrong.edu*
Modeling feeding biomechanics of the asymmetrical flatfish Paralichthys lethostigma

The vast majority of bony fishes are characterized as being symmetrical morphologically, and due to this, most observations can be made solely from the sinistral side. However, flatfishes (Order Pleuronectiformes) have an obvious asymmetry that results from the migration of one of the eyes to the opposite side. This study examined whether or not any asymmetries in the morphometric features of southern flounder, *Paralichthys lethostigma*, affect the design and function of the feeding mechanisms. *P. lethostigma* were collected by seine net, hook and line, or aquaculture facilities. For each fish, the lower jaw and associated muscles were extracted from fixed individuals of the species. Using digital photographs of the jaws, measurements were made of the opening and closing in-levers, out-lever, length of the adductor mandibulae muscle, dorsal and ventral jaw length, as well as the distance from the origin of the adductor mandibulae muscle to the articulate joint. These measurements were then entered into jaw simulation software to determine mechanical advantage of jaw opening and closing as well as properties of the adductor mandibulae muscle. Using these measurements and calculations, comparisons were made of the ocular side versus the blind side for any apparent asymmetrical relationships. The results of the *P. lethostigma* specimen were also compared to another flatfish species with differing lifestyle and diet in order to identify any evidence of an evolutionary trend. The relationships of both the morphometric features and the biomechanics of the lower jaw indicate that the observed asymmetries in flatfishes do contribute to functional differences between the sides. Future research in this area will look at a larger size range of specimens as well as making additonal comparisons with other members of the order.

P3.50 HERNANDEZ, D*; SCHUMAN, M; TOMANEK, L; California Polytechnic State University; *dherna07@calpoly.edu*
Proteomic response of tidal-rhythm entrained Mytilus californianus to acute aerial heat stress

The rocky intertidal mussel species *Mytilus californianus* is native to the Pacific coast of North America. It is frequently exposed to temperatures that can induce the cellular stress response due to the tidal rhythm. Instead of acclimating mussels to common conditions in the laboratory for several weeks, we collected mussels from a site with mussel body temperature recordings (specimens' thermal history) and immediately started experimentation by mimicking the tidal rhythm with different levels of heat stress over multiple low tides and with different recovery periods. By using individuals that were entrained to the tidal rhythm and by maintaining it, we were able to simulate natural conditions and control levels of thermal stress. Immediately after collection, mussels were placed in the artificial tidal cycle so as not to interrupt their entrainment. During the first subsequent low low tide, air temperature was gradually raised to either 10°C, 28°C, or 35°C for the duration of the low tide. Following this low low tide, individuals were able to recover at 10°C water and air temperature (depending on tidal conditions) until the next low tide. Gill tissues from all individuals were prepared for analysis with 2D gel electrophoresis and subsequent 2D gel image analysis (two-way ANOVA; $p<0.02$). 19% of the proteins showed time-dependent heat stress (interaction) effect and about as many showed a heat stress or time (main) effect, with only half of those also showing an interaction effect. Proteins that changed significantly will be identified by matrix-assisted laser desorption ionization (MALDI) tandem time-of-flight (ToF-ToF) mass spectrometry.

P2.185 HESSEL, Anthony L.*; RYERSON, William; WHITENACK, Lisa B.; Allegheny College, University of Connecticut; *hessela@allegheny.edu*
Jumping Kinematics in the Plethodontidae II: the effects of tail loss

Many defense mechanisms exist in the tool belts of the Plethodontidae family. At least 6 species of these lungless salamanders are capable of attaining vertical height when threatened, and it has been thought that the tail may play a role in the salamander's specialized C-start jump while also keeping it stabilized in the unloading and mid-air phase. We ran jumping trials on 5 species of Plethodontidae with and without tails at 500 frames per second. The salamanders were placed on a platform and then approached from behind to simulate a predatory attack. This persuaded the salamanders to jump over a 5cm gap to a second, lower platform. Variables measured were bending angles, durations, and velocities, as well as jump height. Our preliminary results indicate no significant differences in the jumping abilities between tailed and de-tailed individuals within each species. Some variables that fall into the initiation of the jumps did have significant P-values, such as the max bed angles of *Desmognathus ochrophaeus* ($P=.078$) and *Plethodon glutinosus* ($P=.04$) during C-start. Removing tails represented a large loss of mass (mean mass loss: 27%, mean length loss: 48%), but they are not gaining more height from their jump than when they had their tails. It is possible that the tail could help stabilize and anchor hind limbs so that no energy is lost to slippage. Tail loss may not play a role in mid-air jumping, since tail loss does not change mid-air characteristics.

P1.9 HICKE, Justin W.*; BOWDEN, Rachel M.; Illinois State University, Normal, IL; *jwhicke@ilstu.edu*

Antipredator behavior of red-eared slider hatchlings in response to visual and chemical predator cues

Vision and olfaction are common channels of predator detection in aquatic vertebrates, though research on predator detection by aquatic reptiles is relatively limited. Young red-eared slider turtles are prey for a wide variety of predators, including many avian species and other reptiles such as snapping turtles. In preliminary work done to characterize an antipredator response, hatchling red-eared sliders (*Trachemys scripta*) were exposed to a series of visual and chemical stimuli. Individuals were presented with visual cues in the form of a sudden overhead movement to simulate and aerial predator as well as chemical alarm cues in the form of filtered conspecific tissue homogenate to simulate an aquatic predation event. Initial analysis indicates that hatchlings tended to respond by ceasing movement and submerging. To further explore these responses, hatchlings will be exposed to two similar tests. First, hatchlings will be presented with a model of an aerial predator. Second, to assess the use of chemical cues, individuals will be exposed to aquatic predator cues and conspecific alarm cues, both separately and simultaneously. For all trials, pre-stimulus and post-stimulus behavior will be scored and will include time spent moving or motionless, and the time spent above or below the surface of the water. These studies will provide a greater understanding of how turtle hatchlings respond to the presence of predators in their environment and may allow for a comparison of how responses differ depending upon the type of predation threat.

P2.186 HICKS, Rebecca*; KATZ, Hilary; MACESIC, Laura J.; GILLIS, Gary B.; Mount Holyoke College; *ggillis@mtholyoke.edu*

Do Bullfrogs Tune Forelimb Muscle Activity in Anticipation of Landing?

Landing from a fall or jump generally requires coordinated, anticipatory activation of limb muscles. For example, in a variety of mammalian species, including cats and humans, both the timing and intensity of pre-landing muscle activity in ankle extensors are modulated in relation to the expected impact. Similarly, recent work with hopping toads (*Bufo marinus*) has shown that the onset timing and pre-landing recruitment intensity of elbow antagonists vary predictably with hop distance. To test if such landing preparation is unique to toads among anurans, we studied muscle activity patterns in elbow antagonists in bullfrogs (*Rana catesbiana*). Electromyographic recordings were made in the coracoradialis, an elbow flexor, and the lateral head of the anconeus, an elbow extensor, during hops of varying distance. Particular attention was paid to the average signal intensity in the 50 ms before landing and to the onset timing of activity. Results reveal that like cane toads, bullfrogs modulate pre-landing forelimb muscle activity patterns depending the expected time and magnitude of impact. Hops in which animals are in the air longer, and presumably hit the ground harder, lead to more intense pre-landing activity in both elbow antagonists. Moreover, onset timing in the anconeus tracks the time of impact, so as to consistently begin approximately 100 ms before landing, regardless of the aerial phase duration. Our data suggest that tuning forelimb muscle activity to landing is not unique to toads and is more widespread among anurans.

P3.73 HIEBERT, L.S.*; MASLAKOVA, S.; University of Oregon; *lhiebert@uoregon.edu*

Comparing axial patterning in nemertean larvae - insights into the evolution of a novel larval body plan

Within the nemerteans, a phylum of lophotrochozoan worms, indirect development appears to be derived. This provides a unique opportunity to explore the evolution of a novel body plan: the pilidium larva. The pilidium is a hat-shaped planktotrophic larva equipped with an apical tuft and an elaborate ciliated band. Inside the pilidial body, a juvenile worm emerges over a number of weeks from isolated rudiments that fuse around the larval gut. The juvenile body is seemingly disjointed from the larval body and the transition from larval to juvenile habitat requires a drastic metamorphosis, in which the juvenile breaks free of the larva and consumes the larval tissues. While the pilidial mode of development is derived within a single clade of nemerteans, basal nemerteans develop directly into juvenile worms, without major body plan modifications. Thus, the pilidium can be considered a novel body plan inserted into this direct-developmental pathway. During the evolution of this new body plan, morphogenesis of the larval and juvenile bodies became decoupled both spatially and temporally. It is likely that patterning mechanisms used to set up these two body plans also became developmentally decoupled. Decoupling may exist at the level of axis specification since different pilidium-bearing species harbor developing juveniles with head-tail axes positioned at wide range of angles with respect to the major axis of the pilidium. In order to understand the developmental mechanisms and evolution of the pilidial body plan, we compare body axis patterning in a species with pilidial development (*Micrura alaskensis*) with another possessing direct-development (*Pantinonemertes californiensis*). We present data on expression of axial patterning genes in both species and comparative data on axial perturbations using inhibitors of conserved developmental pathways.

P1.104 HIERONYMUS, TL*; SIMONS, ELR; Northeast Ohio Medical University, Midwestern University; *h.tobin@gmail.com*

Morphology and histology of avian quill knobs: The fine structure of remigial feather attachments

The primary and secondary flight feathers (remiges) of bird wing are attached to the appendicular skeleton by a series of short ligaments. These ligaments form a link that assists in transmitting the aerodynamic forces generated by the wing to the remaining body mass of the bird. All bird species examined to date have similar arrangements of remigial ligaments. However, the presence and size of the bony exostoses (“quill knobs”) associated with the ligaments of the secondary remiges is variable among avian taxa, and there are no prominent bony landmarks associated with the attachments of the primary remiges. Variability in quill knob size has been tentatively linked to flight performance, but the relationship between quill knob morphology, remigial ligament morphology, and wing shape is still largely unexplored. We examined the osteohistology and soft tissue histology of remigial attachments to the ulna, carpometacarpus, and major digit in a number of species exhibiting a range of body size and flight behaviors. Preliminary results indicate that even in the absence of grossly visible bony quill knobs (as in some galliform birds), ossified portions of the remigial ligament on the dorsal surface of the ulna mark sites of secondary remex attachment. Ossified ligament remnants appear in histological sections as shallow patches of extrinsic (Sharpey’s) fiber bone overlying fibrolamellar bone. Primary remigial ligament attachments in the manus, which typically lack bony exostoses, also show similar patches of extrinsic fibers. Further exploration of the relationships between remigial ligament attachment histology, quill knob morphology, wing shape, and flight behavior may provide a means of documenting the evolution of avian wings from bony features preserved in fossil specimens.

P2.11 HOCHBERG, Rick*; ATHERTON, Sarah; KIENEKE, Alexander; ROTHE, Birgen; THACKER, Cheryl; GOUGE, Daniel; Univ. Massachusetts Lowell, Senckenberg Forschunginstitut und Naturmuseum, Universitat Hamburg, University of Florida; *rick_hochberg@uml.edu*

Marine Meiofauna of Little Cayman Island with a focus on Gastrotricha

Surveys of littoral and sublittoral sediments from diverse marine environments around Little Cayman Island have produced the first records of marine meiofauna from one of the most remote West Indian islands in the central Caribbean province. Forty six stations ranging from littoral to 40m depth produced records of 11 phyla. Gastrotricha, our focus taxon, included more than 20 putative morphospecies from nine genera (6 Macrodasyida, 3 Chaetonotida) representing six families. Six previously described morphospecies were present at several stations: *Aspidiophorus paramediterraneus*, *A. tentaculatus*, *Chaetonotus dispar*, *Macrodasys achradocytalis*, *Paraturbanella pacifica* and *Urodasys viviparous*. Sampling was purely qualitative, but general estimates indicate that species from two genera dominate the gastrotrich fauna of Little Cayman: *Macrodasys* and *Aspidiophorus*. In addition to new geographic records of Gastrotricha, we provide the first general survey of meiofauna from Little Cayman including new records for the following taxa: Acoela (Acoelomorpha), Acochlidia (Mollusca: Opisthobranchia), Annelida (Nerillidae, Protodrillidae, Syllidae), *Gnathostomula* (Gnathostomulida), *Halammohydra* (Cnidaria: Actinulida), *Echinoderes* (Kinorhyncha), *Gyratrix cf hermaphroditus* and several higher taxa of Platyhelminthes (Kalyptorhynchia, Macrostomida, Proseriata, Tricladida, “Typhloplanoida”), *Platyhedyle* (Mollusca: Sacoglossa), Neomeniomorpha (Mollusca), *Nermetillina* (Nemertea), *Rotaria* (Rotifera: Bdelloidea) and Tardigrada.

P3.182 HOCHBERG, A.*; HOCHBERG, R.; Univ. of Massachusetts, Lowell; *Adele_Hochberg@student.uml.edu*

Comparative Morphology of the Musculature in Larviparous Rotifers: Gradual Versus Drastic Metamorphosis

Most sessile rotifers secrete protective tubes that they attach to underwater vegetation. The sessile lifestyle is a derived condition within the Rotifera. It is a rare lifestyle among monogonont rotifers, and includes approximately 100 species distributed within the Superorder Gnesiotrocha. Sessile rotifers generally have larviparous lifecycles, possessing free-swimming larvae that are both ecologically and morphologically distinct from the adult. To date, very little is known about rotifer larvae or the process of metamorphosis that leads to the adult body form. In this study, we follow the fate of the muscles in different sessile species to determine how metamorphosis reconfigures muscular architecture, and whether or not species with drastic metamorphosis have significantly different muscular patterns than those that display gradual metamorphosis. A combination of phalloidin stain, CLSM and 3D software are used to reconstruct the muscular systems of species of *Collotheca*, *Floscularia*, *Ptygura*, and *Stephanoceros*. Preliminary results indicate that species with an infundibulum (i.e., those species that undergo drastic metamorphosis) show greater disparity in muscle architecture relative to species with a more gradual form of metamorphosis.

P1.227 HOCHGRAF, JS*; SOCHA, JJ; Virginia Tech; *hochgraf@vt.edu*

Does tracheal compression in carabid beetles function as a unidirectional pump?

Insects breathe using an extensive system of tracheal tubes that ramify throughout the body. Rhythmic tracheal compression, the periodic collapse and reinflation of parts of the tracheal system, has been identified in multiple taxa, but little is known about the precise dynamics of tube collapse. It has been hypothesized that tracheal collapse occurs synchronously throughout the body, but it is possible that tube collapse proceeds unidirectionally along the length of a tube, functioning as a pump to transport air and augmenting gas exchange. This study aims to characterize patterns of tracheal compression in one species of carabid beetle, *Platynus decentis*, to test the hypothesis of directional compression. The internal tracheae of living beetles were visualized using synchrotron x-ray imaging at the Advanced Photon Source, Argonne National Laboratory. We identified that tracheal tube collapse was characterized by the formation of discrete, buckled regions in the tube wall, which gave the appearance of dimpling. Dimple formation in the main dorsal tracheal trunks of the prothorax occurred as two semi-circular fronts spreading symmetrically along the longitudinal tube axis. In the transverse axis, the main ventral trunks collapsed in the medial to lateral direction, whereas the dorsal trunks collapsed dorsoventrally. Along the length of a tracheal tube, dimples formed synchronously, not sequentially. Synchronous longitudinal compression and consistent dimple formation kinematics within an animal suggest that *Platynus decentis* employs a stereotyped mechanism to produce cycles of tracheal collapse and reinflation, but such compression does not function as a unidirectional pump. Further data on spiracle opening and closing patterns are needed to determine actual airflow patterns within the body.

P3.1 HODGE, Anne-Marie C.; Univ. of North Carolina, Wilmington; *ach7229@uncw.edu*

Margay (Leopardus wiedii) habitat preference based on vegetation structure in the eastern Andean foothills of Ecuador

The margay (*Leopardus wiedii*) is a small, spotted felid that faces critical population declines in many regions within its range throughout Central and South America. This species is thought to be the most arboreal cat species in the Americas, which has led to concern that it may be especially sensitive to deforestation and habitat destruction. The margay is elusive and relatively rare, and little is known about its ecology and natural history. Here I present the results of a study conducted at a mid-elevation site in the eastern Andean foothills of Ecuador. A camera trap survey was used to investigate whether margay abundance and activity patterns and correlated to vegetational structure in a mid-elevation forest. Camera transects were placed along both edge and interior forest habitats, and several structural habitat variables were assessed in order to identify whether any of these factors are predictive of margay presence and/or abundance. The data showed that canopy cover and tree dispersion were significant predictors of margay trap success. These results highlight the importance of curbing habitat destruction and deforestation as part of efforts to reverse the margay’s declining population trend and protect habitat conducive to restoring populations.

P3.88 HOFSTEE, J.C.*; COLLIN, R.; Smithsonian Tropical Research Institute ; *jeanettehofstee@gmail.com*

Modification of velar lobe morphology across different developmental modes in Calpytraeid gastropods

Mode of development in marine invertebrates can include planktotrophic larvae, lechithotrophic larvae, direct development from large eggs and direct development with nurse eggs. It is generally believed that evolutionary changes in development are more likely to result in the loss of feeding larvae than in the re-evolution of feeding larvae from direct developers. A transition from planktonic larvae to direct development can lead to the loss of complex feeding structures which are essential in planktonic larvae for particle capture. In gastropods this often includes the reduction in the size of the velum and reduction or loss of the velar cilia (the prototroch, metatroch, and food groove). Direct developing species that lose these feeding structures are thought to be un-likely to re-evolve planktotrophic larvae. Phylogenetic analysis of calyptraeid gastropods, however, suggest that feeding larvae have re-evolved in this group. Therefore we used SEM to examine a variety of developmental stages of 13 calyptraeids including planktotrophs, lecithotrophs and direct developers both with and without nurse eggs, to determine the extent of the reduction of the velum and its ciliation species lacking feeding larvae. We found typical velar lobe ciliation in embryos of planktotrophs as well as embryos with direct development with nurse eggs. This was true for most direct developers as well, although two, *Bostrycapulus aculeatus* and *Crepidula ustulatulina*, lacked metatrochal cilia. These results suggest that most species may have the potential to re-evolve planktotrophic larvae but, for the species with lost or modified ciliation, reacquisition of feeding larvae is not likely.

P1.107 HOLLINGSWORTH JR., PR*; HULSEY, CD; University of Tennessee; *phollin1@utk.edu*

Evolution of the adductor mandibulae and premaxillary protrusion angle across eastern North American minnows (Cyprinidae)

Premaxillary protrusion is an important ecomorphological innovation driving the success of modern Teleosts. Cypriniformes exhibit a novel mechanism of premaxillary protrusion that is quite divergent from that of the well-studied Perciformes. In this study, we use a multi-locus phylogenetic approach to trace the evolution of premaxillary protrusion angle (PPA) across the hyperdiverse eastern North American minnows. We then examine the phylogenetically corrected correlations between PPA and the masses of the adductor mandibulae (AM) muscles to determine if changes in AM muscle masses are associated with enhanced PPA in cypriniform fishes. Our results should inform our understanding of the role individual AM muscles play in the evolution of the Cypriniform mechanism of jaw protrusion.

P2.20 HOLM, E.R.*; GOWING, S.; SANCHEZ DE LOZADA, M.F.; Naval Surface Warfare Center, Carderock Division; *eric.holm@navy.mil*

Flow-generated forces on hull fouling organisms and relationship to hydrodynamic self-cleaning of fouling-release coatings

Fouling-release coatings represent a non-toxic approach to the control of ship hull fouling. These coatings allow organisms to attach but promote their release from the hull as a result of hydrodynamic forces experienced during routine operations (hydrodynamic self-cleaning). More complete knowledge of the hydrodynamic forces experienced by fouling organisms improves our ability to predict the efficacy of fouling-release coatings. As well, the data can produce performance targets for polymer chemists or materials developers. We are using an experimental approach to quantify the forces generated by ship movement on organisms recognized as important ship hull foulers. Initial experiments focus on three types of sessile invertebrates; barnacles, serpulid tubeworms and bivalve mollusks. Organisms are scanned with a laser, resulting in three-dimensional point clouds that are processed into CAD models for manufacture by Rapid Prototyping. Hydrodynamic testing is performed in a 30.5 cm water tunnel on models scaled for accurate force measurement. Model organisms are rotated to allow measurement of three orthogonal forces at all angles to the direction of flow. Screens are used to vary the boundary layer thickness to simulate the effect of location of the fouling organism along the ship hull. Our approach and results may also be applicable to sessile invertebrates occurring in wave-swept or other hydrodynamically-challenging environments.

P3.53 HOLM, E.R.*; ANIL, A.C.; HADFIELD, M.G.; Naval Surface Warfare Center, Carderock Division, National Institute of Oceanography, Goa, INDIA, Kewalo Marine Laboratory, University of Hawaii; *eric.holm@navy.mil*

Quantitative genetic analysis of acquisition of metamorphic competence in Hydroides elegans, and consequences for larval dispersal

Dispersal of planktonic larvae of sessile marine invertebrates is the product of physical processes acting on the larvae while they are in the water column, larval behavioral responses affecting exposure to those processes, and the length of time the physical processes and behaviors have to act. Minimum time in the plankton is set by the age at onset of metamorphic competence. We used a sib analysis to quantify genetic and maternal components of variance in the timing of acquisition of competence in larvae of the serpulid polychaete *Hydroides elegans*. After 4 and 5 days of development, larvae from each cross were challenged with a metamorphosis-inducing biofilm. We considered the proportion of larvae responding to the biofilm by metamorphosing as equivalent to the proportion of larvae that had attained metamorphic competence. Additive genetic and maternal environmental effects significantly influenced acquisition of competence for 4-day old larvae. In contrast, the proportion of competent larvae after 5 days of development exhibited a significant additive genetic effect, but no maternal effect. These results suggest the presence in *H. elegans* of substantial genetic variation in the timing of acquisition of metamorphic competence, and thus the potential for larval dispersal.

P2.56 HOLMES, K.D.*; THICKMAN, J.D.; MILLER, C.W.; University of Florida; *deirdre.k@ufl.edu*

The influence of vegetation structure and social group composition in the habitat use of a cactus bug

Habitat selection is fundamental to ecology and evolution because of its broad effects on population dynamics, natural and sexual selection, and rates of speciation. I conducted a field study of the cactus bug *Chelinidea vittiger* by walking random transects through areas containing prickly-pear cactus. I counted insects and compared habitat use to what would be expected by chance. Greater numbers of adults were found on larger cactus patches, suggesting such large patches were preferred. In addition, patch size and the height of surrounding vegetation predicted the social composition of groups. This research is an important step in understanding habitat selection in a cactus-feeding insect.

P1.157 HOLSINGER, Rachel C.*; POTENZA, Jensen B.; MERCIER, A. Joffre; COOPER, Robin L.; Univ. of Kentucky, Lexington, KY, Transylvania University, Lexington, KY, Brock University, St. Catherines, Canada; *rcholsinger@uky.edu*

Modulation and calcium sensitivity in rate and force of contraction of the crayfish gut

Although, the crayfish hindgut has been a research model for over a century, it is still an excellent model for investigating the generation and regulation of peristaltic rhythms and for describing the mechanisms underlying their modulation, both at the level of neural circuitry and at the level of ion channels within the neurons and muscles. The crayfish hindgut is unique when compared to the smooth muscle in the GI tract of vertebrates, as this invertebrate system not only contains striated muscle with gap junctions but also has the ability to generate intrinsic pacemaker activity. We first investigated the influence of the ventral nerve cord (VNC) and, in particular, the sixth abdominal ganglion on the innervation of the hindgut of *Procambarus clarkia* by measuring the force and frequency of GI contractions. Then we examined the influence of neuromodulators selectively on the drive to the hindgut from sixth abdominal ganglion as well as the whole chain of abdominal ganglia (A1-A6). In addition, we assessed the effects of neuromodulators selectively to the central brain on descending drive of the hindgut and direct application to the hindgut isolated from the VNC. Serotonin, octopamine and dopamine (1 uM) all enhance the rate of contractions when the VNC or the GI is directly exposed. Direct application of neuromodulators on the GI produced more forceful contractions and a faster rate than exposure only to the VNC.

P2.103 HOOD, Wendy R; Auburn University; *wrhood@auburn.edu*

Growing up in the dark isn't so bad: Development of cavity nesting bluebirds birds is not limited by vitamin D

Cavity nesting birds have young that typically display slower growth rates than their open nesting counterparts. It has been argued that faster development in open nesting birds has evolved in response to greater risk of predation. Recent work in chickens has shown that vitamin D enhances skeletal growth, immune function, and gut development in chicks maintained in dark conditions and low vitamin D inhibits brain development in mouse pups. Thus, I reasoned that differences in the rates of development between cavity nesting and open nesting birds might be explained by differences in available sunlight, its effects on vitamin D synthesis, and the effect of vitamin D on development. I addressed this question by comparing the skeletal size and mineral content and organ size between Eastern Bluebird chicks supplemented with vitamin D3 (cholecalciferol) or water (control) on days 4-13 post-hatching. Treatment groups were compared on day 14. There was no effect of treatment on body mass, body size, bone mineral content, size of the immune organs, length of the intestine, or mass of the brain. Assuming that vitamin D is important for development in bluebirds, it is likely that mothers are depositing sufficient vitamin D in their egg yolk to support pre-fledging development.

P2.71 HORN, R.*; KITTS, J.; MILLER, B.; SCHREIBER, A.M.; St. Lawrence Univ.; *aschreiber@stlawu.edu*

Pharmacological suppression of matrixmetalloprotease (MMP) activity inhibits intestinal remodeling during Xenopus laevis metamorphosis

Metamorphosis of the herbivorous *X. laevis* tadpole into a carnivorous frog is accompanied by an abrupt remodeling of the gut: the intestine shortens in length by 75%, the connective tissue and smooth muscle layers thicken, 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 (i.e. stromelysin-3) or indirectly (e.g. gelatinase A and MT1-MMP) in the mesenchyme of the small intestine by TH. Although the kinetics of intestinal MMP mRNA expression have been studied extensively in the amphibian model and shown to correlate with gut remodeling, the influence of actual MMP enzymatic activity on intestinal remodeling has not been well-described. Here we show that treatment of pre-metamorphic tadpoles (Nieuwkoop and Faber stage 50 and 54) with broad-spectrum inhibitors of MMP activity (doxycycline and ilomastat, each administered in the tadpole rearing water at a concentration of 75 micrograms/ml) dramatically inhibits general MMP activity, and also inhibits intestinal shortening, thickening of the mesenchyme and smooth muscle layers, and development of involutions on the lumen compared with controls following treatment with TH (3 nM triiodothyronine) for 4 days. These findings directly support the hypothesis that an upregulation of TH-responsive MMP activity during metamorphosis mediates diverse changes that accompany intestinal remodeling.

P2.95 HOWARD, J.R.*; BUCKIO, B.R.; DILLON, M.E.; University of Wyoming, Laramie; *jhowar22@uwyo.edu*

Within-nest allometry of the bumblebee tracheal system

The scaling of insect respiratory systems with body size has important implications for ecology and evolution of insects, ranging from allometry of aerobic performance to current and past environmental constraints on insect body size. Previous work examining scaling across beetle species and during ontogeny of grasshoppers suggests strong tracheal hypermetry, with larger insects investing relatively more volume in their tracheal systems. However, these approaches potentially confound body size differences with species or life stage differences in morphology or physiology. To circumvent these issues, we took advantage of large body size variation within bumblebee nests, with workers (sisters) varying 10-fold in body size from 50 to 500 mg and queens exceeding 1g. We estimated tracheal volume by volume displacement and tracheal casting, dimensions of pronotal and propodeal spiracles, and body size of individual bumblebees (*Bombus impatiens*) from lab-reared nests. We describe the allometry of tracheal morphology within and among bumblebee nests, and discuss implications for size-related performance, and for respiratory limitations on adult body size.

P1.189 HOWELL, A.L.*; FRANCIS, JR., A.W.; Armstrong Atlantic State Univ., Savannah, GA; *ah8353@students.armstrong.edu*

Abundance and Variation of Invertebrate Zooplankton in a Georgia Estuary

Zooplankton is an essential source of nutrition for larval and juvenile fishes as well as many adult planktivores. While temporal patterns of zooplankton occurrence and abundance have been described for many coastal environments, these temporal patterns have not been well examined within the estuaries where many larval and juvenile fishes occur. It was the purpose of this investigation to identify and describe the temporal occurrence and abundance of invertebrate zooplankton in the Moon River, a salt marsh based estuary south of Savannah, Georgia. From July 2009 until July 2010, weekly collections were made with a 3:1 zooplankton net having a 0.5-m diameter hoop and 0.5-mm mesh. The net was deployed in the water column just below the surface after sunset and before sunrise during a night flood tide. A flow meter was also deployed to measure water volume sampled. Zooplankton samples were vital stained with neutral red and subsequently fixed in 10% formalin. During collections, measurements were made of environmental conditions, including water depth, salinity, temperature, dissolved oxygen, and pH. In the lab, samples were sorted and identified to the lowest possible taxonomic level. Major invertebrate zooplankton included assorted copepods, mysid shrimp, amphipods, hydromedusas, cumaceans, and marine mites. Temporal patterns include mysid shrimp peaking in abundance in January (647) and May (646) of 2010. Amphipod abundance showed an increase in September 2009 (58) with a spike in abundance in May (123) and June (96) of 2010. Future work will compare temporal patterns of zooplankton occurrence and abundance with larval and juvenile fish occurrence and abundance.

P3.198 HRANITZ, J.M.*; BARTHELL, J.F.; SULLIVAN, N.; RICCI, P.R.; Bloomsburg University of Pennsylvania, University of Central Oklahoma; *jhranitz@bloomu.edu*

Microsatellite Variation in Invasive and Native Populations of the Centaurea Leafcutting Bee

The *Centaurea* leafcutting bee (*Megachile apicalis*) is an invasive solitary bee and an established member of the cavity-nesting bee community in the western U.S. As fine-scale genetic markers, microsatellite loci used in comparative population genetic analyses may identify factors underlying this biological invasion from contemporary samples of this species. Our objective in this study was to investigate the suitability of cross-species microsatellite primers to amplify microsatellite PCR products in native and invasive populations of *M. apicalis*. Use of existing microsatellite primers from related species provides a much faster and cheaper alternative to traditional microsatellite isolation methods. We used five of six microsatellite primer sets developed for another megachilid solitary bee, *Osmia rufa*, to amplify homologous microsatellite loci in *M. apicalis*. We amplified DNA of bees from native populations in Lesvos (Greece) and Uludag University (Republic of Turkey) by PCR and conducted fragment analysis on a CEQ 8000. The *O. rufa* primers amplified 2-5 alleles at the five loci studied in *M. apicalis*. About 12.3% of the samples did not amplify an amplicon at a locus, suggesting that species-specific primers may be needed. Genetic divergence between the two native samples (Lesvos and Uludag University) was greater than the genetic divergence between the invasive population and the two native populations. We conclude that five *O. rufa* microsatellite primer sets amplified homologous microsatellites in *M. apicalis* suitable for population genetic studies of this invasive species.

P3.9 HUANG, H.-D.*; LIU, H. C.; National Museum of Natural Science, Taiwan, Providence University, Taiwan; *hdhuang@nmns.edu.tw*

Comparison of visual orientation between two land crabs Sesarmops intermedium and Scandarma lintou in Kenting National Park, southern Taiwan

This study aims to examine the visual orientation of two land crabs, *Sesarmops intermedium* and *Scandarma lintou*, in southern Taiwan, and to explore the ecological implication. Mid-sized *S. intermedium* are widely distributed among grasses, on river banks, and under maritime forests. Small-sized *S. lintou* are typical tree-living crabs, living on the vegetation close to running fresh water and seldom down to the ground except for larval release. On the contrary, *S. intermedium* mainly live on the ground, and occasionally get onto the plant preying other animals including *S. lintou*. Animal collection and experiments were conducted in Gangkou River estuary, Kenting National Park. Orientation of crabs was examined in circular arena with visual targets of various sizes. Both crabs perform significant orientation toward the targets larger than 45 degrees, and move directly to the center of 350-degree target, which represents the typical shelter-seeking behavior. However, tree-living *S. lintou* were significantly attracted by the shadow targets as small as 10 and 30 degrees, but ground-active *S. intermedium* showed random movements. This may reflect the characteristics of arboreal habitats where *S. lintou* lives and avoid predators.

P2.36 HUANG, Y*; HSU, Y; National Taiwan Normal University; *yuyun7595@gmail.com*
How does a new contest experience interact with an old one to influence subsequent contest behavior?
The outcomes of recent contests are known to influence an individual's behavior in subsequent contests: a winning/losing experience increases/decreases an individual's aggressiveness and probability of winning a subsequent contest (winner/loser effect). Animals in the field are likely to have multiple contest encounters in a short time, but how these multiple experiences combine to influence an individual's subsequent contest behavior is rarely explored. In this study, we give individuals of *Kryptolebias marmoratus*, a mangrove killifish, two contest experiences (2 days and 1 day prior to a staged contest) to examine whether the effects of these two experience were additive or not. The two individuals in a contest were also matched for the outcome of contests that they had taken part in more than one month previously. The results showed that the combined effect of the 1-day and 2-day experiences depended on the outcome of the 1-month contest. In contests between two 1-month winners, two losing experiences combined to have a more-than-additive effect. It is possible that the 1-month winners, had better intrinsic fighting ability, and showed a loser effect only after receiving two consecutive losing experiences. On the other hand, the effects of the 1-day and 2-day experiences appeared additive in contests between two 1-month losers, suggesting that one experience was enough to induce a change in contest behavior in these individuals.

P2.23 HUANG, S.-P.*; PORTER, W. P.; CHIOU, C.-R.; LIN, T.-E.; LIN, C.-C.; TU, M.-C.; University of Wisconsin, Madison, National Taiwan University, Taiwan, National Taiwan Normal University, Taiwan; *sphuang0711@gmail.com*
Mechanistic predictions of climate warming effects on energetics, activity and distribution of a high-altitude pit viper, Trimeresurus gracilis, in Taiwan
Global warming has been reported to cause negative impacts on many taxa, but its influence on high-altitude reptiles, a rarely studied taxa, has never been forecasted. We employed a mechanistic model Niche Mapper™ to investigate warming effects on energetics, activity and distribution of a rare high-altitude pit viper, *Trimeresurus gracilis*, in subtropical Taiwan. We measured functional traits for modeling, including preferred body temperatures, standard metabolic rates, evaporative water loss, and skin reflectivity. We used previously collected data on digestive physiology and feeding behaviors of this species and its congeneric species. The predicted performances were projected onto its current range in Taroko National Park using a fine-scale spatial dataset of longitude, latitude, topography, vegetation type, and climate. The results indicate that 1) energetics and activity time of this species are constrained by low body temperatures caused by the cold mountain climate and vegetation type, 2) the habitat of this species is severely limited to sunny areas with sufficient solar radiation, such as grassland and open areas, to obtain positive discretionary energy and longer activity time, and 3) activity time, maintenance energy cost, discretionary energy and habitats occupied would increase in response to a 3ºC increase in air temperature, assuming food resources are unlimited. Based solely upon temperature effects, our study revealed that this species could benefit from increasing warmth by invading more habitats in the park and by enhancing energetic and activity performances generally.

P2.190 HUDSON, PE*; CORR, SA; WILSON, AM; Royal Veterinary College, London; *phudson@rvc.ac.uk*
Gearing of galloping in the cheetah and racing greyhound
Within an animal's limbs there are several levels of gearing; from the myosin isoforms and the internal architecture of a muscle to the overall limb posture. Previous work on cheetahs and greyhound found cheetahs to have significantly longer muscle moment arms than the greyhounds. Following on from this we investigated whether the differences observed in their musculoskeletal gearing have an impact on the functional capabilities of their limb.

Simultaneous force plate (3500 Hz) and high speed video data (1000 Hz) were collected for two captive South African cheetahs and six ex-racing greyhounds, whilst they performed a steady state rotary gallop, and their limb posture, joint moments and Effective Mechanical Advantage (EMA) were investigated.

Posture is often thought of in terms of body weight support, i.e. larger, more massive, animals use a straighter limb posture (larger EMA). In this study it was hypothesised that the cheetah, a faster animal would use a straighter limb posture than the greyhound and that limbs would be straighter at higher speed to withstand the larger peak forces the limbs experience at higher speeds. No correlations between joint angles and speed were found with the exception of the tarsus and metatarso-phalangeal joints which became more flexed with increasing speed. The cheetahs also used a more crouched posture than the greyhound throughout stance. This may reflect greater leg shortening/compression at higher forces or an adaptation for manoeuvring.

P2.199 HUSAIN, DI*; GONZALEZ, G; MAXKWEE, K; BERG, O; GOTO, JJ; MULLER, UK; California State University, Fresno, Fresno City College; *umuller@csufresno.edu*
How Flies Stumble: The Effects of a Glutamate Agonist on Climbing Ability in Adult Fruit Flies
Previous studies have shown that the neurotoxin BMAA, a glutamate agonist, affects the walking behavior of fruit flies: high doses cause loss of motor ability (flies are unable to walk up an incline and right themselves after a fall); low doses cause hyperactivity (fruit flies walk faster and longer). Flies treated with low doses also stumble more often: they are more likely to lose their footing and roll down the incline. In this study we explored whether treated flies lose their footing more often because they walk faster or because BMAA affects their motor control. Our Null hypothesis is that walking faster reduces the contact surface and duration of the stance phase, making the flies more likely to lose their footing during incline walking. If loss of motor control is caused by BMAA, then the geometries of the tripod gait would be significantly altered, showing loss of fine motor control. Adult fruit flies were fed BMAA at four doses (0, 12.5, 25 and 50 mM BMAA); their walking behavior was recorded for 30 minutes 24 hours after feeding started. We digitized the footfall pattern of flies to determine the effect of BMAA on the tripod gait, walking speed and number of stumbles. We found that in the control flies, stumble frequency does not increase monotonically with walking speed, but the highest stumble frequency occurs at 2 mm/s with two thirds of the stumbles at velocities of 4 mm/s and below. In treated flies, stumble frequency peaks between 3 and 6 mm/s. Our data on footfall pattern suggest that BMAA impairs motor ability, leading to an increase in stumble frequency due to impaired leg coordination.

P1.27 HUTCHISON, ER*; GUNDERSON, MD; MILANOWSKI, AC; COVI, JA; UWSP; *joseph.covi@uwsp.edu*

Effect of lipophilic compounds on the early development of microcrustaceans

Micro-crustacean embryos may be more susceptible to lipophilic toxicants than the adults that are currently used as a standard for environmental assessment of toxicity. Most invertebrate embryos possess large stores of lipids in the form of lipid granules. These granules present a location for the bioaccumulation of lipophilic compounds that could interfere with metabolic or developmental processes. Because these embryos remain metabolically and developmentally arrested for years to centuries, pollutant levels that are permissive for short-lived adults could negatively impact embryos during recruitment from dormancy. The implications of this are profound. Exposure of these genetic storehouses to lipophilic toxicants could drastically, and irreversibly, reduce genetic variation in isolated populations. Individuals and/or species with the greatest capacity for embryonic dormancy would be most affected. As a test of the bioaccumulation hypothesis, embryos of the brine shrimp, *Artemia franciscana*, were exposed to common toxicants found in freshwater and coastal marine habitats (rotenone and crude oil). Hatching success was monitored for intact and dechorionated embryos after acute and prolonged exposures to lipophilic toxicants. Hatching of dechorionated embryos was completely abrogated by acute and chronic exposures to rotenone. Chronic exposure of dechorionated embryos to crude oil decreased hatching success, but exposure to volatile compounds released by the burning of crude oil had no effect. The data presented here suggest that invertebrate embryos possessing only cuticular barriers are susceptible to lipophilic toxicants. Given the broad distribution of invertebrates that rely on dormant embryos for survival of adverse environmental conditions, and their essential role in diverse ecosystems, it is imperative that we understand the effects that toxicants have on embryo viability.

P3.94 JAECKLE, William B*; STRATHMANN, Richard R; Illinois Wesleyan University, Bloomington, Friday Harbor Labs and Univ. Washington, Seattle; *wjaeckle@iwu.edu*

The anus as a second mouth: Anal suspension-feeding by an oral deposit-feeding sea cucumber

Respiratory trees of holothurians are blind-ended evaginations of the posterior digestive system that are rhythmically inflated with seawater via the anus and are considered to have respiratory and excretory functions. We tested the assimilatory capability of the respiratory tree epithelium by exposing adults of the oral deposit-feeding aspidochirotid sea cucumber *Parastichopus californicus* to (1) ^{14}C-labelled unicellular algae and (2) iron-containing macromolecules and then following the distribution of the labels in tissues. The ^{14}C label distribution indicated uptake by the respiratory tree and transfer to the associated hemal system. The iron-label from the protein ferritin and the polysaccharide iron dextran entered cells of the endothelium of the respiratory tree; mesenchyme cells within the connective tissue compartment of the respiratory tree were also labeled in ferritin exposed specimens, suggesting an avenue for transfer of materials. Nutritionally, holothurians appear to be bipolar anal retentives; the anus serves as a second mouth.

P3.172 JALLI, I.S.*; NIJHOUT, H.F.; Duke University; *isj@duke.edu*

Physiological response to homocysteine stress in Escherichia coli

Variation in response to environmental homocysteine stress on lab strain *Escherichia coli* (MG1655) and wild isolates is studied. The methionine cycle, a pathway central to the regulation of intracellular homocysteine, is mathematically modeled. The math model helps account for variation in growth and physiological response to metabolite stress in *E. coli*, both in lab strain and wild isolates. We also report on the effects of S-methylmethionine, a plant-derived metabolite common in the environment but poorly studied in relation to metabolic stress, on *E. coli* growth and intracellular physiology.

P1.212 JAYASUNDARA, N.*; SOMERO, G.N.; Stanford University; *nishadj@stanford.edu*

Cardiac thermal plasticity in the longjaw mudsucker Gillichthys mirabilis

An insufficient supply of oxygen under thermal stress is thought define thermal limits in aquatic animals including fish. In most fish venous blood provides oxygen to the hearts. Considering the already depleted Po_2 in venous return, fish cardiac performance might be compromised when under a thermal stress. Thus heart function might play a key role in establishing thermal limits in fish. We investigated effects of temperature acclimation on cardiac function of a eurythermal goby fish, the longjaw mudsucker *Gillichthys mirabilis*. We measured heart rate, metabolic enzyme activity, hemoglobin content and the change in global protein expression in fish acclimated to 9°C, 19°C and 26°C. Heart rate measurements were recorded under an acute heat ramp until the fish reached their cardiac arrhythmia temperature (T_A). Fish acclimated to 9°C for one month had a lower heart rate than 19°C and 26°C acclimated fish at their respective acclimation temperatures. Fish acclimated to higher temperatures were able to extend their T_A by 7°C; however, there was no significant difference between 19°C and 26°C acclimated fish. Blood hemoglobin content increased significantly with acclimation temperature, from 35 g/L in 9°C fish to 60-80 g/L in 19°C and 26°C fish. Fish acclimated to 26°C showed a decrease in aerobic metabolism. Elevated anaerobic enzyme activities were detected at both 9°C and 26°C. Global proteomic analysis suggests a variation in protein expression across different acclimation temperatures. These results illustrate the phenotypic plasticity of G. mirabilis and suggest that this eurythermal species maximizes its ability to circulate O_2 at 19°C, a temperature shown by behavioral studies to be close to the species' preferred temperature.

P2.169 JAYNE, Melissa K.*; DUDLEY, Erin; GREENE, Virginia; MOORE, Ignacio T.; DAVIS, Jason E.; Radford University, Virginia Tech, Virginia Tech; *MJayne2@radford.edu*

Effects of short term stress on plasma corticosterone and testosterone levels in captive and wild house sparrows (Passer domesticus)

A trade-off exists between stress and reproduction in which allocation of energetic resources to support individual survival may result in a temporary decrease in allocation to reproduction. Chronic stress can lead to long term dysregulation of stress responses, including reductions in baseline corticosteroids, alterations to corticosteroid response profiles, and inhibition of reproductive function. Acute stress can also cause dramatic alterations to reproductive physiology, including a rapid reduction in plasma testosterone. This may serve to reduce short-term reproductive activity, freeing resources for investment in individual survival. It is unclear what effect moderate chronic stress, such as captive housing, might have on the dynamics of the acute stress-reproductive interaction. In order to examine this system, we conducted a study in which corticosterone and testosterone levels were measured in male house sparrows (*Passer domesticus*), at baseline (< 3 minutes after capture) and after 60 minutes of restraint in both captive and wild conditions. Our study found that male house sparrows subjected to 60 minutes of restraint displayed both an increase in corticosterone as well as a simultaneous decrease in testosterone. Captive housed males exhibited decreased baseline testosterone relative to wild males. However, both captive and wild males exhibited an increase in corticosterone and a decrease in testosterone following acute stress. These findings demonstrate the importance of acute stress in control of reproductive physiology, even under chronic stress conditions.

P1.215 JEFIMOW, M*; GUTOWSKI, JP; WOJCIECHOWSKI , MS; Nicolaus Copernicus University, Torun, POLAND; *jefimow@umk.pl*

Different diet does not affect thermal preferences and daily energy expenditure of golden and Siberian hamsters

To test the prediction that the degree of dietary fat unsaturation affects thermal preferences and daily energy expenditure of animals we measured oxygen consumption of golden and Siberian hamsters in a thermal gradient system. Animals were housed under semi-natural conditions of Central Poland and fed standard food supplemented with mealworms (M-Group) or with sunflower and flax seeds (S-Group). In winter (December) we measured oxygen consumption of hamsters placed in a thermal gradient system where ambient temperature (T_a) ranged between 5 and 45 °C. Mean mass-specific daily (24h) energy expenditure (DEE/m_b) of Siberian hamsters from M-Group and S-Group was the same (1.09±0.19 and 1.08±0.09kJ/g, respectively). In golden hamsters mean DEE/m_b was 0.72±0.18 and 0.79±0.10 kJ/g, in M-Group and S-Group, respectively. In Siberian hamsters mean T_a selected in the thermal gradient system was 28.8±2.8 °C in M-Group and 27.3±2.2 °C in S-Group (p>0.05). In golden hamsters these values were 29.7±2.3 °C and 28.2±2.7 °C, respectively (p>0.05). Mass-specific metabolic rate (MR/m_b) was not affected by dietary supplements and equalled 12.6±2.2 and 12.5±1.1 mW/g in M- and S-Group of Siberian hamsters and 8.4±2.1 and 9.1±1.2 mW/g in M- and S-Group of golden hamsters (p>0.05). We did not record day-night differences in DEE/m_b, selected T_a and MR/m_b in either Siberian or golden hamsters. These results suggest that dietary fat unsaturation does not affect thermal preferences and daily energy expenditure of Siberian and golden hamsters. *This work was supported by a grant from the Polish Ministry of Science and Higher Education [N N303 347535].*

P2.65 JEMMETT, Jessica*; STAROBINSKYA, Ella; WOZNICA, Arielle; DAVIDSON, Brad; University of Arizona, Tucson; *jjemmett@email.arizona.edu*

FGF/Ets Target Genes in Ciona intestinalis Heart Cell Specification

Activation of the transcription factor Ets1/2 through FGF signaling is known to specify heart cell precursor fate in *Ciona intestinalis*. In previous research, we identified candidate target genes of Ets1/2 through microarray analysis. Through in situ hybridzation assays we have identified a subset of these candidate genes that are expressed specifically in the heart precursor cells immediately following their specification. To find the enhancers for the regulation of these presumed Ets target genes, we are employing bioinformatics to find conserved areas of DNA in the upstream non-coding DNA between *Ciona intestinalis* and *Ciona savignyi*. This analysis will be used to guide ongoing efforts to clone and test predicted enhancer regions using reporter constructs. In depth analysis of identified enhancers will be used to find transcription binding sites for Ets and identify co-transcirption factors presumed to act in concert with Ets to drive heart precursor cell specification.

P3.113 JENNEY, C.R.*; BOUCHARD, S.S.; WARKENTIN, K.M.; Otterbein Univ., Boston Univ.; *chelsea.jenney@otterbein.edu*

Carryover effects of larval digestive plasticity in postmetamorphic red-eyed treefrogs, Agalychnis callidryas

Larval environment has a profound effect on post-metamorphic nutrition in red-eyed treefrogs. Small froglets emerging from high density larval environments begin feeding sooner and grow at a faster rate than large froglets from low density environments. Additionally, froglet insect intake does not scale with body size despite large differences in froglet mass. We assessed to what extent these patterns could be attributed to effects of larval plasticity that carry over post-metamorphosis. We hypothesized that larvae from high densities would have longer guts (increasing digestive efficiency) and smaller livers (reducing metabolic costs) in response to lower per capita food resources. We reared larvae at three densities (5, 25 and 45 individuals per 400 L tank), and euthanized 10 size-matched larvae and 10 froglets from each density. We dissected and weighed the guts, livers, and fat bodies of all individuals. The guts were uncoiled and photographed, and gut length and area were assessed using image analysis software. As predicted, guts of high- and medium-density larvae were 23% longer than those of low-density larvae, and livers and fat bodies were significantly smaller. Low-density froglets were three times heavier than high-density froglets. Despite this extreme size difference, gut length did not vary with density, although high- and medium-density guts were lighter and thinner than low-density guts. High- and medium-density froglets also had proportionately smaller livers and fat bodies than low-density froglets. These results confirm carryover effects of larval plasticity post-metamorphosis and likely have important metabolic implications for froglets leaving the pond.

P1.2 JIMENEZ, R.R.; ABINETTE, S.H.*; TOUCHON, J.C. ; VONESH, J.R. ; WARKENTIN, K.M. ; Univ. Nac. de Costa Rica, Virginia Commonwealth Univ., Boston Univ., Boston Univ.; *randall87@gmail.com*

Ontogeny of risk across the aquatic-terrestrial interface: how changing behavior and morphology affect predation through anuran metamorphosis

Metamorphosis dramatically changes morphology, physiology, behavior and performance. As anurans change from aquatic tadpoles to terrestrial juveniles, they pass through a period of poor locomotor performance and high predation risk, and individuals behaviorally determine when they shift habitats. Red-eyed treefrogs, *Agalychnis callidryas*, alter when they move onto land in response to aquatic giant water bugs and semi-terrestrial fishing spiders. We conducted predation trials and behavioral experiments at multiple stages to assess changes in the interactions of *A. callidryas* with each predator through metamorphosis. In aquatic trials, *A. callidryas* reduced activity with both forelimb emergence and chemical cues from water bugs. Nonetheless, forelimb emergence substantially increased the predation rate. In semi-terrestrial trials, conducted in shallow water with dense floating vegetation, metamorph activity increased as tails were resorbed, and metamorphs did not reduce activity in the presence of a spider. Predation by spiders increased as metamorphs resorbed their tails. Close observation in small venues revealed that most spider attacks occurred after metamorph movements, and attack rates on shorter-tailed metamorphs were higher. Longer-tailed metamorphs were, however, less likely to escape from attacks. Thus, the ability of metamorphs to behaviorally compensate for morphological constraints on escape ability appears to be better out of the water. Nonetheless, in natural ponds, the effect of activity on the rate of encounters with pond-associated predators will depend on how rapidly metamorphs leave the environs of the pond.

P3.144 JONES, S.K.*; MILLER, L.A.; HEDRICK, T.L.; Univ. of North Carolina, Chapel Hill; *skjohnsn@email.unc.edu*

Dynamic Drag of Broad Leaves and Physical Models in Strong Wind

Leaves reconfigure into cone shapes that reduce drag in strong wind and moving water, compared to rigid objects of similar surface area. The flexibility of the leaves allows for reconfiguration, which is responsible for the reduction in drag. However, flexibility and reconfiguration are themselves insufficient to produce a reduction in drag; objects such as flags experience greater drag than equal area flat plates. Thus, it is not clear how flexible leaves reconfigure into stable shapes with reduced flutter and oscillations. Here, the dynamic drag experienced by tulip poplar, *Liriodendron tulipifera*, leaves in wind are compared to physical models of flexible sheets attached to petiole-like flexible beams. Leaves and physical models are attached to a cantilever beam equipped with strain gauges to measure dynamic drag over a range of wind speeds in a wind tunnel. Flutter and oscillation frequencies are analyzed by inspecting the power spectrum of the drag signal. Average drag, peak drag and frequency of oscillation are compared in leaves and physical models. Flexible rectangular models that reconfigure into U-shapes experience larger peak forces and oscillation compared to models that reconfigure into a cone-shape. These results suggest that the three-dimensional cone shape adopted by leaves, in addition to flexibility, is important to reducing forces.

P1.101 JORGENSEN, Michael,E.; Ohio University; *mj207406@ohio.edu*

Examining the relationship between locomotor mode and rate of morphological evolution in frogs.

Recent studies posit that habitat use affects the rate of morphological evolution in animals. Aspects of an animals' morphology in part determine the way in which it interacts with its habitat. Anurans comprise a morphologically diverse group that has a global distribution and possess taxa that inhabit all but marine environments. Many of these frog groups seem to have undergone adaptive radiations at certain points in their evolution. Yet we know little about these radiations, the rates of morphological evolution in frogs, or if these evolutionary rates are correlated with some artifact of frog habitat use. One of the first steps to approaching this multi-faceted inquiry is to examine the relationship between locomotor behavior ([swim: aquatic; hop/jump: terrestrial; hop/walk/climb: scansorial; climb/jump: arboreal; burrow/walk/hop: fossorial]), and rate of morphological evolution in locomotor traits. Using a variety of packages implemented in the R statistical program I investigate the model and rate of evolution of each frog loco-morph trait within lineages across the frog phylogeny, then compare rate changes with locomotor modes to probe for a relationship between locomotor mode and rate of morphological evolution.

P1.95 KAATZ, I.M.*; STEWART, D.J.; SUNY-ESF Syracuse NY; *ingridmkaatz1@yahoo.com*

Morphological correlates of vocal traits in a clade of Neotropical catfishes (Siluriformes: Doradidae and Auchenipteridae): an adaptive radiation driven by vocal traits?

Signal divergence can drive speciation events. We found phylogenetic shifts in disturbance sound and vocal morphology traits at the genus level among doradoids, a catfish superfamily (Doradidae and Auchenipteridae; 20 genera, 25 species, 1-15 individual/species). The basal condition, represented by the Aspredinidae, is low dominant frequency and absence of accessory vocal mechanism structures. Doradoid derived vocal morphology includes an ESA (elastic spring apparatus) with vocal muscles that arise on the posterior cranium attaching to the anterior face of the ESA that inserts into the swimbladder. Diverticula, outpocketings of the swimbladder wall, are also derived. Vocal morphotypes and signal traits were compared between outgroups and doradoid families using t-tests, ANOVA and ANCOVA. In the family Doradidae sounds with lower dominant frequency are present in genera with larger (>1cm long) diverticula, although genera with different types of diverticula or their absence have similar sounds. Doradids producing the highest dominant frequency sounds have reduced (conical and plug-shaped) ESA processes while genera that produce lower dominant frequency sounds have discoid ESA processes. Auchenipterids varied in dominant frequency but lacked diverticula and had discoid ESA processes. Recurring transitions in sound frequency among doradoids suggests that these traits may correlate with an evolutionary driver that could be either: 1) incidental change along an ecomorphological gradient effecting changes in body form; or 2) changes in vocal morphology directly selected to serve sound communication functions in different behavioral contexts or under different environmental constraints.

P3.55 KAINI, P*; SHRESTHA, S; ROBERTS, B; ZHU, N; BRODIE, R; Mount Holyoke College; *rbrodie@mtholyoke.edu*
Response to adult conspecific odor is modulated by salinity in metamorphosing megalopae of the fiddler crab Uca minax
The complex lifecycle of decapod crustaceans involves a free swimming larval stage and a benthic adult stage. Larvae of the fiddler crab *Uca minax* are spawned in freshwater and low salinity adult habitats along tidal rivers, then travel downstream to the coast where they complete larval development in the marine plankton. After metamorphosing to the megalopal stage, they return to inland tidal creeks where they metamorphose again into juvenile crabs and remain as adults. Previous studies have demonstrated that adult conspecific odor is a potent metamorphic cue for megalopae. However, in natural environments, adult odors could be advected downstream during ebb tides into high salinity areas. Because a response to odor alone could lead megalopae to settle and metamorphose in inappropriate areas, we hypothesized that megalopae would not respond to conspecific odor unless they were in a low salinity environment. In a laboratory experiment, we found that megalopae delayed metamorphosis in low salinity (5), high salinity (25) and high salinity plus odor cue treatments. Megalopae metamorphosed about a week sooner in the treatment that included an adult conspecific odor cue in a low salinity environment. Hence, salinity modulates the response to the adult odor metamorphic cue in this species.

P2.157 KANAGAWA, M*; MURPHY, DW; WEBSTER, DR; KAWAGUCHI, S; KING, R; YEN, J; Georgia Institute of Technology, Australian Antarctic Division; *marleenkanagawa@gmail.com*
Swarming to Schooling Transitions in Antarctic Krill Aggregations
Collective animal behavior is a natural phenomenon in which up to thousands of animals self-organize into groups without an apparent external stimulus. Antarctic krill (*Euphausia superba*) aggregations display such behavior as they transition from random swimming in swarms to coordinated swimming in schools. These schools may range up to 100 meters deep and several kilometers in length. The factors that initiate this self organization and the process by which it occurs are unknown, although animal aggregation density is thought to play a role. We present an analysis of a swarming to schooling progression in Antarctic krill using three-dimensional animal positions derived from stereophotogrammetric videos acquired at the Australian Antarctic Division (AAD) in Hobart, Tasmania. Using a 45-minute time series, animal positions and headings (taken at 3-minute intervals) were interrogated for parameters such as speed, polarity, and average nearest neighbor distance. The analysis showed a sharp change in the group polarity over a short period of time as the animals moved from swarming to schooling behavior. Possible factors that initiate this change will be discussed.

P3.32 KAO, S.T.*; HADFIELD, M.G.; Univ. of Hawaii, Manoa; *skao@hawaii.edu*
The effects of ocean acidification on biofilm bacterial populations
In marine ecosystems, bacteria are major components of biofilms on all surfaces. Marine bacterial films are known to provide essential cues for recruitment of benthic animals and algae. With global climate change occurring at a rapid rate, the natural environment that marine bacterial biofilms occupy has begun to change. Continued atmospheric CO_2 emissions are causing increasing ocean acidification. While previous studies of the impacts of declining ocean pH have focused primarily on calcifying organisms, the current study examined how declining pH may affect bacterial biofilm communities. The effects of three acidity levels on survival and diversity of biofilm bacteria from Pearl Harbor, HI were examined: pH 8.20 (the pH of seawater at Pearl Harbor, HI), pH 7.85, the estimated pH of the ocean by 2105, and pH 7.60, the estimated pH of seawater by 2205. A LIVE/DEAD® Bac-light™ viability kit was used to assess bacterial viability and densities after 5 days in the altered pH treatments. The live to dead bacterial cell ratios for all treatments were above 1, confirming that for all test groups the pH treatments were not toxic to bacteria. Bacterial density counts revealed no significant differences between pH treatments and the control. The bacterial communities in seawater of different acidity levels were compared using Denaturing Gradient Gel Electrophoresis (DGGE). A PCR-amplified fragment of the 16s rDNA gene was used in the DGGE analysis. Preliminary results show low and similar diversity in the biofilm bacterial communities across pH treatments. These results may be due to selection of a very few hardy bacterial strains by the warm polluted waters of Pearl Harbor during the summer, a hypothesis being examined in on-going studies.

P1.54 KAPPER, M.A.; Central Connecticut State University, New Britain; *kapper@ccsu.edu*
IS THE SUBCELLULAR LOCATION OF AQUAPORIN-2 REGULATED BY REVERSIBLE PHOSPHORYLATION DURING SALINITY ADAPTATION IN G. demissa GILL?
Water permeability of cell membranes is predominantly controlled by the presence of aquaporins. When water permeability is changed for physiological reasons, aquaporins will be inserted or removed from the cell membranes. In the collecting duct of the mammalian kidney, aquaporins located in cytosolic vesicles are phosphorylated by a cAMP activated protein kinase when antidiuretic hormone binds to cell surface receptors. These vesicles are then incorporated into the cell membranes, increasing their water permeability. Constitutively active protein phosphatases dephosphorylate the aquaporins, initiating their removal from the cell membranes. It is well known that osmoconforming marine invertebrates lessen or eliminate the osmotic gradient imposed by the changing tides by modulating the concentration of intracellular organic osmolytes, primarily free amino acids. Before this regulatory step is completed, there is a transient change in cell volume due to osmotic movement of water across the cell membranes. We are testing the hypothesis that water permeability in gill epithelia of the ribbed mussel *Geukensia demissa* is modulated by removing aquaporins from the cell membranes during the initial stages of salinity adaptation. Immunofluorescence microscopy suggests that aquaporin proteins are removed from the cell membrane after transfer from low to high salinity. Western blotting and immunoprecipitation indicate that both phosphorylated and unphosphorylated forms of aquaporin-2 are present in *G. demissa* gill. We are currently determining whether the amount of unphosphorylated aquaporin increases during the initial stages of salinity adaptation. Supported by a CSU/AAUP Faculty Research Grant to MAK.

P3.47 KARCH, KELLY R.*; FIELDS, PETER A.; Franklin and Marshall College; *kelly.karch@fandm.edu*

Effects of Chronic Heat Exposure on Protein Expression in the Mussel Geukensia demissa

Geukensia demissa, the ribbed salt marsh mussel, inhabits intertidal zones from the Gulf of St. Lawrence to the Gulf of Mexico. Salt marshes are harsh environments for intertidal organisms, and this species experiences physiological stress from a number of abiotic factors. For example, the body temperature of *Geukensia* individuals can vary drastically both daily and seasonally, at times approaching the species' upper lethal limit. My study focuses on discovering and describing changes in protein expression during acclimation to high temperature to determine how these organisms cope with chronic environmental stress. Control mussels collected from southern New Jersey were acclimated to 15°C for three weeks, while treatment groups were exposed to 20°C, 25°C, 30°C or 35°C for three weeks. All mussels exposed to 35°C died within two weeks, but individuals acclimated to lower temperatures survived. Proteins were extracted from the gill tissue of six mussels per group, and proteins were separated using 2D-gel electrophoresis. Changes in protein abundance were detected and measured using gel image analysis software. An ANOVA test revealed that of 1,060 proteins detected, 61 showed significant differences in expression between groups. I used Pavlidis template matching (PTM) to identify proteins that increased in abundance most significantly under each treatment, and I am using liquid chromatography-tandem mass spectrometry (LC-MS/MS) to attempt to identify these proteins. My results will provide insight into which proteins and biochemical pathways are most important in adapting to chronic heat stress.

P1.210 KAWARASAKI, Y.*; TEETS, N.M.; KOBELKOVA, A.; DENLINGER, D.L.; LEE, R.E.; Miami University, Oxford OH, Ohio State University, Columbus OH; *kawaray@muohio.edu*

Rapid cold-hardening in the frozen state increases cold tolerance in the Antarctic midge, Belgica antarctica

Endemic to the Antarctic Peninsula, the Antarctic midge, *Belgica antarctica (Diptera: Chironomidae), is the southernmost insect. During its two-year life cycle, larvae must endure extended periods of sub-zero temperature. These larvae are unique in their capacity to undergo rapid cold-hardening (RCH) while frozen. In this study, we further characterized this acclimatory response. The temperature of crystallization was -7.3 ± 0.6 &degC. RCH occurred at temperatures as low as -12 &degC, significantly increasing survival rates from 22.0 ± 5.7% (control) to 98.2 ± 1.8% after exposure to -18 &degC for 24 h. At the cellular level, RCH at -5 &degC for 2 h significantly increased survival rates of midgut cells from 32.1 ± 5.9% to 76.0 ± 1.6%. To compare the capacity for RCH in supercooled and frozen larvae, two groups of larvae were acclimated at -5 &degC for 2 h. Frozen larvae were significantly more cold tolerant than supercooled larvae, 84.8 ± 2.7% and 49.3 ± 5.8% respectively. As little as 1 h at -5 &degC significantly increased survival of larvae at -18 &degC. Similarly, protection by RCH was rapidly lost upon warming— After 2 h at 2 &degC, the cold tolerance was indistinguishable from control values. These results suggest that larvae can quickly change their cold tolerance in response to diurnal and capricious changes in microclimatic temperature on the Antarctic Peninsula.* *Supported by NSF grants ANT-0837559 and ANT-0837613.*

P2.14 KEDDELL, Robert/W*; DRAKES, Damisha; SHIFFLETT, Brandon; SCHOLL, Noah; MORTENSON, Chris; Johns Hopkins University; *bkeddell@aol.com*

stri researchers in k-12 scientific literacy programming

STRI RESEARCHERS IN K-12 SCIENTIFIC LITERACY PROGRAMMING Visit this poster session to learn about a K-12 Motivation Education Program entitled RAINFOREST RESEARCHERS. The teaching methodology emulates and simulates the work of scientists working at the Smithsonian Tropical Research Institute of Panama. This program, now in its eighth year, integrates the AAAS Benchmarks for Scientific Literacy with the Theory of Multiple Intelligences and the Teach for Understanding Framework found in Harvard's WIDE World Education coursework. The full program is used with families, at risk youth, museum visitors and in school based programming.

P3.170 KELLENBERGER, JW*; VIRAY, EN; SMITH, AL; HAHN, DA; HATLE, JD; Univ. of North Florida, Univ. of Florida; *jhatle@unf.edu*

Life-extending ovariectomization or dietary restriction each show a lack of cellular responses, despite large differences in storage levels, in grasshoppers

Reduced reproduction or reduced diet extends lifespan in many animals. Because life-extending dietary restriction (DR) decreases fecundity, it has been suggested that reduced reproduction and reduced diet may extend lifespan by similar mechanisms. In the grasshopper *Romalea microptera*, ovariectomy (OVX) increased lifespan 16% and reduced feeding 36%. Dietary restriction (a 30% reduction in feeding) increased lifespan 17% and reduced fecundity 15%. These similarities led us to compare the physiology of OVX grasshoppers with DR grasshoppers that were fed the same amount as that consumed by the OVX group. Ovariectomy increased fat body mass 3-fold and increased collected hemolymph 5-fold (both $P<0.0001$), a massive increase in storage tissue. Historically, the free-radical theory of aging has suggested that increased anti-oxidant activity may help increase lifespan. However, no significant differences were recorded in total anti-oxidant activity for mandibular muscle ($P=0.62$) or hemolymph ($P=0.12$) due to OVX or DR. A more recent hypothesis of aging suggests that increased mitochondrial count decreases mitochondrial workload, leading to lifespan extension. Estimates of mitochondrial counts in fat body tissues showed no effects of OVX or DR ($P=0.27$). TOR signaling, a nutrient-dependent sister pathway to insulin-like signaling, has also been implicated in mediating lifespan by DR. No effect of DR or OVX was observed on TOR transcript quantity in femur muscle ($P=0.23$). Thus far, life extension by OVX and DR appear to work through massively different levels of organismal storage but similar cellular responses. We thank NIH for awarding 1R15AG028512-01 and 2R15AG028512-02A1 to JH.

P2.80 KEMER, K.M.*; FURIMSKY, M.M.; Westminster College, PA; *kemerkm@wclive.westminster.edu*

The Development of the Visual System in the Polyodon spathula

The paddlefish, *Polyodon spathula*, is a primitive cartilaginous fish that lives primarily in the Mississippi river system in the United States. These economically important fish are thriving over some parts of their historical range, but their numbers have been slowly declining in many areas due to human activities and they are already extirpated in parts of the U.S. and Canada. Strong efforts are, however, being made to re-introduce this species to its original native waters, including rivers in western Pennsylvania. Paddlefish are the largest species of freshwater fish in the United States and are distinguished by their elongated snout, the rostrum, and their heterocercal tail. The rostrum is a sensory organ which uses electroreception to locate zooplankton in the deep murky water which is their preferred habitat. The visual system, however, remains a key part of the paddlefish's ability to sense its environment. Following hatching, paddlefish rely solely on their eyes for prey detection until the rostrum begins to develop. In the fully developed eyes, the photoreceptor layer of the retina contains a higher percentage of rods than cones, allowing the paddlefish to see easily in the dimly lit water. Since very little is known about paddlefish development and anatomy, the purpose of this study was to use a histological approach to describe visual system development and ocular structure in these prehistoric animals. The results of this study will be presented.

P2.105 KEMIREMBE, K*; LIEBMANN, K.L.; SMITH, W.A.; SUZUKI, Y; Wellesley College, Northeastern University; *ysuzuki@wellesley.edu*

The effects of diet on the timing of larval molts in the tobacco hornworm, Manduca sexta.

In insects, juvenile growth occurs by molting, in which the animal sheds its old skin and acquires a new one. It is known that the release of the steroid hormone, ecdysone, plays a key part in the initiation of the molt, but the signals that trigger the timing of its release remain poorly understood. Previous studies have shown that nutritional inputs influence the timing of a molt. In order to determine the role of diet on molt timing, fourth instar *Manduca sexta* were fed different diets lacking specific nutrients. Animals were monitored, weighed daily and sacrificed for dissection of the prothoracic gland, from which ecdysone is released. Animals fed amino acid-deficient diets failed to molt. All essential amino acids were discovered to be necessary for molting, although those animals fed diets lacking tryptophan were found to be capable of surviving for more than three times the usual instar duration. Rapamycin, an inhibitor of amino acid sensor target of rapamycin (TOR) signaling, was found to delay molting without dramatic retardation of growth. Furthermore, the growth of prothoracic gland was found to be particularly sensitive to nutritional intake. A model linking nutrients to the timing of a larval molt will be presented.

P2.113 KHALILIEH, A,I.*; MCCUE, M,D.; PINSHOW, B; Mitrani Dept of Desert Ecol, Jacob Blaustein Inst Desert Research, Ben-Gurion Univ of the Negev, 84990, Dept of Biol Sci, St. Mary's Univ, San Antonio TX, 78228; *anton_khalilieh@yahoo.com*

House sparrows oxidize endogenous fuels differently from fasting-adapted species

Many wild birds fast during reproduction, molting, migration, or because of limited food availability. Fasting-adapted species sequentially oxidize endogenous fuels in three phases; post-absorptive phase; protein sparing phase; and lethal phase. We hypothesized that species not adapted to long fasts have truncated, but otherwise similar fasting phases, sequential changes in fuel oxidization, and similar blood metabolite changes, to fasting-adapted species. To test the predictions that 1) fasting birds sequentially oxidize substrates in the order: carbohydrates, lipids, and protein; and 2) changes in blood metabolites reflect changes in metabolic fuels as determined by breath analysis. We analyzed the birds' breath for $^{13}CO_2$ at regular intervals for 24 h after dosing with labeled glucose, palmitic acid, and glycine; we also analyzed plasma for metabolites that reflect catabolism of these substances. Contrary to prediction 1, we found continuous, parallel oxidation of the fuels that correlate with changes in blood metabolites, and these did not indicate division into discrete phases. The rate of glycine oxidization peaked at 30 min, at 2705±687 mmolmin^{-1} and was also significantly higher ($p<0.001$) than all other tracers at all post-dosing intervals. Plasma glucose concentration was lowest at hour 8 (225.5±49.7mg/dl) while plasma β-hydroxybutyrate levels increased 6 fold, to 64.3±5.3 mg/dl at the same time. We conclude that the inability of house sparrows to fast for longer than 24 hours is likely related to their inability to separately use different fuels as do fasting-adapted birds.

P1.158 KHOZEIN, R.T.*; CASTRO, D.J.; MCCARTHER, N.M.; WADE, J.; JOHNSON, M.A.; Trinity University, San Antonio, TX, Michigan State University; *rkhozein@trinity.edu*

Evolution of muscle physiology and reproductive behavior in Anolis lizards

Across animal taxa, the morphology and physiology of muscle fibers are generally associated with the frequency and duration of contractions of those muscles, but these traits remain rarely considered in an explicitly phylogenetic context. In this study, we examined muscles involved in copulation and social display to determine evolutionary relationships between muscle contractile speed, endurance, and the behavioral use of these muscles. We used tissues from ten males of each of nine *Anolis* lizard species (eight Caribbean species and the green anole *Anolis carolinensis*) to characterize fibers in a copulatory muscle (retractor penis magnus; or RPM) and a muscle involved in dewlap extension (ceratohyoid). We stained these muscle fibers for myosin ATPase, which provides a measure of contraction speed, and succinate dehydrogenase, which provides a measure of aerobic capacity. With these two stains, we distinguished each fiber as fast-glycolytic (FG; used in quick, high intensity movements), fast oxidative glycolytic (FOG) or slow oxidative (SO; used in longer duration movements), or tonic (T; used in slow movements). Consistent with previous work on the green anole, our results show that RPM fibers are strikingly homogenous across species, while fiber type composition of the ceratohyoid is heterogeneous. In a subset of four species, we found that while all the species have the highest proportion of FOG fibers (compared to other fiber types) in the ceratohyoid, SO fibers appear to be more prevalent in species with low rates of dewlap extension. Together, these results suggest that fiber type evolution may be differentially associated with the behavioral use of muscles in this species group.

P2.154 KIDERA, N.*; MORI, A.; TU, M.C.; National Taiwan Normal Univ., Kyoto Univ.; *h089890@lab.u-ryukyu.ac.jp*

Can sea kraits detect freshwater resource?

Water is indispensable for any organisms. Most of marine animals possess physiological osmoregulation system to survive in the environment surrounded by higher salinity than their internal salinity. Sea snakes are also known to possess salt glands to excrete excess salts. Because of this, it has been thought that they are able to maintain water balance without consuming freshwater. Recent studies, however, demonstrated that amphibious sea kraits (*Laticauda* spp.) refuse seawater and require freshwater or highly dilute water to maintain water balance. Furthermore these studies revealed that the sea kraits are quite abundant at sites where freshwater are available. These facts suggest that the sea kraits require not only the physiological osmoregulation function but also the ability to detect freshwater. Using *Laticauda* species, we investigated their ability to discriminate water salinity. Dehydrated sea kraits were placed in Y-maze apparatus where freshwater and seawater were flowing out. Sea kraits selected more frequently the side connected to freshwater resource than the seawater side. Furthermore, the latency to reach freshwater resource was longer than that to reach seawater resource, implying that it takes times for the snakes to reach freshwater resource.

P2.19 KILGOUR, M.J.*; SHIRLEY, T.C.; Texas A&M University-Corpus Christi; *morgan.kilgour@tamucc.edu*

A zoogeographic analysis of galatheoid and chirostyloid crabs in the Gulf of Mexico

Galatheoid and chirostyloid crabs include squat lobsters or pinch bugs, and are prominent and abundant crustacean macrofauna in the deep Gulf of Mexico; we examined 3 galatheoid families and 2 chirostyloid families. We found 76 of the 84 species known from the Gulf from 1185 personal collections and museum lots. A typical inverse J curve was present; a few species were abundant, but most were rare. *Munida valida* and *Munida pusilla* were the most common species and represent one of the most common genera. Regional analysis of beta diversity and species richness of squat lobsters was completed by subdividing the Gulf into 48 polygons based on region and depth. Squat lobsters occurred in 39 of the 48 polygons in depths of 0 to >3000 m; 36 species occurred in one polygon in the Florida Strait. Diversity of galatheoids among the polygons and their distributional patterns were analyzed using similarity metrics, cluster and ordination techniques. Depth and region explained many distributional patterns; some species were depth restricted, while others were spatially restricted. The northern and eastern Gulf had higher species richness and diversity and were more similar to each other than to the southern and western Gulf. Sampling effort bias may offer partial explanations for this pattern. Each family of the Galatheoidea displayed bathymetric zonation. Although the Gulf of Mexico is approximately 2% of the area of either the Atlantic or Indian Oceans and is considerably shallower than either, the species richness of galatheoids and chirostyloids in the Gulf is about 50% of the species richness of these oceans. The Gulf of Mexico appears to be a galatheoid biodiversity hotspot; we expect more species to be discovered with continued exploration of deep habitats.

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Ontogeny of constitutive innate immune function in free-living altricial house sparrow nestlings

Some developmental studies in mammals and birds suggest that juveniles depend primarily on innate immune defenses during the growth period, given that adaptive defenses require weeks to generate cells with antigen-specific receptors. Studies of ontogenetic changes in altricial birds, which undergo rapid development post-hatch, have been few until relatively recently. We hypothesized that altricial house sparrows rapidly develop constitutive, innate immune function during the nestling period, and that function reaches adult levels prior to fledging (~15 days post-hatch (d) in house sparrows). We collected nestlings at 3, 6, 9, or 12 d. Body mass and skeletal lengths were measured and blood samples were taken for hematocrit and for analysis of 3 measures: natural antibody-mediated agglutination, complement-mediated lysis, and bacterial killing activity of lysozyme. Adults were sampled for comparison to nestlings. Body mass and tarsus length of nestlings increased with age, reaching adult levels by 9d, and hematocrit reached adult levels by 12d. We observed no significant increase in agglutination from 3d to 12d, while lysis activity gradually increased from 3d to 12d. Agglutination and lysis at 12d were at least 60% lower than adult levels. Lysozyme results and details of assay optimization will be reported. From the assays performed thus far, we conclude that constitutive innate immune function does not follow the rapid developmental patterns of other structural and physiological measures in house sparrows. Further, given that constitutive innate immune function is still at sub-adult level at the end of the nestling period, altricial fledglings may be more vulnerable to infection than adults. Support: NSF-GRF, USDA-Hatch, AOU.

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Visual Cues for Burrow Surveillance in Fiddler Crabs

Fiddler crabs show a surveillance behavior against a potential intruder to protect their burrow. In the vicinity of the intruder, they rush back to the burrow to keep its possesion. Recent work by biologists shows that crabs combine visual information and path integration. They can always do path integration to return to the burrow after exploring for food, indicating that crabs estimate the distance to the burrow from a far-away region. Additionally, a matched filter with the azimuth and elevation position of the intruder in the retinal view can draw the visual geometry of the environment. It is believed that crabs combine the visual information and path integration for the surveillance. Several visual cues including the position of an intruder, the apparent size and the speed of the intruder in the retinal map are available. To respond to the intruder appropriately, crabs should estimate the relative location of the intruder to the burrow. Here, we propose that the movement speed estimation of an intruder using the variation of size and transition of the intruder's movement in the retinal view can build a spatial geometry for the movement of the potential intruder. It can provide the distance and direction of the intruder from the burrow entrance. In our modeling experiments, it is shown that the target speed estimation can be another visual cue to judge the intruder-burrow distance. It suggests a hypothesis that crabs might use several different cues, azimuth and elevation of the intruder in the retinal view, the image size variation, and the movement speed in the retinal view.

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Electrolocation Measure in Weakly Electric Fish

There have been many approaches to explain the electrolocation process in weakly electric fish. A collection of electroreceptors along the rostrocaudal line can read the electric potential perturbed by a target object. The rotrocaudal position of the target can be simply estimated with the position of the maximum amplitude in the sensor readings. The lateral distance estimation needs non-trivial measures. Two representative measures are the maximum slope-to-maximum amplitude, and FWHM (Full Width at Half Maximum). The first measure has been suggested for the electrolocation with the pulse-type electric fish and the second with the wave-type. Our modeling studies suggest the the first measure can be applied to the electrolocation process for the wave-type electric fish. If we take the inverse of the slope-to-amplitude, the measure becomes similar to the FWHM. More exactly, the measure is simplified to the distance between the point with the maximum peak amplitude and zero crossing point in the electrosensor readings along the rostrocaudal line. From this analysis, the electrolocation measure can approximately localize a target object. This result is consistent with other modeling approaches for weakly electric fish, and also has the theoretical foundation in the analysis of electric field.

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Pelvic limb morphology in the lungfish Protopterus annectens

The lungfish *Protopterus annectens* is a benthic pelvic fin biped. Its long, slender pelvic fins are capable of a wide range of movements, and in particular are used during locomotion for substrate contact and propulsion. While it has been shown that the pelvic fins in *P. annectens* are composed of small, serially homologous skeletal elements, the arrangement and orientation of the muscles relative to the skeleton and how this morphology relates to the wide range of movement of the fin is unknown. Here we used histological methods to reconstruct a segment of the pelvic fins in *P. annectens*. The fins consist of a cartilaginous skeleton with serially repeating elements; between consecutive elements is a pad of soft connective tissue. Connective tissue sheets ran along the long axis of the fin from proximal to distal at an angle of approximately 15º relative to the medial skeleton, and were continuous around the circumference of the fin, in a cone shape. Each cone of connective tissue extends approximately two cartilage segments, originating at the skin distally and inserting on or near the joints between the cartilage segments. Between adjacent layers of connective tissue was a layer of muscle with varying fiber angles. Muscle is distributed around the skeleton and down the length of the fin. The muscles are not divided into discrete groups corresponding to the dorsoventral plane or adductor abductor regions, but appear to be radially arranged. We hypothesize that this cone-shaped arrangement of muscle, integrated with the skeletal elements and skin, provides bending and may also stiffen the fin, allowing for the complex movements observed during locomotion.

P1.160 KING, M.O.*; ZHANG, Y.; TORDSEN, T.; SWANSON, D.L.; University of South Dakota; *marisa.king@usd.edu*

Seasonal Phenotypic Flexibility of Muscle Aerobic Enzyme Activities in Small Birds.

Small birds increase thermogenic capacity during the energetically demanding periods of winter and migration. This increase could be supported by enhanced cellular aerobic capacity and provision of fats as fuel. We examined activities of citrate synthase (CS), beta-hydroxyacyl CoA dehydrogenase (HOAD) and carnitine palmitoyl acyl transferase (CPT) in skeletal muscles and heart in several species of small birds during migration and winter in cold climates to determine if enzyme activities varied with energy demand and thermogenic capacity. Pectoralis and heart CS activity increased in winter black-capped chickadees, but not in winter American goldfinches. Muscle CS activity did not vary significantly with migration for any muscle for any species. Muscle HOAD activity did not vary significantly with season or migration for any muscle or any species. CPT activity increased significantly with migration in some muscles of warbling vireo and yellow warbler, but decreased in heart muscle of yellow-rumped warbler and did not vary significantly in many cases. Muscle CPT activities did not increase with thermogenic capacity in winter birds. The absence of consistent variation in muscular enzyme activities with seasonal variation in energy demand agrees with previous data from small birds and suggests that this is not the principal mechanism generating phenotypically flexible responses of thermogenic capacity to changing energy demands. Future studies will include (1) path analysis of the lipid provision and catabolism pathway, including lipid transporters, to determine if lipids limit aerobic capacity during prolonged exercise and (2) examination of concomitant variation in muscle masses and regulation of seasonal or migration-induced muscle growth.

P3.186 KINGSLEY, R.J.*; ARMISTEAD, B.E; HOOPER, C.W.; OSZUSTOWICZ, A.L.; PALMER, A.D.; University of Richmond, Richmond VA, University of Richmond, Richmond VA;
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Bacterial endosymbionts in the gorgonian Leptogorgia virgulata and their potential role in spicule formation.

Leptogorgia virgulata is a gorgonian species lacking endosymbiotic zooxanthellae. Their possible relationship with symbiotic bacteria however, has not been previously studied. We are particularly interested in urease-producing bacteria, which could be involved in a pH regulatory mechanism in the calcifying tissues of *L. virgulata*. Like all calcifying systems, calcium carbonate spicule formation in *L. virgulata* causes a drop in pH, which must be quickly neutralized to prevent decalcification. We propose that bacterial urease catalyzes the hydrolysis of urea to ammonia and carbon dioxide. The subsequent formation of ammonium and bicarbonate ions would rapidly raise the pH, sustaining spicule formation. DGGE analysis shows a highly diverse microbial community within *L. virgulata*. The community structure varies depending on the different tissue types. Sequencing data illustrates the presence of at least one urease-producing strain of bacteria living in the *L. virgulata* tissue. Scanning electron microscopy also reveals the presence of bacteria in tissues. Preliminary stable isotope data indicates that bacteria are not a source of nutrition however; nitrogenous products appear to be transferred from bacteria to gorgonian host. These findings support our hypothesis that *L. virgulata* harbors endosymbiotic bacteria that may be involved in spicule calcification.

P2.26 KISH, N.*; HELMUTH, B.; DENNY, M.W.; University of South Carolina, Columbia, Stanford University; *kishn@email.sc.edu*
Predicting patterns of thermal stress in Mytilus californianus
In the marine intertidal zone, a variety of factors, such as air temperature, water temperature, wind speed, and solar radiation, drive the body temperatures and thus levels of physiological stress of the organisms that live there. However, temporal and spatial patterns in stress, mortality, and shifts in species distributions are frequently estimated using single environmental variables, such as air temperature, as proxies. Using seven years of temperature data collected by biomimetic sensors designed to mimic the thermal characteristics of the intertidal mussel *M. californianus* at Hopkins station, CA, and weather station data collected adjacent to this site, we analyzed the strength of the relationship between aerial (low tide) body temperature and air and water temperature at daily and monthly intervals. A very weak relationship (R^2 0.00-0.60) was found between all metrics of body and air temperature, with the strongest correlations observed between measurements of minimum body temperature and minimum air temperature. These results strongly suggest that studies relating measurements conducted at “habitat” level, such as air or water temperature, are not always good indicators of physiological stress, even in relative terms.

P1.148 KLINGENSMITH, K/C*; JORGENSEN, D/D; Roanoke College; *kcklingensmith@mail.roanoke.edu*
Immune Response to Acute Bacterial Exposure in the American Lobster
Bacterial infection in some crustacean arthropods evokes an immune response involving the mobilization of hemocytes that recognize and engulf the bacterial cells. It has been suggested that these hemocytes move to the gills through the circulation where they aggregate in gill hemolymph channels for later removal from the animal. Our experiments were designed to follow the timing of immune response in American lobsters (*Homarus americanus*) to acute bacterial exposure. *Vibrio campbellii* cells were suspended in lobster saline so that $2x10^8$ CFU (colony forming units) could be delivered in an injection volume of 0.5 µL/g wet body mass. Injection of bacterial suspension was made directly into the heart to insure rapid circulation. Access to the heart was made through an opening drilled in the carapace and sealed with dental dam. Hemolymph samples were withdrawn from the pericardial sinus at set time points and analyzed to determine bacterial and hemocyte hemolymph concentrations. Lobsters injected with saline alone served as controls. Our data show that nearly 90% of the bacteria are cleared from the hemolymph within 30 min post-injection. Circulating hemocyte concentrations decreased by nearly 2/3 within about 20 min post-injection, doubled within an hour, but returned to pre-injection levels within about 90 min. Our experiments suggest a relatively rapid and effective immune response to bacterial infection in lobsters.

P2.170 KLUKOWSKI, M; Middle Tennessee State University; *mklukows@mtsu.edu*
Influence of reproductive state on plasma corticosterone levels in free-living female fence lizards (Sceloporus undulatus).
Numerous factors have been shown to alter stress responsiveness in vertebrates including age, sex, season, body condition, and social status. The potential role of reproductive state has received less attention, particularly in reptiles. Since maternal steroids may be transferred to the yolk, elucidation of the influence of reproductive state on plasma corticosterone levels has important implications for offspring development and phenotype. Here I tested whether females of differing reproductive state (early-, late-vitellogenic, or gravid) differed in baseline or stress-induced levels of plasma corticosterone. Adult female fence lizards were captured in the field and bled as quickly as possible to obtain baseline blood samples. Females were subsequently confined for one hour in a cloth bag, bled again, and then brought into the laboratory where laparotomies were performed to determine each female’s reproductive condition. Females were released the following day. Plasma triglyceride and lactate levels were measured in addition to corticosterone. Gravid females had significantly higher baseline corticosterone levels than the vitellogenic groups and exhibited the weakest stress responses in terms of both corticosterone and lactate. All three groups differed in plasma triglyceride levels with the highest levels observed in late-vitellogenic females. Altogether these results indicate a substantial influence of reproductive condition on plasma corticosterone levels in female fence lizards. In particular, whether the relatively high baseline corticosterone levels observed in gravid females is indicative of chronic stress or plays some role in reproduction deserves further study.

P1.187 KNIGHT, M.S.*; FRANCIS, JR., A.W.; Armstrong Atlantic State Univ., Savannah, GA; *mk5278@stu.armstrong.edu*
Catch and Compare: Ichthoplankton Sampling Methods in a Georgia Estuary
This study examined the temporal distribution and abundance of ichthyoplankton occurring in the Moon River, a salt marsh estuary near Savannah, Georgia using two different nets over a three month period. The purpose of this study was to determine the effect of net design on ichthoplankton sampling by comparing juvenile fish collected by two different nets. Beginning in July 2011, weekly sampling was performed on a night flood tide. The two nets were deployed three separate times for 30 minutes each. Both ichthyoplankton nets had a diameter of 1 m, a 3:1 shape, and 1 mm in mesh. One net was a traditional bridle-based setup with an attached cod end jar. The second net was bridle-less with a dorsal float and ventral weight to orient the net and a bucket clasped to the end. The float and weight combination allowed the net to be lower in the water column than the bridled net. The bucket had several openings on one side covered by 1 mm mesh allowing water to pass through the end of the net. Additional abiotic factors were measured including weather and presence or absence of the moon, salinity, pH, dissolved oxygen, water depth, water temperature, water flow, and air temperature. The samples were preserved in the field with 10% formalin. In the lab, samples were sorted, identified to the lowest taxon, and transferred to 70% ethyl alcohol. A comparison of each net’s numbers of juvenile fish demonstrated that the bridle-less net collected greater numbers of each species than the bridled net. The bridle-less net also collected more species than the bridled net. The most common juvenile fishes were *Anchoa mitchilli*, *Gobiosoma bosc*, *Gobiosoma robustum*, and *Microgobius thalassinus*. *M. thalassinus* was one species only collected in the bridle-less net.

P3.13 KOHL, Z.F.*; HEDRICK, M.S.; CROSSLEY, D.A.; Univ. of N. Texas; *zac.f.kohl@gmail.com*

Ontogeny of viscosity in the chick embryo, Gallus gallus: Cheating the hematocrit dependence of blood viscosity

Peripheral resistance in the cardiovascular system is dictated by two variables, vessel geometry and blood viscosity (η_{bl}). While many studies have emphasized the vascular contribution, fewer studies have addressed the potential variance in resistance attributed to η_{bl}. Hematocrit (Hct) is the primary determinant of η_{bl} and rises during development, requiring embryonic animals to deal with increasing viscosity over the same time period. We measured η_{bl} of chick embryonic blood in the latter 50% of development and compared it to previous adult data at 38°C. We hypothesized that η_{bl} would increase as a function of Hct during development and would be comparable to adult blood over a similar range of Hct values. The equation for η_{bl} is $\eta_{bl}=\eta_{pl}^{(k*Hct)}$, where η_{bl} is plasma viscosity and k is a constant. Embryonic η_{bl} showed remarkably little variance at 1.67 ± 0.03 centipoise (n=27; ±SEM) at 60%, 70%, 80%, and 90% of incubation (days 13, 15, 17, and 19) with a range of measured Hcts of 18-35%. Embryo η_{bl} was also invariant when Hct was set to 20-40% at 1.72 ± 0.04 centipoise (n=29) and began to increase exponentially when Hct exceeded 40%. Blood viscosity as a function of Hct is described in embryos by $\eta_{bl}=0.57^{(0.036*Hct)}$ and in adults by $\eta_{bl}=0.96^{(0.039*Hct)}$. Overall, embryonic chickens had 55 ± 1.4% (n=39) lower η_{bl} than adults from 0-70% Hct, and this lower viscosity cannot be attributed only to differences in plasma viscosity. The unique viscous properties of chick embryo blood allow systemic O_2 transport capacity to increase during development while minimizing resistance to blood flow due to η_{bl}. Supported by NSF CAREER IBN IOS-0845741 to DAC.

P3.97 KOLMANN, Matthew A*; HUBER, Daniel R; DEAN, Mason; ERICKSON, Gregory M; GRUBBS, R Dean; Florida State University, University of Tampa, Max Planck Institute; *mkolmann@bio.fsu.edu*

Muscle, shell, and tooth: a comprehensive investigation of durophagy in the cownose ray

Durophagy is a feeding strategy which implies not only the ingestion of hard-shelled prey but also the dismantling of the prey carapace. The cownose ray, *Rhinoptera bonasus*, is a large coastal pelagic stingray thought to specialize on bivalves. Investigation of feeding performance in such an animal is particularly interesting in such that the ray's skeletal structure is oftentimes much more compliant than the skeleton of its prey. Traditional morphometric analysis of jaw adductor muscle architecture coupled with physiological estimations of muscle forces have allowed development of a three dimensional static equilibrium model which calculates bite forces in cownose rays over their ontogeny. Live bivalve samples representing the ontogenetic and species diversity of cownose ray prey will be subjected to materials testing whereby the exoskeleton of the shellfish will be forced to failure. Failure events will be filmed at high speed and the wear patterns on the tooth plates of *Rhinoptera* will be characterized in order to qualitatively validate a normal loading regime during feeding. The forces at which shellfish valves exhibited failure will be compared to bite forces from *Rhinoptera* and used to determine the susceptibility of the prey to predation over the ontogenetic size range of both predator and prey. Preliminary data regarding bite force production in *Rhinoptera* over their ontogeny show force production spanning from 17 N in neonate animals to over 200 N in mature adults. An ecomorphological approach to this feeding system implies that typical predator-prey interactions are complicated by morphological considerations such as gape limitation, differential allometry of muscle forces, and skeletal component strength.

P1.24 KOMOROSKE, Lisa M.*; BOWEN, Lizabeth; MILES, A. Keith; University of California, Davis, United States Geological Survey, Western Ecological Research Center; *lmkomoroske@ucdavis.edu*

BIOMARKER DEVELOPMENT TO EXAMINE SUBLETHAL IMPACTS OF POLLUTANTS IN MARINE TURTLES

Environmental stressors like pollution can exert sublethal impacts on organisms that may in turn affect individual fitness and population dynamics. The current knowledge of these relationships in marine turtles is very sparse because conventional laboratory studies are difficult to conduct on sensitive, long-lived vertebrates. We developed novel biomarkers to investigate relationships between pollutants such as polycyclic aromatic hydrocarbons and physiological condition using gene expression profiling. The fundamental advantage of this approach is that the response of many genes providing transcriptional messages can be quantified from a small amount of blood, serving as proxies for proteins and cellular regulation. We sequenced and developed quantitative real-time polymerase chain reaction primers for a panel of relevant genes, including the aryl hydrocarbon receptor, thyroid hormone receptor beta, heat shock protein 70, vitellogenin, and the major histocompatibility complex in green *(Chelonia mydas)* and loggerhead *(Caretta caretta)* turtles. This approach has great potential in marine turtle research because it yields important insight into physiological function and subsequent health of free-ranging animals while utilizing minimally invasive, field-friendly sampling methodology. We plan to develop additional gene expression biomarkers and apply them to investigate relationships among pollutants, pathogens, and physiological condition in wild and clinically healthy captive populations of these marine turtles.

P2.136 KOZOL, RA*; DALLMAN, JE; PERICAK-VANCE, MA; University of Miami; *rkozol@my.uri.edu*

Knockdown of putative Autism genes, SYNGAP and SHANK3, in zebrafish disrupts rhythmic motor behaviors.

A robust and stereotypic behavioral repertoire makes zebrafish a suitable model to understand the functional link between genes and behavior. Our goal is to establish an Autism Spectrum Disorders (ASD) zebrafish model to study the mechanistic underpinnings of implicated genes that are conserved in zebrafish. As a first step we are knocking down putative human autism genes and characterizing the resultant behaviors in zebrafish. To knockdown gene expression we use morpholino anti-sense technology. Morpholinos were designed against SHANK3 and SYNGAP, two ASD implicated genes with important roles in the postsynaptic density (PSD) of the glutamatergic synapse. Morpholinos were shown to disrupt normal splicing, producing either exon-skipping or intronic insertions and resulting in protein truncations. Morpholino injected zebrafish display disrupted behaviors. Morphant behavior progresses from uncoordinated coiling/bending at embryonic stages to unproductive swims ("wobble") at later stages. Our hypothesis is that the "wobble" phenotype results from tonic excitation that reduces the ability of the fish to produce strong alternating bends seen in control larvae. These studies in zebrafish represent one branch of a multidisciplinary collaboration to achieve a better understanding of Autism Spectrum Disorders.

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Further Investigation of the Effects of Putative Neurotransmitters on the Body Wall of Lumbricus terrestris

Previous studies have suggested that putative neurotransmitters modulate body wall contractions of *L. terrestris*. To investigate body wall modulation, a dorsal strip of 10 segments anterior to the clitellum was removed from the animal and placed in a tissue bath. Contractions were measured with a force transducer, and analyzed with LabScribe. The tissue was exposed to increasing concentrations of the neurotransmitter of choice, and the resulting changes in contractions were used to create log-dose response curves. 5-hydroxytryptamine increased contraction frequency and decreased contraction amplitude at a threshold of 10 nM. Dopamine decreased contraction frequency at a threshold of 10 nM, and increased at a threshold range of 1 nM. Dopamine increased contraction amplitude at a threshold of 10 nM, and decreased at a threshold of 1 nM. Acetylcholine decreased contraction frequency and increased contraction amplitude at a threshold of 10 nM. Octopamine had no significant biological effect on contraction frequency and amplitude. Epinephrine decreased contraction rate and increased contraction amplitude at a threshold concentration of 1.0 nM. Norepinephrine increased contraction frequency and amplitude at a threshold concentration of 0.1 to 1.0 µ M and 1.0 to 10 mM. GABA decreased contraction frequency at a threshold of 1.0 nM. GABA did not significantly change contraction amplitude. FMRFamide increased both contraction frequency and amplitude at a threshold of 0.1 µ M.

P2.181 KRAUSE, J.S.*; DORSA, D; WINGFIELD, J.C.; University of California, Davis; *jskrause@ucdavis.edu*

A new view of the stress response in free-living birds: 3-way adrenal steroid response

To better understand the integrated response to capture stress through the increased plasma levels of three major adrenal steroids – corticosterone (Cort), dehydroepiandrosterone (DHEA) and progesterone - we present data from our recently developed protocol for partition chromatography that effectively separates the steroids from a single plasma sample of <100ul in 3 taxa of Zonotorichia sparrows. Following separation, quantification of each steroid was determined by specific radioimmunoassay (RIA). As is well known, the stress response is the activation of the hypothalamo-pituitary-adrenal (HPA) axis in reaction to unpredictable events, which allows organisms to cope behaviorally and physiologically to the disruption. To date, most studies have focused on Cort as the major stress hormone; however DHEA and progesterone are also synthesized and released into the blood stream and thought to modify the stress response. DHEA has been widely implicated to have anti-stress properties that may decrease the severity of the stress response if levels rise during the stressor. If progesterone levels rise, Cort may be displaced from corticosterone binding globulin (CBG) due to its higher affinity for progesterone than for Cort. This would result in displacement of Cort from CBG and increase plasma levels of free cort that could modify the stress response further. To test these ideas while developing our chromatographic procedures, we utilized a standard capture and restraint protocol in wintering populations of white crowned sparrows (Z. l. gambelii and Z.l. nuttalli) and golden crown sparrows (Z. atricapilla). Our results indicate support for the involvement of these 3 steroids in the stress response and further our understanding of how organisms cope with unpredictable events.

P2.151 KRUEGER, J.A.*; ROBERTSON, J.C.; Westminster College, PA; *robertjc@westminster.edu*

Characterization of the Rostrum Lateral Line of Juvenile Paddlefish (Polyodon spathula)

Paddlefish (*Polydon spathula*) are found predominantly in the Mississippi River drainage basin and are characterized by the prominent rostrum that extends from their cranium. While not present at hatching, the rostrum appears quickly and grows rapidly in juvenile paddlefish. The rostrum is covered superficially by electroreceptors that respond to electrical signals emitted by planktonic prey and are used in feeding. Our studies have identified an internal lateral line canal system that extends from base to tip in the paddlefish rostrum. Lateral lines function in sensing hydrodynamic stimuli in water. Neuromasts are the receptive elements of the lateral line that detect vibrations or movement in water originating from prey, predators, other fish, or environmental obstacles. The objectives of this work are to describe and characterize the lateral line canal in the rostrum of juvenile paddlefish. We examined H&E stained slides of cross sections of rostrums; three sections of the rostrum of six juvenile paddlefish of uniform body length were examined. The three sections were obtained from standard locations at points 25%, 50% and 75% along the eye-to-tip length of each rostrum, allowing for comparison of the lateral line at different locations along the rostrum. An image analysis program was used to obtain measurements of different features of the rostrum lateral line. These measurements include canal diameter, canal area, and the cross-sectional heights of sensory cells and canal wall cells. Qualitative observations additionally allow comparison of the paddlefish rostrum system with the lateral line canals of other species. This work furthers understanding of the functional anatomy and sensory biology of the paddlefish rostrum and may be of use in ongoing efforts to conserve paddlefish.

P3.66 KRZYKWA, J.C.; New College of Florida; *julie.krzykwa@ncf.edu*

A Survey of Distribution and Movement of Cyphoma gibbosum in Relation to the Fungal Pathogen Aspergillus sydowii

The fungal disease *Aspergillus sydowii* has been an ongoing epizootic in the Caribbean since its identification in 1995. This disease has had a considerable impact on coral reefs. One potential biological vector of the fungal disease is the gastropod *Cyphoma gibbosum*, as a previous study has shown that this gastropod was able to pass viable spores of *A. sydowii*. A study was done to examine the movements of the gastropod *Cyphoma gibbosum* and the presence of *A. sydowii* on *Gorgonia ventalina* and *Gorgonia flabellum*. Over a two year period, 71 sites were investigated along a portion of shallow (<3m) fringing reef at Los Cayos Cochinos in the Honduran Bay Islands. Fans with *C. gibbosum* present were identified and visually checked for the presence of *A. sydowii*. Identification of *A. sydowii* was done through examination of lesions and purpling around the lesions along the base of the sea fan. A Spearman's rank correlation was performed to determine if gastropods were found more frequently on fans showing signs of infection with *A. sydowii* than on apparently healthy fans. If *C. gibbosum* prefers consuming infected corals, and frequently moves among infected and healthy corals it could provide vital information about the movement of the epizootic through coral reefs in the Caribbean.

P1.75 KULATHINAL, Rob J.*; LIANG, Yu; HSIEH, S. Tonia; Temple University; *robkulathinal@temple.edu*
lizardbase: An integrative scientific database and educational resource for discovery and learning
lizardbase is a publicly accessible knowledgebase hosted by the Kulathinal and Hsieh labs at Temple University. By providing datasets that range from genetics and genomics to organismal and ecological studies, *lizardbase* offers biologists a centralized and consolidated informatics resource. With the recent publication of the green anole, *Anolis carolinensis*, genome project, lizards are rapidly becoming a model system for interdisciplinary biological research. Our two principal goals are: 1) to provide a resource facilitating scientific discovery and collaboration, and 2) to increase student and citizen involvement in the sciences. We highlight novel features that we have developed during the last year including new K-12 genomics and GIS-based curricula, a smartphone application that automatically uploads student data (including photos) onto *lizardbase* via a curated platform, new gene nomenclature tables, multi-species alignments, new next-gen sequence data from other species of anoles, and a mechanism to upload valuable datasets from published and unpublished studies via an easy-to-use curation mechanism. We also demonstrate how this genomics and data-mapping portal can address tractable hypotheses from such diverse fields as functional morphology, invasion biology, and evolutionary genetics.

P2.35 KUO, J*; HSU, Y; National Taiwan Normal University; *greatliona@hotmail.com*
What types of contest interaction modify a contestant's behavior in a subsequent fight?
A contest can be viewed as a process for two contestants to assess each other's fighting ability (FA). At any stage of a contest, the weaker opponent may decide that it has gathered enough information to confirm its inferior FA, and retreat. After a contest is resolved, the winner/loser may raise/lower its evaluation of its FA relative to those of others in the population and adjust its behavior in future contests accordingly. This results in a higher/lower chance of winning in future (winner /loser effects). Interactions of different intensities probably provide more or less accurate information: lower intensity interactions demand lower energy/ability and reveal less informative about FA than higher intensity interactions. We may then expect different intensity interactions to have different impacts on contestants' future contest decisions (more intense interaction==>more accurate information==>more obvious behavioral change). We test this hypothesis by allowing focal individuals to have either non-physical (NPI) or physical (PI) interaction with either a much stronger or a much weaker trainer, using a mangrove killifish (*Kryptolebias marmoratus*). The results so far show that only the fish subjected to the PI treatment display changes in contest behavior: (1) individuals that interacted with a stronger trainer were less likely to initiate attacks or win and persisted for less time in a subsequent contest, and (2) individuals that interacted with a weaker trainer were more likely to escalate a contest than those that interacted with a stronger trainer. These results suggest that the information acquired from non-physical interaction is not sufficient to modify an individual's decisions in a subsequent fight.

P3.143 LAM, K*; ZENG, Y; DUDLEY, R; Univ. of California, Berkeley; *kenrickcl@yahoo.com*
The Effect of Asymmetric Morphology in the Aerial Righting of a Larval Stick Insect
The mechanism by which invertebrates aerially right themselves has only recently been elucidated. Our previous work with a larval stick insect (*Extatosoma tiaratum*) has shown that when released upside-down, the righting reflex initiates immediately after the loss of contact. Such righting behavior is characterized by a simultaneous, bilateral symmetrical dorsiflexion of the legs, forming a shuttlecock-like body geometry that enables a 180 degree turn through aerodynamic torque. In this work we further investigated such passive righting mechanism by studying how asymmetry in leg morphology may affect the performance. The mass, surface area and length of legs were experimentally manipulated in larval stick insects. With high-speed filming and analyses based on three-dimensional reconstructions, we compared the kinematics and aerodynamic properties of righting performance in insects with different treatments. Our results may help understand the importance of morphology in the basic aerial maneuvers of invertebrates.

P3.30 LANDAU, MATTHEW P.*; CURTIS, MICHELLE D.; REILEY, SUSANNA J.; Richard Stockton College; *landaum@stockton.edu*
Distribution of three sponges in a Florida seagrass bed.
While the ecology of sponges on mangrove roots and in coral reefs has received recent attention, sponges in other tropical environments are less well studied. We looked at the distribution of three sponges (*Tedania ignis, Chondrilla nucula*, and *Chalinula* sp.) in a seagrass bed adjacent to Long Key, Florida. Sampling was done using random quadrats (3mx3m) as well as 6mx3m quadrats in a 150m continuous grid. Densities varied from 0.04 to 0.19 individuals/m^2. There were no significant correlations between seagrass densities and the number of sponges/quadrat. All three species had aggregated spatial patterns ($p=0.003$, $p=0.015$, $p<0.001$, respectively, when compared to a random Poisson distribution); calculating Green's Index of Dispersion, *Chalinula*'s rate of clumping (0.131) was much greater than either *Tedania*'s (0.037) or *Chondrilla*'s (0.032). In contrast, using Hill's TTLQV method for analysis of continuous grid data, *Tedania* aggregates look less distinct and broader than those of either *Chondrilla* or *Chalinula*, which appear somewhat similar.

P3.168 LANE, S.J.; MANCINELLI, G.E.; MARTINEZ, E.E.; SANDOE, L.H.; KOPKE, D.L.; ELEKONICH, M.M.; ROBERTS, S.P.*; Central Michigan Univ, Univ of Nevada Las Vegas; *rober2sp@cmich.edu*

The aging and senescence of Drosophila from different behavioral regimes.

The effects of behavioral costs on physiological performance and senescence may be profound in volant insects, which during flight have among the highest metabolic rates ever measured. Indeed, previous studies have shown that natural and experimental limitation of flight behavior in insects extends lifespan and slows the age-related loss of antioxidant capacity and accumulation of oxidative damage in flight muscles. In this study, we manipulated the lifetime flight behavior of *Drosophila melanogaster*. Specifically, 5-day old adult flies were separated into three life-long treatments: (A) those not allowed to fly (no flight), (B) those allowed – but not induced – to fly (voluntary flight), and (C) those mechanically stimulated to perform over 100 flight bouts per day (induced flight). Consistent with the oxidative stress model of aging, preliminary results show that *Drosophila* prevented from flying lived longer than those allowed or stimulated to fly. Flight capacity, measured as the ability to fly in a hypodense gas mixture (21% O_2, 39.5% N_2, 39.5% He; 0.81 g l^{-1}), decreased with age in all treatment groups, but decreased earliest in flies from the no-flight treatment. Extended longevity in flies from the no-flight treatment suggests that oxidative damage accrues more slowly in this treatment group. However, early loss of flight capacity in the no-flight group indicates that disuse effects are the primary determinant of the age-dependent decay of flight capacity in this group. Additional experiments are ongoing to compare age-dependent oxidative damage, flight muscle ultra-structure, flight kinematics, immune function, reproduction and metabolic capacity among the treatment groups.

P3.163 LANGE, E.C.*; SEDA, J.B.; PTACEK, M.B.; Clemson Univ.; *elange@clemson.edu*

The influence of male size and social context on activity, boldness, sociability and mating behaviors in the sailfin molly (Poecilia latipinna)

Body size often influences behavior resulting in strong directional selection for increased size. In the sailfin molly, *Poecilia latipinna*, male size is genetically fixed and highly variable. Size influences alternative mating strategies; large males use courtship displays while small males utilize gonopodial thrusting. Intermediately-sized males are more flexible, switching between courting and thrusting depending on social context. We examined the influence of male size and social context on levels of activity, boldness, sociability and mating behaviors for *P. latipinna* from a single population. For each male, we measured activity in a social group, boldness in inspecting a fish predator, sociability with a conspecific group and mating behaviors in four social contexts (presence and size of competitor males). We found that male size was positively correlated with activity level (r^2=0.113; p=0.045) and courtship display rate in all social contexts (r^2=0.14-0.49; p<0.0001-0.044). Gonopodial thrust rates were negatively correlated with size only when the competitors were large (r^2=0.19; p=0.017). There was no relationship between size and boldness or sociability. For courtship display rates, intermediate males showed an effect of social treatment on courtship display rates (F=3.507; p=0.026), but small and large males did not differ among different social contexts. In all male size classes, courtship display rates tended to increase when competitor males were the same or smaller in size and decrease when males competed with larger males. For thrust rates, males did not differ among social treatments. Future work on the genetic basis of male size and behaviors will determine the degree to which behavioral repertoires can evolve independently of size.

P2.172 LATTIN, Christine R*; BAUER, Carolyn M.; DE BRUIJN, Robert; ROMERO, L. Michael; Tufts University; *christine.lattin@tufts.edu*

Seasonal differences in the functioning of the hypothalamus-pituitary-adrenal axis and initial transference to captivity in wild House Sparrows

The hypothalamus-pituitary-adrenal (HPA) axis is essential in helping wild animals cope with environmental challenges. HPA activity is modulated seasonally in many species, and the stress of captivity can interfere with HPA functioning. However, it is not known how these two factors interact–are there particular life history stages when animals are more or less vulnerable to the stress of captivity? We tested this hypothesis by capturing wild House Sparrows during five different seasons: early winter, late winter, pre-breeding, early breeding and late breeding. At each time point, we did a full test of HPA functioning by measuring baseline and stress-induced corticosterone (CORT), negative feedback in response to an injection of dexamethasone, and maximum response through an injection of adrenocorticotropic hormone (ACTH) both before and after 5 days of captivity in the lab. Thirty-nine of the 41 birds lost weight during the 5 days of captivity; mean weight loss was 2.8 g, or ~10% of a sparrow's total body weight. Across all seasons, sparrows showed an increase in baseline CORT due to the stress of captivity. However, there was an among-season difference in how ACTH challenge was affected by captivity. This seems to be due to a downregulation of the initial response to ACTH in the late summer compared to other seasons, which is then upregulated during the 5 days of captivity. It is possible that these birds are showing an anticipatory downregulation of their response to ACTH in preparation for molt, a time of year encompassing a natural nadir in HPA activity. In any case, these data suggest that birds in the late summer may potentially be more vulnerable to the stress of captivity.

P3.175A LAUMER, C.E.*; SMITH, III, J.P.S.; GIRIBET, G.; Harvard Museum of Comparative Zoology, Winthrop University; *claumer@oeb.harvard.edu*

New and useful knowledge on the genus Gnosonesima (Platyhelminthes: Neoophora)

Gnosonesima is a monogeneric taxon of rare meiofaunal Platyhelminthes known largely from (sometimes very deep) marine subtidal sediments. Most of the six known species are described from one or two specimens, or only an illustration. They nonetheless comprise a higher taxon within Platyhelminthes (Gnosonesimida *sensu* Karling 1968), and much interest has thus been expressed in the functional and phylogenetic significance of their unusual character systems (e.g., monocellular ocelli/tangoreceptors, genito-intestinal connections, "coniform" pharynx, and tetrapartite germovitellaria). We present the anatomy of four undescribed species of this taxon, the first to be reported from the Americas. Using live observations, HD video recordings, semi-thin histological sections, and confocal laser scanning microscopy, we demonstrate that these newly discovered species evince a number of dramatic departures from the anatomy of the known representatives. These include stably di- or tri-partite germovitellaria, a flattened or miniaturized body habitus, and several new types of male copulatory organs, including two forms sharing a conical sheath of sclerotic spines reminiscent of types known from other basal Neoophora (e.g., Prorhynchida, Proseriata). It is tempting to consider that these new morphologies may shed light on the plesiomorphic character states of Gnosonesimida. However, the discovery of such deviant species also implies that sampling of *Gnosonesima* and its relatives remains superficial. Thus, pending the discovery of further forms, and a phylogenetic analysis of the total group, we adopt an agnostic view on such questions of character evolution. For practical reasons, we recommend presently that these new species be accommodated in the classical genus *Gnosonesima* via an amended definition of the taxon.

P2.48 LAW, C. J.*; DORGAN, K. M.; ROUSE, G.; Scripps Institution of Oceanography; *cjlaw9@gmail.com*

The kinematics and anatomical features of undulatory burrowing in Armandia brevis

Recent work has shown that diverse polychaetes extend burrows through muddy sediments by fracture. Radial body expansions near the anterior, achieved both by peristalsis and eversible pharynges and proboscis, apply forces that are amplified at the tip of the crack-shaped burrow, resulting in fracture. The opheliid annelid, *Armandia brevis* (Moore 1906), lacks an expansible anterior consistent with burrowing by fracture. Instead, *A. brevis* burrows with a lateral undulatory motion in heterogeneous sediments. We hypothesized that surficial sediments on the scale of this small burrower are granular aggregates rather than a cohesive elastic solid. Kinematic analysis of worms burrowing in clear granular analog materials (cryolite and gelatin grains) showed a wave efficiency during burrowing close to one, indicating minimal slipping and that the grains are not fluidized. In addition, histological 3D reconstruction (Amira 5.3) of the internal anatomy shows transverse muscles extending from the ventral groove that act antagonistically to the longitudinal muscles along the interior of the body wall. Circular muscles—used to contract the body radially during peristaltic locomotion—are lacking in this sinusoidal burrower. Further kinematic analysis of *Ophelina acuminata* (Oersted 1843), a larger and morphologically similar opheliid species that inhabits fine-grained porous muds, revealed similar non-slipping sinusoidal locomotion. Behaviors and anatomies of both species differ substantially from peristaltic burrowers and are consistent with living in loosely packed granular sediments rather than consolidated elastic muds.

P1.49 LEARY, Brian P.*; KAVANAGH, Kathryn; University of Massachusetts Dartmouth; *bleary@umassd.edu*

The range of variation in pedal phalangeal proportions increases over the evolution of the avian lineage

The proportions of the pedal digit phalanges of modern birds have been found to be predictive of their function. Ratites and many other strictly cursorial birds exhibit a gradient phalangeal pattern that decrease in length proximodistally, while falconiforms and other predatory birds display short, evenly sized proximal phalanges with an elongate distal phalanx. Interestingly, the phalangeal proportions of birds collectively vary within a limited range and many possible phalangeal patterns are absent in nature. We explored the variation in pedal phalanges proportions in non-avian dinosaurs. We found that the variation of these taxa is a subset of the range of variation in modern aves. Furthermore, analysis of proportions in morphospace for specific fossils lends further evidence to particular hypotheses of function of function in extinct taxa.

P3.188 LECHLITER, S. M.*; CEVASCO, M. H.; Coastal Carolina University; *smlechli@g.coastal.edu*

Kleptoplasty in the Foraminifera of Coastal South Carolina

The phenomenon of kleptoplasty in which the plastids of algal prey are sequestered by predators/hosts and are kept functional (photosynthetically active) for an extended period of time (weeks/months), is examined in foraminiferal taxa collected from tidal lagoons habitats along the SC coast. The taxonomic identity of the hosts and the sequestered plastids involved in this form of plastid husbandry are determined using both sequence and morphological data. These data are compared to those collected by (Pillet et al, 2011) from field sites in the Northeastern Atlantic. This work explores the geographic patterning, influence of prey diversity, and overall specificity of the kleptoplastic condition in the foraminifera of coastal South Carolina.

P3.107 LEE, D.; GEORGE, S.B.*; Georgia Southern University; *georges@georgiasouthern.edu*

Vertical distribution of Pisaster ochraceus larvae in haloclines after prior exposure to low salinity

An increase in the frequency and intensity of fresh water incursions into the Puget Sound could change the dynamics of rocky shore communities in the Pacific North West due to the potential negative effects on the larval stage of the keystone species *Pisaster ochraceus*. The present study investigated the effect of prior exposure of embryos and bipinnariae to low salinity on the vertical distribution of brachiolariae 1, 11, and 24 hours after introduction in haloclines. Four treatments were setup; controls (31‰), larvae exposed to 20‰ throughout development (CL), gastrulae exposed to 20‰for 3 days (SF3), bipinnaria exposed to 20‰ for 7 days followed by a gradual increase to 31‰ by the 14th day (SF14). Five day-old larvae from the SF3 and CL treatments were significantly wider and shorter than those from the SF14 and control treatments. Those from the CL treatment remained wider and shorter up to 26 days. Differences in larval morphology and other salinity-induced stresses influenced the vertical distribution of brachiolariae in haloclines. One hour after introduction a significantly higher proportion of brachiolariae from the control treatment hovered around the halocline compared to brachiolariae from the SF14, SF3, and CL treatments. Eleven hours later, a significantly higher proportion from the controls and the SF14 treatment had moved above the halocline and by 24 hours a majority of the brachiolariae had moved to the surface. These results suggest that fresh water incursions into the rocky intertidal during the reproductive season could affect the morphology, feeding and swimming of *Pisaster* brachiolariae.

P2.42 LEE, EA*; EARLEY, RL; HANNINEN , AF; The University of Alabama; *elee21@crimson.ua.edu*

The hormonal response to fasting in an amphibious fish

The mangrove rivulus (*Kryptolebias marmoratus*), is a self-fertilizing hermaphroditic vertebrate capable of producing lineages of genetically identically animals, making it an exceptional model organism to study plasticity in hormonal responses to variable feeding regimes. In its natural environment of mangroves, the mangrove rivulus is exposed to periods of time where it is in the water and when it is out of the water, due to the tides. These fish are known to be able to survive out of water for an extended period of time, but little is known about the availability of food while this fish is out of water. We investigated variation in progesterone, estradiol, testosterone, and 11-ketotestosterone (KT) of fed versus fasted individuals within and between genotypes. We used a total of 38 fish, half fed and half fasted from two different isogenic lineages, DAN2K and RHL derived from Belize and the Bahamas, respectively. Water borne hormones were taken before and after exposure to the feeding regiment and then were assayed using enzyme immunoassay. We also harvested gonadal and digestive tissues to later explore changes in reproductive investment, gonad and gut morphology using histological techniques. Initial analyses illustrated that there were no differences in the endocrine profiles of fed and fasted individuals; however, gonad size was significantly smaller in individuals that were fasted compared to those that were fed. These results suggest that limited food availability could be a cause for a reduction in reproductive investment.

P1.164 LEE, R.J.*; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *leerj@hendrix.edu*

Betamethasone treatment of the diaphragm of fetal Cavia porcellus: a look at glycogen storage

Prenatal steroid use has shown benefits in accelerating fetal lung development in women at risk of preterm birth. However, the effects of these steroids on breathing muscle development are not as well known. Previous work in our lab demonstrated that steroid treatment leads to higher oxidative enzyme concentrations in treated muscles. Therefore, we hypothesize that there will be more glycogen stored in the fibers of treated muscles to support the fuel requirements of the oxidative enzymes. To study the effects of prenatal steroids on the glycogen storage of fetal diaphragms, pregnant guinea pigs were injected with betamethasone or sterile water twice a week, 24-hours apart, for three weeks at 65%, 75%, and 85% gestation. At 59 days of gestation, the guinea pig mothers were sacrificed, and fetal diaphragm tissue samples were taken. These samples were cut in a cryostat, and sections of these samples underwent myosin ATPase and glycogen staining. The stained sections were imaged, and the glycogen staining density was measured using Scion Image. Staining densities were converted into Z-scores, which were then used to calculate the percentages of slow- and fast-twitch fibers staining lightly or darkly for glycogen. If our hypothesis is supported, prenatal steroid treatment will lead to diaphragms with a high level of glycogen storage, which will make these muscles more fatigue resistant in comparison to the diaphragms in untreated preemies. Knowing the effects of these steroids on the development of the diaphragm could allow physicians and expecting mothers to make more informative decisions about prenatal steroid use.

P3.78 LEE, A.K.*; SZE, C.C.; SUZUKI, Y.; Wellesley College; *klee3@wellesley.edu*

Identification of developmental genes involved in larval leg regeneration in the flour beetle, Tribolium castaneum

Regeneration is widespread among the Metazoa. Understanding of the molecular process underlying this phenomenon has profound implications for current domains, such as regenerative medicine. To investigate the mechanisms of leg regeneration in a holometabolous insect, *Tribolium castaneum*, our lab has been studying the roles of a few candidate transcription factors, *abrupt* (*ab*), *dachshund* (*dac*), *Distal-less* (*Dll*), and *spineless* (*ss*) during larval limb regeneration. To understand the functions of these genes during regeneration, we used RNA interference (RNAi) to knockdown the expression of genes in larvae with ablated legs. Our study suggests that *ab* is essential for leg regeneration even though it is not required for embryonic leg formation. *Dll* and *dac* were found to be important for patterning the regenerating legs as well as normal embryonic legs. In contrast, *ss* was not necessary for either regenerative or embryonic leg development but played a role during adult leg metamorphosis. However, *ss* has been known to regulate the embryonic specification of antennae, and we found that knock-down of *ss* caused heteromorphic regeneration of amputated antennae into larval legs. Our results suggest that larval limb regeneration relies on genes activated during embryonic limb development, and that *ab* may have required a unique function during larval leg regeneration.

P1.40 LEMA, SC*; SALVESEN, KE; SLANE, MA; GODWIN, J; California Polytechnic State University, Pennsylvania State University, North Carolina State University, North Carolina State University; *slema@calpoly.edu*

Isolation and expression patterns of two V1a-type arginine vasotocin receptor mRNAs in the protogynous bluehead wrasse

Arginine vasotocin has been implicated as a key regulator of behavioral and reproductive plasticity in teleost fishes. Several studies have now demonstrated changes in vasotocin circuits in the hypothalamic preoptic area during sex change in fish, but the role of vasotocin receptors in this process remains unknown. Here, we isolated and sequenced two full-length cDNAs encoding V1a-type receptors (V1a1 and V1a2) from the protogynous bluehead wrasse (*Thalassoma bifasciatum*) using degenerate primer PCR and 5’- and 3’-rapid amplification of cDNA ends (RACE). RT-PCR revealed that the relative abundance of these two receptor transcripts varied among wrasse tissues with V1a1 receptor mRNAs at greatest levels in the telencephalon, hypothalamus, optic tectum, cerebellum and testis, but V1a2-type transcripts most abundant in the hypothalamus, cerebellum and gills. Quantitative real-time RT-PCR further demonstrated that these transcripts varied in relative abundance with sexual phase. Relative levels of the V1a2 transcript were greater in both the whole brain and isolated hypothalamus of terminal phase (TP) male wrasse compared to initial phase (IP) males or females. Meanwhile in the gonads, V1a1 mRNAs were at levels 2.5 fold greater in the testes of IP males – and 4 to 5 fold greater in the testes of TP males – than levels of this same transcript in the ovarian tissues of females. These results provide evidence that vasotocin receptor transcript abundance in the hypothalamus and gonads of bluehead wrasse varies in distinct patterns linked to sexual phase, and bestow a foundation for future studies investigating how expression patterns of these receptor paralogs are influenced by gonadal and social status.

P3.75 LESOWAY, M.P.*; COLLIN, R.; ABOUHEIF, E.; HENRY, J.J.; McGill University, Montreal and Smithsonian Tropical Research Institute (STRI), Panama, STRI, Panama, McGill University, Montreal, U. of Illinois, Urbana;
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MAPK activation and early development in the calyptraeid gastropods

The calyptraeid gastropods have undergone numerous transitions in mode of development with little apparent phylogenetic constraint. The developmental mechanisms underlying these transitions remain unknown, but in other groups such as echinoderms, similar transitions are associated with shifts in the timing of axis specification. Mitogen activated protein kinases (MAP kinases; or extracellular signal-related kinases, ERK) have been implicated in early signaling events in the D quadrant of spiralian lophotrochozoans, the lineage responsible for dorso-ventral axis patterning and mesoderm specification. Previous work with the indirectly developing calyptraeid gastropod, *Crepidula fornicata*, has shown that MAPK activation is consistent with the timing of D quadrant specification. Embryos of the direct developing calyptraeids *C. convexa*, (a direct developer with large eggs) and *C. cf. onyx* Panama (a direct developer with nurse embryos) were immunologically stained for activated MAPK. The pattern of MAPK activation was similar to that described for *C. fornicata*, with MAPK activated in the 3D cell at the 24-cell stage and the 4d cell at the 25-cell stage in both species. The direct developer with large eggs showed an earlier arrest in MAPK activation, perhaps due to slower cleavage times associated with increased egg size. Staining in the nurse embryo developer was uneven, and it remains unclear how organizer activity is related to formation of nurse embryos.

P1.182 LESSIOS, N*; RUTOWSKI, R; Arizona State University;
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Orientation Behavior and Possible Visual Statocyst in a Crustacean found in the Sonoran Desert: Triops (Branchiopoda: Notostraca)

Triops are branchiopod crustaceans found in ephemeral freshwater pools. As non-malacostracan crustaceans, they are often considered as basal for both crustaceans and hexapods (group including insects). *Triops* are mainly benthic foragers, but also swim to the air-surface boundary in hypoxic conditions. They have two compound eyes, as well as four median ocelli (naupliar eyes). They lack a corneal focusing lens. This study describes an inverted swimming behavior in response to a change in illumination from the hemisphere above the animal, to below. Responses are compared to animals in which black paint had been applied to the cuticle of their compound eyes and ocelli. Sections of their eyes and ocelli were analyzed using light microscopy to determine refractive index, focal length, and facet diameter of these structures. Orienting behavior is compared to photo-behavior in the horizontal plane using projected light in a rectangular trough. Their visual behavior is discussed in the context of mechanoreceptor statocysts. Many flying insects are known to use their ocelli for rapid body orientation corrections during flight, and their compound eyes for higher acuity vision, while some terrestrial insects use their ocelli for celestial cues. Understanding the adaptive significance of eyes in *Triops* and other non-malacostracan crustaceans will help to infer transitions in eye evolution, and will illustrate the diversity of extant insect-crustacean sensory systems.

P1.208 LEWDEN, Agnes; PETIT, Magali; VEZINA, Francois*; UniversitÃ© du QuÃ©bec Ã Rimouski, Qc. Canada;
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Low ambient temperatures may reduce cold endurance in wintering black-capped chickadees

Regulation of body temperature is of premium importance for the maintenance of physiological functions in homeotherms. However, for small resident birds wintering at northern latitudes, heat loss is substantial and thermoregulation involves high energy demands. In some species, daytime body temperature (Tb) is known to decline during acute cold conditions. This can entail additional costs because a lower Tb may impair physiological functions and reduce alertness to predators. Winter cold acclimatization in these birds is associated with a seasonal increase in maximal shivering capacity (summit metabolic rate, Msum, measured under helox cold challenge), which is considered an indicator of cold endurance. Using black-capped chickadees wintering in eastern Canada as our model species, we hypothesized that birds with a higher thermogenic capacity would do better during cold days and would be less affected by ambient temperature in their capacity to maintain Tb constant during the day. From November 2010 to March 2011, we measured Tb at capture and Msum in free-living birds over a range wintering ambient temperatures (8°C to -22°C). Tb was negatively correlated to ambient temperature, with chickadees exhibiting a Tb 1-3°C lower during the coldest days. However, Msum was not related to Tb, when considering the effect of ambient temperature, but birds that had a lower Tb in the field attained their Msum earlier during the cold challenge. These results suggest that prolonged periods of cold temperature during winter may weaken cold endurance capacity in small resident passerines.

P2.162 LEXA, C.M.*; DAVIS, J.E.; Radford University;
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The effects of juvenile hormone modulation on development and stress-related behavior in Madagascar hissing cockroaches (Gromphadorhina portentosa).

Growth, maturation, and stress are systems with close physiological relations. When conditions are stressful due to a lack of resources or extreme environmental conditions, energy is directed away from systems that are not essential for survival, such as reproduction. This martialing of resources for immediate survival at the cost of immediate reproduction may increase long-term reproductive output. In insects, the activities of these systems are partially regulated by juvenile hormone (JH); high levels of JH generally prevent a nymph from maturing into an adult state, while a reduction in juvenile hormone can induce reproductive development. We predicted that chronic stress, or chronically increased JH would lead to an overall delay in reproductive maturity, increased body size, and an increase in anxiety-related behaviors. In subjects with chronically decreased JH would exhibit inverse responses. To observe the effects of chronic low and chronic high JH levels we reared three different groups of Madagascar hissing cockroach nymphs for 9 months under exposure to one of three hormonal conditions; one group received an agonist to JH(methoprene), another group was given a JH antagonist (allostatin IV), and a control group received no manipulation. Growth, mortality, and fecundity of each group were monitored throughout the study. To test how JH levels affect stress related behaviors, three behavioral tests were performed; a photosensitivity test, an exploration test, and a food deprivation test. Here we present findings demonstrating the effects of JH modulation on both physiological and behavioral profiles.

P3.81 LI, Y*; WOZNICA, A; STAROBINSKA, E; JEMMETT, J; DAVIDSON, B; Univ. of Arizona; *younanli@email.arizona.edu*

Analysis of Enhancers of Ets1/2 Target Genes In the Basal Chordate Ciona Intestinalis

Fibroblast growth factor (FGF) signaling and downstream activation of the transcription factor ETS1/2 specify the heart cell lineage in the basal chordate Ciona intestinalis. Based on our previous work, 144 candidate FGF/ETS1/2 dependent heart genes have been identified from the Ciona genome. The expression of a large subset of these genes have been verified in the heart precursor lineage using in-situ techniques. Among these target genes bioinformatics has led to the identification of candidate heart lineage enhancers. Now, we are conducting experiments to test these predicted enhancers through reporter analysis. Based on our study, the Ets1/2 binding site GGAW and the co-motif ATTA are required for heart lineage enhancer activity. The annotation and analysis of these regulatory regions will help in identifying the precise role of FGF signaling and Ets1/2 activation in the heart gene regulatory network and the way that this network can be shaped by selective forces during evolution.

P2.174 LIEBL, A.L.*; MARTIN, L.B.; University of South Florida; *aliebl@mail.usf.edu*

Seasonal Variation of Glucocorticoid Regulation in House Sparrows (Passer domesticu)

Many animals demonstrate distinct seasonal variation in baseline glucocorticoids (GCs), release in response to stressors, and adrenal sensitivity to corticotrophins. However, whether the capacity to down-regulate GCs or the expression of the mineralocorticoid receptor(MR) or glucocorticoid receptor (GR), receptors integral to GC regulation, vary seasonally has been studied less. Whereas MR is predominantly responsible for maintain baseline levels, GR controls negative feedback of GCs. Here, we measured GCs at baseline, after exposure to a restraint stressor, and in response to negative feedback (pharmacologically induced by dexamethasone) as well as GR and MR expression in hippocampus in wild house sparrows (*Passer domesticus*). GCs were measured during both breeding and molt, as GC release and adrenal sensitivity differs between these two seasons in sparrows. Consistent with previous studies, restraint-induced GCs were suppressed during molt when compared to breeding. Interestingly, despite considerable variation, birds were only able to down-regulate GCs during the breeding season. Neither MR nor GR expression was correlated with hormone titers during molt, but this could be an artifact of a dampened up and down regulation of the hormone. We predict correlations between GR and capacity to down-regulation GCs during the breeding season; analysis is ongoing.

P3.38 LINDSAY, S.M.; University of Maine; *slindsay@maine.edu*

Is all injury equal? Measuring the effect of repeated injury on sediment disturbance by the polychaete Abarenicola pacifica

Past research has shown that injury can decrease activity and sediment disturbance by infaunal polychaetes, thereby influencing sediment-mediated competition, adult-larval interactions and recruitment success in marine soft-sediment habitats. However, these studies examined only the effect of single injuries on activity, when repeated injury is more likely the rule. Revisiting a classic study by Woodin (1984), this field experiment examined the effect of single and repeated injury on sediment disturbance by the lugworm *Abarenicola pacifica* to determine whether repeated injury caused additional reductions in activity. Growth and fecal production by adult worms that had posterior segments ablated once (on day 0), twice (on day 0 and day 14), or not at all (i.e., intact) were monitored for 28 days. By 6 days following injury/handling, >80% of worms in all treatments had defecated at least once. On a daily basis, however, the proportion of worms defecating was lower for worms injured twice compared to those injured once or not at all, and this pattern persisted for two weeks. On average, worms injured once produced less feces compared to intact controls, but only in the first 3 days following injury. In contrast, there was no significant reduction in the mass of feces produced by worms following repeated injury. Relative growth rates of worms in the 14 days following injury/handling were slightly negative for intact worms and worms injured once, but positive for worms injured twice. These results differ from laboratory studies examining the effect of repeated injury on maldanid polychaetes. Factors contributing to this difference and the implications for sediment-mediated interactions will be discussed. Supported by NSF grant OCE0805667 to SML.

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Spatial Navigation Strategies of Green Poison Dart Frogs in a Morris Water Maze Task

Dendrobatid frogs have evolved complex parental behaviors, including egg attendance and tadpole transport, which require the ability to relocate offspring over distances. We know little about the strategies used by dendrobatids to return to their offspring. Thus, we tested the possibility that the green poison dart frog (Dendrobates auratus), which exhibits male parental care, could navigate to a visible platform 1.5cm above the surface in a water-filled circular arena akin to the Morris Water Maze. Because dart frogs are terrestrial, they are motivated to find the platform in order to escape from the water. In experiment 1, we changed the release point and platform location each trial, and tested subjects in 4 trials/day for 7 days. We found that the latency to locate the platform did not vary across days, indicating that the frogs were unable to learn the task. In experiment 2, the release point and platform location were fixed in each trial. Under these conditions, the latency to find the platform decreased over the experiment and the successful trials increased, indicating that they learned the task. We then conducted two probe trials to test the strategy by which the frogs completed the task. In probe 1, we submerged the platform and found that the frogs' performance was unchanged, indicating that they were not using the visual properties of the platform to solve the task. In probe 2, we moved both the release point and platform location and found that latency increased and success rate decreased to levels comparable to the beginning of the experiment. From this we conclude that the frogs were likely using a motor strategy (i.e., praxis) to complete the task rather than relying on the visual cue.

P1.177 LOPEZ, I.L.*; ARACENA, J.; Southwestern Oklahoma State University; *lopezi@student.swosu.edu*

Decision-making in feeding and mating behaviors of field collected fruit flies (Drosophila melanogaster)

Fruit flies (*Drosophila melanogaster*) are excellent models to study the genetic basis of behavior. Our main purpose is to test the flies' ability to make decisions between conflicting excitatory inputs: feeding and mating. Individual virgin and previously mated flies of both sexes were placed in test tubes and deprived of food for 0 or 18 hours. One male and one female were placed in a testing arena containing food. We recorded the hierarchy of behaviors (mating, grooming, or feeding) as well as the time spent on each behavior for each individual fly. Preliminary observations suggest that both virgin and previously mated flies spend about fifty percent of their time walking and exploring. It also has shown that mating status highly influences their behavior. More time was spent mating than feeding in both previously mated and virgin flies. Virgin flies are more likely to mate than previously mated flies.

P1.191 LOTHERY, C.J.*; THOMPSON, C.F.; SAKALUK, S.K.; Illinois State University; *cjmorr2@ilstu.edu*

Self-maintenance versus reproduction: effect of experimentally increased food availability on female incubation behavior, chronic stress levels, and offspring condition in house wrens

Corticosterone (CORT), the “avian stress hormone,” increases in the plasma during times of chronic or acute stress (e.g., low food availability or presence of a predator, respectively), and can mediate a shift toward self-maintenance behaviors that ensure survival (e.g., foraging or nest abandonment). Birds incubating eggs face the potentially stressful problem of how to allocate their time and energy between maintaining the proper temperature of the embryos developing in their eggs and obtaining enough food to meet their own metabolic demands. We tested the hypothesis that female house wrens (*Troglodytes aedon*), which incubate their eggs without male help, face a trade-off during the incubation period between self-maintenance behaviors (leaving the nest to forage for food) and warming their eggs, and that this trade-off results in increased levels of chronic stress during incubation. We predicted that food-supplemented females would (i) incubate their eggs for longer periods, (ii) experience less stress, and (iii) produce offspring in better condition than control females. The results are consistent with the hypothesis as food-supplemented females spent more time incubating their eggs than control females. Results of the analyses of plasma CORT levels and measures of offspring condition will also be reported.

P3.150 LOVE-CHEZEM, T.*; AGGIO, J.; DERBY, C.; Georgia State University; *tlovechezem1@student.gsu.edu*

Chemical defense through sensory disruption in spiny lobster-sea hare interactions

Antipredator defenses are ubiquitous and diverse. The ink secretion of sea hares (*Aplysia*), consisting of ink and opaline, has been shown to be an antipredator defense acting on the chemical senses, as a decoy and repellent. It has also been hypothesized that the ink secretion, particularly the opaline component, may also act through sensory disruption. In this study, we test this hypothesis using the spiny lobster, *Panulirus argus*, as a predator. Opaline is a highly viscous substance, containing hundreds of millimolar concentrations of amino acids, which coats the antennules and mouthparts of attacking lobsters. This coating may contribute to a physical disruption of both chemical and mechanical sensing as well as contribute to chemical disruption by overstimulation of chemoreceptive neurons. Our experiments reproduce the coating of an antennule with opaline, components of opaline, and a mimic, which resembles its physical nature but lacks its chemicals. We used a food stimulus to understand the protective mechanisms behind this defensive secretion by measuring changes in motor activity associated with antennular movement, which occurs by chemical stimulation. We saw a significant decrease in this motor activity when opaline, the sticky component of opaline, or the mimic were applied to the antennule, but not when the amino acids from opaline or ASW were applied. This decrease suggests that opaline is a physical barrier against chemosensory input. We are currently completing electrophysiological recordings to understand how opaline affects the sensory cells in the antennules. Supported by NSF IOS-1036742

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Evolution and Function of ftz and ftz-f1 in Hemipteroid Assemblage Insects

fushi tarazu (ftz) arose as a duplication of a homeotic gene but functions solely in segmentation in *Drosophila melanogaster* as a pair-rule gene to direct the development of alternate body segments. Dm-Ftz activity is regulated by interaction with the nuclear receptor Ftz-F1. This switch in function from a homeotic gene to a segmentation gene resulted from changes in both expression pattern and protein function: Dm-Ftz is expressed in seven stripes, while the other homeotic genes are only expressed in a domain of the embryo. Dm-Ftz acquired an LXXLL motif which mediates its interaction with Ftz-F1 necessary for segmentation function, and it lost its ancestral YPWM motif necessary for homeotic function. Recent data suggest that the LXXLL motif was acquired at the stem of holometabolous insects. To understand how ftz’s role in development switched during evolution, we are studying its expression and function in the Hemipteroid assemblage, the sister group of holometabolous insects. Using RACE and modified genomic-walking, we isolated ftz and ftz-f1 from hemipteran insects, including *Oncopeltus fasciatus* (milkweed bugs), *Acyrthosiphon pisum* (Aphids), *Leptoglossus occidental* (Leaf-footed bug) and *Halyomorpha halys* (Stink bug). Combining this with genome project data reveals that Hemiptera have not acquired the LXXLL motif and many have highly degenerated YPWM motifs. To determine the roles of hemipteran *ftz* and *ftz-f1* genes, we are examining their expression and function in *Oncopeltus* . Preliminary results suggest that both *Of-ftz-f1* and *Of-ftz* are expressed in non-overlapping stripes during embryogenesis. *Of-ftz-f1* parental RNAi blocked oogenesis while *Of-ftz* RNAi blocked embryogenesis at around one to two days after egg laying. Future studies will analyze phenotypes associated with loss of Of-ftz and Of-ftz-f1 function in embryos to determine their biological roles in this lineage.

P2.34 LUKE, Kelly/ N.*; BECHLER, David/L.; South Georgia College, Douglas, GA, Valdosta State University, Valdosta, GA; *kelly.luke@sgc.edu*

Dyadic interactions in the mixed-mating strategies of the mangrove rivulus, Kryptolebias marmoratus. II. The role of male-male parings.

Male-male dyads were examined in *Kryptolebias marmoratus* to determine the possible role such dyads might play in territoriality and dominance. However, a dichotomy in the behaviors displayed by dyads in which one male possessed an ocellus required that the male-male dyads be divided into subcategories to better understand the complexity of behaviors. When neither male possessed a caudal ocellus, significant levels of aggression occurred between the males with bouts resembling those of hermaphrodite-hermaphrodite dyads. Such behaviors suggest that males without ocelli are territorial and/or develop hierarchies of dominance in the wild. The presence of a caudal ocellus on one male correlated with the other male responding as if the male with the ocellus was a hermaphrodite and as such a potential mate. In such dyads, aggressive, submissive and reproductive behaviors were found, but no distinct pattern of exclusively reproductive or aggressive acts were observed as seen in hermaphrodite-male and hermaphrodite-hermaphrodite dyads respectively. It is not known whether the ocellus was the primary signal initiating reproductive behaviors or some other stimulus such as pheromones or the posture of the male with the ocellus. This suggests that males with an ocellus are in a transitional stage transforming from hermaphrodites to secondary males and do not provide the male without the ocellus a distinct set of stimuli to allow discrimination of its sexual state.

P2.33 LUKE, Kelly/N.*; BECHLER, David/L.; South Georgia College, Douglas, GA, Valdosta State University, Valdosta, GA; *kelly.luke@sgc.edu*

Dyadic Interactions in the mixed-mating strategies of the mangrove rivulus, Kryptolebias marmoratus. I. The role of hermaphrodite-male and hermaphrodite-hermaphrodite dyads.

The mangrove rivulus, *Kryptolebias marmoratus*, is a small cyprinodont fish native to tropical and subtropical waters of Florida, Brazil, and the Caribbean. It is the only known self-fertilizing, hermaphroditic vertebrate and the only one to display androdioecy, a complex reproductive system involving hermaphrodites and males most often seen in plants and some invertebrates. Kryptolebias marmoratus dyads exhibited a total of 23 distinctive behaviors. Acts were divided into four categories: aggressive, submissive, neutral, and reproductive. Leading and following behaviors played important roles in the behavioral repertoires of these fish. In the hermaphrodite-male dyad, males initiated the reproductive process exclusively and actively pursued the hermaphrodite. Hermaphrodites were especially receptive to male tactile acts and responded with a unique set of behaviors not seen in the hermaphrodite-hermaphrodite dyad. No spawning acts were observed nor were eggs recovered from the observation tank suggesting that actual spawning may be rare or that courtship is protracted. Hermaphrodite-hermaphrodite dyads showed no evidence that they behaved like other simultaneous hermaphrodites alternating sex roles nor were any reproductive behaviors observed. Rather, dyads were extremely aggressive towards one another with the aggressor establishing dominance immediately. Most lead acts involved aggression by the dominant fish followed by submissive acts from the subordinate. These findings support the hypothesis that heterozygosity observed in wild populations resulted from hermaphrodite-male outcrossing and not hermaphrodite-hermaphrodite outcrossing.

P2.121A LUTTERSCHMIDT, D.I.*; MAINE, A.R.; WILCZYNSKI, W.; Portland State University, Oregon, Georgia State University, Atlanta; *d.lutterschmidt@pdx.edu*

Melatonin and seasonal variation in GnRH: Lessons for interpreting changes in immunoreactive cell number

Seasonal rhythms in reproductive physiology and behavior are regulated by changes in the activity of the hypothalamus-pituitary-gonad axis. The neuroendocrine factors mediating these changes, however, are poorly understood. We investigated whether the pineal hormone melatonin alters seasonal changes in gonadotropin-releasing hormone (GnRH) and sex steroids in green treefrogs (*Hyla cinerea*). Male and female frogs collected during the winter (nonreproductive) or summer (reproductive) were implanted subcutaneously with either a melatonin-filled or blank silastic capsule for 4 weeks. Melatonin did not modulate GnRH-immunoreactive (GnRH-ir) cell number or sex steroid hormones in either sex, suggesting that the reproductive axis of green treefrogs is not directly sensitive to melatonin signaling. As expected, male testosterone and female estradiol concentrations were higher in reproductive frogs collected during the summer breeding season. Seasonal differences in GnRH immunoreactivity were also observed, although the pattern was not as expected. Reproductively active frogs had significantly fewer GnRH-ir cells than nonreproductive frogs ($F = 8.76$; $P = 0.006$). Our data suggest that increased release of GnRH during the summer breeding season leads to both increased sex steroid hormone concentrations and a decrease in GnRH-ir cell number. Several studies have provided data consistent with this alternative interpretation of increased immunoreactive cell number, although current examples represent neuropeptides with complex roles in seasonal and social behaviors (e.g., arginine vasotocin). Our results provide support for this alternative hypothesis with a relatively simple example of GnRH in a seasonal breeder.

P2.58 LYONS, Deirdre/C*; MCCLAY, David/R; Duke University, Durham NC; *dcl.duke@gmail.com*

Programmed cell fusion of PMCs during skeletal development in the sea urchin Lytechinus variegatus

Skeletogenesis in sea urchin embryos occurs after the development of a multinucleate syncytium that will surround the larval skeleton. Syncytium formation requires a cell-cell fusion event within the primary mesenchyme cell (PMC) population. We are using a transplant-based fusion assay to study the events of PMC fusion in vivo. The PMC lineage undergoes multiple specification-state transitions, some of which are described by the PMC gene regulatory network (GRN). The necessary fusogenic kernel remains to be defined. Previously, the transcription factors FoxN2/3, Alx1 and Twist were shown to be necessary for PMC fusion using a transplant assay with control and morpholino-knockdown micromeres, the PMC progenitors. This assay is now being used on other genes in the network to identify the top of the PMC fusion kernel. These fusion morphants provide an entry point for studying the cell biological mechanisms controlling fusion in the sea urchin. Studies of fusion in other systems—such as in mammalian trophoblast formation and muscle formation in fly and mammals —provide a list of fusion-associated candidate genes that might be conserved in urchin PMC fusion. These include the membrane protein tetraspanin, the metalloprotease ADAM, the guanine nucleotide exchange factor Dock180 and FGF-like receptor 1 (FGFRL1). The expression pattern of sea urchin homologs of these genes has been examined in cleavege, gastrula, and larval stages. To test if these genes are involved in PMC fusion, we are examining their expression levels in FoxN2/3-, Alx- and Twist-knockdown embryos, in which fusion is blocked. Identifying the network that drives fusion in sea urchins, and studying this process in vivo, will contribute to our general understanding of syncytium formation in metazoans.

P1.73 MACLEAN, HJ*; HIGGINS, JK; KINGSOLVER, JG; BUCKLEY, LB; Univ.of North Carolina, Chapel Hill ; *hmaclean@live.unc.edu*

Local Adaptation and Responses to Climate Change in Colias Butterflies

Species are expected to move upward to seek thermal refuge from climate change. Effectively predicting these movements requires linking functional traits and behaviors to environmental variables. The close functional relationship between the degree of wing melanin and body temperature in *Colias* butterflies enables establishing this link. We examine local adaptation and thermal tolerance of three *Colias* species: *C. meadii* (3,200-3,800m), *C. alexandra* (2,400-3,200m), and *C. eriphyle* (1,700-2,700m) that partition the elevation range in the southern Rocky Mountains. We reciprocally transplanted adult males of all three species across elevations and documented how phenotypes and environmental conditions jointly determine patterns of basking behavior and flight activity. Our results show that not only is there local adaptation of thermally important traits across elevation gradients (i.e. populations at higher elevations show increased wing melanin relative to their lower elevation counterparts), but population differ in basking and flight behavior. High elevation *Colias* exhibited higher performance at high elevation. On cooler mornings, their delays in flight initiation allowed sustained flight whereas low elevation *Colias* achieved only intermittent or failed flights. These results indicate that behavior is an important consideration in predicting species responses to climate change.

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Repeatability and Plasticity of Baseline Corticosterone

Evolutionary physiologists have recently begun to appreciate the adaptive significance of variation in baseline glucocorticoid levels, and its potential for mediating life history decisions related to energetic condition and environmental quality. To determine whether, and if so how, selection can act on glucocorticoid concentrations, we must determine the consistency (i.e., the repeatability) of such hormone levels. Studies presenting repeatability estimates of baseline corticosterone (CORT) concentrations in wild populations have reported variable results, and few have investigated repeatability within any environmental context. Here we present data on the repeatability and plasticity of baseline CORT in Tree Swallows (*Tachycineta bicolor*) within and across breeding seasons, with specific consideration of the contexts of age, reproductive stage, and habitat quality. These results can help determine whether static measures of baseline glucocorticoids, or plasticity in such traits, are more important for predicting fitness.

P1.67 MAGINN, K.E.*; KLAUS, J.M.; WELCH, A.M.; College of Charleston, SC, University of Central Florida; *kemaginn@g.cofc.edu*

Environmental factors influencing the selection of breeding habitat by the Carolina gopher frog, Lithobates capito

The Carolina gopher frog (*Lithobates capito*) is a habitat specialist with a limited range within the southeastern coastal plain of the United States, and it is therefore a species of conservation concern. In order to maintain viable gopher frog populations on a local scale it is important to identify and maintain suitable breeding wetlands within the limited matrices of upland habitat used by this species. To determine which factors influence the use of breeding wetlands by gopher frogs, we compare several environmental variables with the presence of *L. capito* as determined by a chorus survey. The calling census was conducted across 24 wetlands in the Francis Marion National Forest in Berkeley County, SC, and the occurrence of *L. capito* along with an estimate of the number of males heard calling from each pond was recorded. For each wetland environmental data were collected, including vegetation characteristics, water quality, forest management regime, and biotic community composition. Our goal is to determine if a relationship between environmental variables and gopher frog presence exists. Information on what environmental factors influence the use of breeding habitat by the Carolina gopher frog will aid wildlife managers in making informed decisions about which ponds to manage and how to best manage those ponds for the benefit of *L. capito*.

P1.172 MAINE, A.R.*; POWERS, S.D.; LUTTERSCHMIDT, D.I.; Portland State University, Oregon; *d.lutterschmidt@pdx.edu*

Fall migration is associated with changes in neurogenesis in red-sided garter snakes (Thamnophis sirtalis)

Seasonal rhythms in physiology and behavior are often associated with changes in brain markers, including the generation of new cells (i.e., neurogenesis). In the present study, we asked whether neurogenesis is associated with seasonal migration in a population of red-sided garter snakes (*Thamnophis sirtalis*) in Manitoba, Canada. Following an attenuated mating season, snakes migrate up to 17 km to feeding grounds where they spend the summer activity period. Fall migration back to the hibernacula is associated with an inactivation of feeding behavior as well as other physiological changes that are necessary for winter dormancy. We collected fall premigratory and postmigratory male snakes from feeding grounds or the den site, respectively and treated them with bromodeoxyuridine (BrdU), a synthetic analog of thymidine that is incorporated into the DNA of proliferating cells. Snakes were housed in outdoor arenas and euthanized at 1, 4, 7, or 10 days post-BrdU treatment. Brains were processed for BrdU immunohistochemistry to visualize newly proliferated cells. Postmigratory snakes collected from the den site during the fall had significantly higher numbers of proliferating cells in the nucleus sphericus than premigratory snakes collected from feeding grounds ($F = 12.01$; $P = 0.003$). In contrast, premigratory snakes exhibited greater cell migration than postmigratory snakes ($F = 8.35$; $P = 0.011$). These results indicate that fall migration to winter hibernacula is concurrent with changes in both cell proliferation and cell migration in the brain of adult snakes. Further studies are needed to determine if these differences are related to changes in spatial memory necessary to relocate overwintering den sites or physiological changes associated with preparation for winter dormancy.

P1.217 MAKI, K.G.*; POWERS, D.R.; TOBALSKE, B.W.; George Fox Univ, Newberg, OR, University of Montana, Missoula, MT; *kmaki09@georgefox.edu*

Heat Dissipation During Flight in Calliope Hummingbirds (Stellula calliope)

The energetic cost of flight in hummingbirds is among the highest transport costs measured and can exceed 10X BMR. Only ~10% of the energy expended during flight is converted to mechanical work with the balance converted to heat. While some of the heat produced by muscular activity during flight can be used in body-temperature maintenance much of it must be dissipated to avoid excessive hyperthermia. To gain a better understanding of heat dissipation from body surfaces during flight we used high-speed infrared video recordings (FLIR SC4000) to monitor changes in surface temperature of Calliope hummingbirds (*Stellula calliope*) during flight in a wind tunnel at speeds ranging from 0-12 m/s and correlated this with metabolic costs over the same range of flight speeds. Mean surface temperature decreased ~2 °C (25-23 °C) over the range of flight speeds measured. Major regions of heat loss (MRHL) were the head, axillary region, breast, and legs. MRHLs exhibited surface temperatures 2-7 °C above mean surface temperature with the size of the head and axillary regions decreasing by 30-50% over the range of measured flight speeds. All MRHLs decreased by at least 2 °C between 0-12 m/s with head temperature decreasing by 4 °C. Our data suggest that excess heat during flight is dissipated primarily from the heat, axillary region, breast, and feet with heat being dissipated most rapidly from the head. The progressive reduction of mean surface temperature and surface temperature of MRHLs suggests that convective heat dissipation is an important mode of heat loss at higher flight speeds.

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Geographic range size and diversification in tailed and tailless molgulid ascidians

A long standing interest in marine invertebrate evolution has been over larval development's contribution to dispersal and speciation. Newly developed methods to assess how geographic range size can affect diversification rates on molecular phylogenies has opened up new avenues of research on this topic. Ascidian species (Tunicata: Ascidiacea) in the Molgulidae are found to have urodele, tailed, chordate larvae with notochord and muscle as well as closely related species with anural, tailless larvae that completely lack larval structures, including the sensory otolith and muscle and notochord in the tail. Tail loss in the Molgulidae has occurred multiple times evolutionarily. We show that tailless species have smaller geographic sizes than tailed species, and hypothesize that species with tailless larvae have a higher diversification rate. With data collected from at least four independent lineages of tailless larvae, we assessed if the evolution of tail loss in these species has affected diversification rates using binary character speciation and extinction models. We also evaluate the impact of geographic range size on diversification rate using a quantitative speciation and extinction model.

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Stress Response Correlates with Reduced Calling Capacity in Spring Peepers (Pseudacris crucifer)

Frogs provide an excellent model to study the physiological constraints on communication behavior. Male *Pseudacris crucifer* use advertisement calls to attract females to mate, and females prefer males with higher call rates. However, the production of acoustic signals is energetically costly, thus variation in the ability to mobilize energy stores, such as lipid and glycogen, likely contributes to variation in call rate and perhaps ultimately male mating success. Recent work suggests that variation in male frog vocalizations is correlated with individual responses to environmental stressors, but the potential physiological effects of stress hormones, such as corticosterone (CORT), on the muscles involved in vocalization has not been studied. To address this question, we observed male *P. crucifer* during the breeding season (April – June) and recorded their calls. We then sacrificed them and collected trunk muscles and blood samples. We measured levels of stored lipid and glycogen in muscles as indicators of energy available for call production, and activity levels of citrate synthase as an indicator of muscle aerobic capacity. We measured plasma levels of CORT to evaluate responses of males to environmental stress. We found that CORT was negatively correlated with citrate synthase; males with high levels of corticosterone had significantly lower levels of citrate synthase activity. In addition, males with high levels of corticosterone tended to have lower call rates. Percent lipid content and glycogen content of trunk muscles were not correlated with either CORT levels or calling rate. These data suggest that male *P. crucifer* that are more affected by environmental stressors have less energy available for calling and produce a less attractive advertisement calls.

P2.89 MANRIQUE, A.; SECOR, S.*; DENARDO, D.F.; Arizona State Univeristy, Univeristy of Alabama; *denardo@asu.edu*

Water balance and the use of a unique internal water reservoir in viper boas (Candoia aspera)

Water is vital to the survival of organisms and survival is based on the balancing of water intake and expenditure. While less common than energy storage, water storage is used by some vertebrates to mitigate short-term (e.g., seasonal) water balance deficiencies. Various organs have been documented to serve, at least in part, as water reservoirs for an organism and include the urinary bladder and distal intestinal tract. We investigated water balance in the viper boa, *Candoia aspera*, and conducted preliminary assessments of the potential use of the ureters as water reservoirs. We demonstrate that viper boas have high evaporative water loss rates (both total and on a per square millimeter basis) compared to other closely related snakes, and, as with other species, these water loss rates are sensitive to both temperature and humidity. As a result, water-restricted viper boas can dehydrate (as determined by changes in plasma osmolality) in as little as 72 hrs. Additionally, we provide gross and histological evidence for the use of the ureters as water storage organs to apparently cope with the high water loss rates seen in viper boas.

P3.192 MARKELLO, K*; MOOI, R; San Francisco State University, California Academy of Sciences, San Francisco; *kmarkello@gmail.com*

Small wonders: The phylogenetics of highly modified micro-echinoids in the genus Echinocyamus

Echinocyamus is a genus of approximately 15-20 species of micro-echinoids in the family Fibulariidae, colloquially called sea peas. These diminutive irregular sea urchins are distributed globally with representatives in all but one of the major oceans, and they exhibit a wide bathymetric range. Despite the abundance of some species, little is known of their biology and ecology. Taxonomic rivalries, inadequate data-collecting, and the urchins' small size have resulted in several invalid and poorly defined species. This study provides the first detailed, species-level phylogenetic analysis of *Echinocyamus*, revising the genus to clarify dubious species. Unfortunately, material of nearly all known taxa is unsuited for molecular analyses. For the cladistic analysis, we collected morphological data from 18 species, and one new species from the Philippines was recognized. Morphological characters included petaloid shape, number of pores in each petaloid, test shape, and relative sizes of specialized pores, the mouth, and periproct. Phylogenetic analysis using parsimony allows us to infer the first-ever tree for the genus, and to map characteristics of the group to elucidate the major events in its evolution. We can also highlight specific features of the biogeography and bathymetric distribution of a widespread genus of very unusual micro-echinoids. By comparing this genus with its sister genus *Fibularia* and more distantly related *Fibulariella*, we hope to gain insight into the evolution of miniaturization in urchins.

P1.213 MARQUAND, T.H.*; BERNER, N.J.; Sewanee: The University of the South; *nberner@sewanee.edu*

Seasonal expression of cytochrome c oxidase and citrate synthase genes in the Eastern red spotted newt (Notophthalmus viridescens viridescens)

Eastern red spotted newts are active in the winter. Previous work has shown that cold-acclimated newts (8°C) have higher activity (per mg wet tissue weight) of cytochrome c oxidase (CCO) and citrate synthase (CS) in skeletal muscle than warm-acclimated newts (26°C). However, their skeletal muscle has a lower mitochondrial density when cold-acclimated than when warm-acclimated and cristea surface area does not change. This experiment was performed to test the hypothesis that an increase in the gene expression of CCO and CS in winter newts could compensate for the decrease in mitochondrial density to increase CCO and CS activity. This hypothesis was tested by comparing the expression of two CCO subunits and CS between summer and winter newts using real-time polymerase chain reaction (rtPCR). We isolated RNA from skeletal muscle, heart and liver from 10 summer-caught newts and 10 winter-caught newts. We used the 16s rRNA as the endogenous control for the mitochondrial gene COX 1, and 28s rRNA gene as the endogenous control for the nuclear genes COX 5a and CS. We found no significant difference in expression of COX1 across seasons in any tissue. Analysis of COX5a and CS gene expression is continuing. If there is no difference in the expression of these genes between seasons, then we will continue to investigate other factors that could impact their activity seasonally.

P1.64 MARSHALL, KL*; CHANG, ES; MYKLES, DL; Colorado State Univ., UC Davis Bodega Marine Lab; *marshallkira@gmail.com*

Myostatin and limb regenerate growth in the blackback land crab, Gecarcinus lateralis

Decapod crustaceans can regenerate appendages lost to injury and predation. Autotomy of at least 5 walking legs stimulates a precocious molt, as animals must molt to restore a full complement of functional appendages. Regeneration of a claw or walking leg occurs in two stages. In intermolt animals, a small basal regenerate, or limb bud (LB), forms from the proliferation and differentiation of stem cells. Basal LBs remain small (R index 8-10) until premolt, during which LBs grow to an R index of 22-23. If a LB ($R < 15$) is autotomized, remaining LBs stop growing and premolt is delayed for 2-3 weeks until a secondary LB forms and grows to the size of the lost LB. In mammals, myostatin (Mstn) is a negative regulator of skeletal muscle growth and acts by suppressing protein synthesis. A Mstn-like factor may have a similar function in *G. lateralis*. In claw muscle, a decrease in Gl-Mstn mRNA is correlated with increased protein synthesis. We hypothesize that Mstn controls LB growth. Real-time polymerase chain reaction will be used to quantify Gl-Mstn expression in LBs. The hypothesis predicts that that Gl-Mstn levels in growing LBs would be lower than levels is limb buds displaying suspended growth. Preliminary results showed a low level of Gl-Mstn expression in growing limb buds. This is in agreement with the hypothesis. Future research will focus on comparing Gl-Mstn expression levels in growing limb buds to levels in limb buds that have ceased growing due to limb bud autotomy. Supported by NSF (IBN-0618203).

P1.147 MARTIN, LB*; ARDIA, DR; HAWLEY, DM; University of South Florida, Franklin and Marshall College, Virginia Polytechnic Institute and State University; *lmartin@cas.usf.edu*

A Research Coordination Network in Ecological Immunology (RCNE)

Ecological immunology, or eco-immunology, is a burgeoning field, as evidenced by high citation rates of its many papers, three special journal issues, and several symposia at meetings throughout the world. In 2010, the National Science Foundation funded a Research Coordination Network in Ecological Immunology to foster conceptual and technical development of the field. Since funding, the RCNE has flourished, including: spawning of several collaborations between members; holding topical workshops in Florida, Scotland and (in late 2012) Virginia; establishing an email list-serv; supporting trainee research exchanges; and producing a website (www.ecoimmunology.org). We present this poster to increase the visibility and membership of the RCNE and spur interest in developing a Division of Disease Ecology within SICB or a stand-alone society. A new SICB division or stand-alone society would be inclusive of researchers working at molecular to landscape scales generally interested in the evolutionary ecology of host-parasite interactions. Indeed, future RCNE workshops are being planned to take this form including being open to interested non-members of the RCNE. The second goal of this poster is to highlight the possible outcomes of RCNs that facilitate interactions among diverse researchers: preliminary results from a meta-analysis of the costs of immune function, a paradigm that shaped research in the field. Information will be provided on joining the RCNE, on access to protocol and other materials, and on funds available to facilitate training in eco-immunological methods for scientists at all levels.

P3.199 MARTIN, R.A.*; RIESCH, R.; LANGERHANS, R.B.; North Carolina State Univ.; *ryan_martin@ncsu.edu*

Evolution of male coloration during a post-Pleistocene radiation of Bahamas mosquitofish (Gambusia hubbsi)

Visual communication signals, such as bright colors, are a conspicuous feature of biological diversity and can vary dramatically both within and between species. In many systems male coloration serves to attract females and is therefore thought to be under strong sexual selection for conspicuousness. However, conspicuous coloration may additionally attract the notice of potential predators and thus increase risk of predation. Moreover, environmental context can strongly influence the evolution of male color, either directly (e.g., variation in light environment) or indirectly (e.g., factors affecting the relative influence of natural and sexual selection). Here we examine male coloration in Bahamas mosquitofish (*Gambusia hubbsi*) inhabiting ten inland blue holes that are characterized by the presence or absence of the piscivorous bigmouth sleeper (*Gobiomorus dormitor*), to evaluate how the predation environment, water color, and other environmental factors (i.e., population density, primary productivity, sex ratio) interact to influence the evolution of male coloration. We found clear evidence that both predation and water color drove male color divergence between blue holes. Specifically, male coloration was significantly correlated with water color across blue holes, however, individuals from low-predation environments were more conspicuous (e.g., greater orange coloration in dorsal fin, larger black shoulder patch) than those from high-predation environments. Furthermore, fish reared in a common-garden laboratory environment maintained their color differences in the lab, revealing a genetic basis to the observed divergence in male coloration.

P3.25 MATSUMOTO, Taro*; ISHIBASHI, Yasunori; Kinki Univ, Nara, Japan; *ns_taro@nara.kindai.ac.jp*

Cloning of the opsin gene in longtooth grouper (Epinephelus bruneus)

The visual systems of aquatic animals have adapted to various light environments, depending on the habitat. The longtooth grouper is a large reef-associated fish. We cloned opsin genes from the grouper to identify visual adaptations of this species to the light environment of its particular habitat. Three longtooth grouper fish aged 2 years (standard length [SL], 258–300 mm) were obtained from Shirahama Experiment Station, Fisheries Laboratory, Kinki University. The total RNA was extracted from the retina or whole body of the fish. Opsin genes were cloned using reverse transcriptase-polymerase chain reaction (RT-PCR) and rapid amplification of cDNA ends-PCR (RACE-PCR). We found 4 types of opsin gene fragments including Rh1 (rhodopsin), SWS2 (blue sensitive), MWS (green sensitive), and LWS (yellow-red sensitive). The full-length open reading frame of Rh1 was 1059 bp. Our results suggest that the vision of the longtooth grouper is sensitive to blue through yellow-red light. This wide spectrum may be advantageous for the light environment from surface water to the sea bottom. We will investigate opsin expression in larvae (0–60 days after hatching) and in young fish (1 year old; SL, 220–235 mm).

P1.26 MATTER, John M*; WAGNER, Desiree; PIERCE, Sarah; Juniata College; *matter@juniata.edu*

Effects of agro-chemicals on testicular recrudesence in Sceloporus undulatus

Many studies have examined the effects of endocrine-disrupting compounds on embryonic development, particularly gonadal differentiation and sex determination. We examined the effects of agro-chemical compounds on testicular maturation in a reptile model, the fence lizard (*Sceloporus undulatus*). We treated groups of male lizards with the following compounds for six weeks, including the period of gonadal recrudesence: A) atrazine, B) trans-nonachlor, C) o,p'-DDE, D) p,p'-DDE and E) estradiol. A group of lizards treated with acetone served as a vehicle-control group. By the end of the treatment period, control males exhibited normal seminiferous tubule enlargement and spermatogenic proliferation. Only male lizards treated with estradiol exhibited significantly different testes volumes, being approximately 40% smaller than testes from control males. Additionally, estradiol-treated males exhibited smaller seminiferous tubule diameters and a lack of spermatogenesis, as evidenced by seminiferous tubules containing only Sertoli cells, spermatogonia, and few proliferative cells. Treatment with agro-chemical compounds resulted in a variety of subtle alterations in spermatogenic activity, as indicated by abnormal cell divisions in the spermatocytes of lizards treated with atrazine and the DDEs.

P2.16 MATZELLE, Allison J*; HELMUTH, Brian S; LAKSHMI, Venkat ; Univ. of South Carolina, Columbia; *allisonmatzelle@gmail.com*

Nearshore Satellite Data as Relative Indicators of Intertidal Organism Physiological Stress

The physiological performance of intertidal and shallow subtidal invertebrates and algae is significantly affected by water temperature, and so the ability to measure and model onshore water temperatures is critical for ecological and biogeographic studies. Because of the localized influences of processes such as upwelling, mixing, and surface heating from solar radiation, nearshore water temperatures can differ from those measured directly offshore by buoys and satellites. It remains an open question what the magnitude of the differences in these temperatures are, and whether "large pixel" measurements can serve as an effective proxy for onshore processes, particularly when extrapolating from laboratory physiological studies to field conditions. We compared 9 years of nearshore (≈10km) MODIS (Terra and Aqua overpasses) SST data against in situ measurements of water temperature conducted at two intertidal sites in central Oregon- Boiler Bay and Strawberry Hill. We collapsed data into increasingly longer temporal averages to address the correlation and absolute differences between onshore and nearshore temperatures over daily, weekly and monthly timescales. Results indicate that nearshore SST is a reasonable proxy for onshore water temperature, and that the strength of the correlation increases with decreasing temporal resolution. Correlations between differences in maxima are highest, followed by average and minima, and were lower at a site with regular upwelling. While average differences ranged from ≈0.199-1.353°C, absolute differences across time scales were ≈0.446-6.906°C, and were highest for cold temperatures. The results suggest that, at least at these two sites, SST can be used as a relative proxy for general trends only, especially over longer time scales.

P1.120 MCCARTNEY, J.A.; Stony Brook University; *jmccartney@ic.sunysb.edu*
Vertebral number is correlated with ecology in snakes (Squamata: Serpentes)
Lack of functional limbs in snakes has led to an increased importance for the trunk in locomotory and feeding behaviors. Because of this, the vertebral column is a likely source of variation related to ecology. Vertebral number, in particular, may vary with ecology; previous work suggests that snakes requiring greater flexibility (e.g., constrictors) have more vertebrae on average, and that snakes requiring greater stability (e.g., fossorial snakes) have fewer. This study investigates the relationships between ecological factors and vertebral number. Vertebral counts were collected from the literature and from new observations, and ecological data (habitat preference, constriction) were drawn from the literature. Snakes were sorted into four preferred habitats: terrestrial, arboreal, fossorial, and aquatic. A total of 292 species representing most families were included. The dataset was analyzed to determine what, if any, effect ecology had in selecting for vertebral number within groups. The results reveal that an Ornstein-Uhlenbeck model in which there is strong selection to maintain vertebral number at four separate optima (corresponding to the preferred habitats) was significantly better at explaining the data than either a single, global optimum or a two-optima model (constriction vs. non-constriction). A further phylogenetic generalized least squares analysis also reveals that constrictors have significantly more vertebrae than non-constrictors. Thus, vertebral number is significantly affected by both preferred habitat and constriction. The strong ecological signal shown here in the vertebral column is of potential interest in reconstructing the paleobiology of extinct snakes, particularly in combination with other morphological data.

P1.16 MCCLARY, JR., M.*; HASSAN, N.; MORRISON, K.; MARTINEZ, E.; EMO, S.; SALEM, H.; SHAH, A.; GARAH, S.; GARAH, M.; Fairleigh Dickinson University, Union Hill High School, North Bergen High School, County Prep High School, Lodi High School, Paramus High School; *mcclary@fdu.edu*
Shell characteristics of barnacles from two New Jersey water bodies
Due to the brittle nature of barnacle shells in the Hackensack River of New Jersey, the thickness of barnacles shells from the Hackensack River and from Laurence Harbor was compared. Barnacles from both New Jersey water bodies were collected, cleaned, identified to species, measured, weighed, and analyzed for calcium concentration. As the shells become longer their apertures become longer. As the shells become heavier they become taller but not wider. Having a larger aperture may explain why the shells break easily. Having height but not a wide base may also explain why the shells break easily. Higher calcium concentrations were found in the barnacles shells from the Hackensack River which may or may not explain why they break more easily than barnacle shells from Laurence Harbor. Future research will determine if this is due to calcium concentrations or pollutants.

P3.31 MCCLINTOCK, J.B*; AMSLER, M.O.; ANGUS, R.A.; CHALLENER, R.C.; SCHRAM, J.B.; AMSLER, C.D.; MAH , C.L.; CUCE, J.; BAKER, B.J.; Univ. of Alabama at Birmingham, Univ. of Alabama at Birmingham , Uni. of Alabama at Birmingham, Museum of Natural History, Smithsonian Inst., University of South Florida, University of South Florida ; *mcclinto@uab.edu*
The Mg-Calcite levels of Antarctic echinoderms: implications for ocean acidification and further support for a latitudinal gradient in levels of Mg-Calcite
The Southern Ocean is considered to be the canary in the coal mine with respect to the first impacts of ocean acidification (OA). As such, calcite and aragonite are expected to become undersaturated within 50 and 100 years. Echinoderms, whose skeletons are comprised of high magnesium carbonate (greater than 4% mol $MgCO_3$), are even more vulnerable to OA than organisms whose skeletons are comprised of aragonite or calcite. Currently there is almost no information on the Mg-Calcite composition of Antarctic echinoderms, a group known to be a major contributor to the global marine carbon cycle. Here we report the Mg-Calcite compositions of 26 species of Antarctic echinoderms representing four classes. As seen in tropical and temperate echinoderms, Mg-calcite levels varied with taxonomic class with sea stars and brittle stars with the highest levels. Both classes are key players in Antarctic benthic communities, and are likely to be the first echinoderms challenged by near-term OA. When combined with published data for echinoderms from primarily temperate and tropical latitudes, our findings support the hypothesis that Mg-Calcite level varies inversely with latitude. The basis of this relationship has been suggested to include temperature, light, salinity, seawater saturation state and/or physiological factors. We propose that predation is also worthy of consideration as crushing predators decline with increasing latitude. As such, high latitude echinoderms may not require as high a ratio of magnesium to calcite to strengthen their skeletal elements.

P2.128 MCCOMMAS, Steven A*; BAUER, Cassandra L; KERSTEIN, Kristopher W; MCCULLOUGH, Kyle A; KRAJNIAK, Kevin G; Southern Illinois University Edwardsville; *smccomm@siue.edu*
The identification of a FMRFamide –related peptide in the earthworm, Lumbricus rubellus
FMRFamide is a neuropeptide that was first isolated from the cerebral ganglia of a bivalve mollusc. Since then many peptides with a sequence similar to FMRFamide have been isolated from many different invertebrate animals. In the phylum Annelida FMRFamide and other FMRFamide-related peptides (FaRPs) have been found in polychaetes and leeches. However so far no one has identified a FaRP from an earthworm. Many animal genomes have been sequenced and placed in public databases, including that of the earthworm, *Lumbricus rubellus*. Therefore we decided to examine whether any of the expressed sequence tags (ESTs) in Lumbribase, the *L. rubellus* database, contained any peptide sequences related to FMRFamide. Using the BLASTx program for translated nucleotide sequences we found an EST from the late cocoon stage that contained multiple copies of a sequence which, if cleaved at the basic residues and amidated would yield the peptide APKQYVRFamide. This peptide is similar in structure to two other predicted annelid peptides, PAKHYVRFamide from a leech and AGAYVRFamide from a polychaete. These three peptide sequences contain a tetrapeptide core of YVRFamide. We have already shown that FMRFamide modulates the motility of the earthworm digestive tract and body wall and are now examining how the tyrosine (Y) and valine (V) found in the YVRFamides affect these bioassays.

P2.153 MCCORMICK, L. R.*; COHEN, J. H.; Eckerd College, St. Petersburg, FL, University of Delaware, Lewes, DE; *mccormlr@eckerd.edu*

Pupillary light reflex in the Atlantic brief squid, Lolliguncula brevis

Coleoid predation is highly visual and requires an eye capable of imaging visual targets in variable photic conditions. Pupillary responses are one feature that contributes to this visual flexibility in coleoids, although pupil responses have yet to be quantitatively documented for squids. The pupillary response of the Atlantic brief squid, *Lolliguncula brevis*, was analyzed by exposing individuals to alternating treatments of varying light intensities and periods of dark recovery while simultaneously recording the eye under direct and indirect light stimulation to determine whether the response was consensual between eyes. A pupil light reflex was measured, with an asymmetrical constriction observed under increasing irradiance levels that was largely consensual between eyes. The response threshold was 12.56 to 12.66 log photons/cm^2/s. The spectral responsivity of the pupillary response was analyzed by measuring the magnitude of the pupil light reflex of the eye directly stimulated by light at equal quantal intensities at wavelengths throughout the visible spectrum. The response spectrum showed a maximum at 500 nm, which was best fit with a rhodopsin absorptance template having a λ_{max} of 511 nm. When collectively examined in the context of the diel light environment in *L. brevis* habitat, these results show the sensory adaptation of *L. brevis* to a coastal environment, with a visual system well-suited for acuity during dusk, when there are rapid changes in irradiance and a peak absorbance of blue-green light (~500 nm). Whether the pupillary light reflex results from visual and/or non-visual photoreceptors remains an open question and will be discussed.

P3.158 MCCORMICK, S.D.*; REGISH, A.M.; CHRISTENSEN, A.K.; BJORNSSON, B.T.; USGS, Conte Anadromous Fish Res Ctr, Turners Falls, MA, USGS, University of Goteborg, Sweden; *mccormick@umext.umass.edu*

Na,K-ATPase Isoform Switching is Critical for the Development of Salinity Tolerance in Juvenile Atlantic Salmon.

The sodium pump, Na+,K+-ATPase (NKA), in the gills of teleost fish is involved in ion regulation in both freshwater and seawater. Freshwater and seawater isoforms of the alpha subunit of Na+/K+-ATPase have previously been identified in gill ionocytes of Atlantic salmon. We examined the abundance and cellular localization of these isoforms during the parr-smolt transformation, a developmental process which is preparatory for seawater entry. NKA activity increased 2.5-fold during smolt development, and salinity tolerance was higher in smolt than in parr. The abundance of NKAa1a was lower in smolts than in parr, but remained relatively constant during spring and decreased in summer. NKAa1b increased ten-fold in smolts during spring, peaking in early May at the time of downstream migration and salinity tolerance, then decreased in summer. NKAa1b increased a further two-fold after seawater exposure of smolts, whereas NKAa1a decreased by 98%. The abundance of NKAa1b-positive and NKAa1b and NKAa1a colabeled ionocytes increase during smolt development, whereas NKAa1a cells decrease. After seawater exposure of smolts, NKAa1b-positive ionocytes increase, whereas colabeled cells disappear and NKA&alpha1a-positive cells decrease. Plasma growth hormone and cortisol increased during spring in smolts, but not in parr, peaking just prior to the highest levels of NKAa1b. The results indicate that the increase in the abundance of NKAa1b during smolt development is directly linked to the increase in salinity tolerance that occurs at this stage, and that significant changes also occur after seawater exposure. Spring increases in circulating levels of growth hormone, IGF-I and cortisol indicate these hormones are involved in upregulation of NKAa1b during smolt development.

P2.43 MCCOY, JA*; KOHNO, S; DOHENY, BD; GUILLETTE, JR., LG; Medical University of South Carolina, OBGYN, Hollings Marine Lab; *jessicacloy@gmail.com*

The potential role of glucocorticoid signaling during sex determination in the American alligator (Alligator mississipiensis).

A critical point of vertebrate sex determination occurs when the bipotential gonad develops into a testis or ovary. Although the role of estrogen is important in ovarian development, the complete network of cellular and molecular signals that influence gonadal development remains poorly understood. We use the American alligator to examine questions related to sex determination and gonadal development. This model is useful as sex is determined by the incubation temperature during a thermo-sensitive period (TSP) of embryonic development. During development, the gonad is part of a complex that includes the adrenal gland and mesonephros. Given the proximity of the developing gonad to the adrenal gland and the fact adrenal function is influenced by heat stress, it is feasible to hypothesize that adrenal steroid hormones influence sex determination. Potential mechanisms of adrenal regulation include: (1) production of HSP90α, a modulator of steroid hormone action, and (2) modulation of anti-Mullerian hormone (AMH) activity, which is essential for testicular development. To explore these questions, we have treated developing embryos prior to the TSP (Stage 19) with either a synthetic glucocorticoid (dexamethasone) or corticosterone. The experimental design and findings presented here aim to unravel the signaling pathways involved in environmental sex determination, specifically the potential role of adrenal gland activity on sex determination of the American alligator.

P1.205 MCCUE, Marshall D; St. Mary's University; *mmccue1@stmarytx.edu*

Atmospheric oxygen availability limits thermotolerance at upper lethal temperatures: an examination of environmental oxygen limitation in insects

Thermotolerance is an important factor in shaping the biogeographic distribution of animals and potentially a species' ability to cope with climate change. The current paradigm is that the primary mechanism restricting survival at high temperatures, particularly in endotherms, is the physiological hysteresis between oxygen supply and oxygen demand. Despite broad support for this thesis, it rests on little direct empirical support, particularly among terrestrial animals. The classic test of resource limitation is to examine performance of an organism under normal conditions and under conditions where the potentially limiting resource is increased and decreased. Oxygen delivery, and possibly thermotolerance, in insects is thought to be limited by the diffusion of oxygen throughout the tracheal system. Therefore, I exposed several species of insects to ambient temperatures just above their thermal lethal limit and recorded lethal exposure times under several ambient oxygen concentrations (i.e. normoxia 21%, hypoxia 0,10%, and hyperoxia 35,95%) to investigate how ambient oxygen availability affects thermotolerance. I also tested specific predictions about how such effects were related to body size and developmental stage. Survival curves were compared using Kaplan-Meyer log rank analyses. The results suggest that insects generally exhibited increased thermotolerance at 35% oxygen and decreased thermotolerance at 10% oxygen, although some species showed no significant effects. Performance was decreased in all cases under anoxia, yet results were mixed at 95% oxygen. Insects have existed over the past 350 million years during which the oxygen availability of Earth's atmosphere is thought to have fluctuated from 10% to 35%; it will be important to consider how oxygen availability may have influenced the physiological performance and biogeography of ancient insects.

P3.116 MCDONALD, A.J.*; JAECKLE, W.B.; Illinois Wesleyan Univ., Bloomington; *amcdonal@iwu.edu*

Uptake of dissolved high molecular weight molecules by larvae of Lytechinus variegatus

Echinoid larvae can absorb small and large dissolved organic materials (DOM) from seawater (e.g., amino acids and proteins, respectively). DOM uptake is normally attributed to ectodermal epithelia, but uptake by the digestive tract has been reported. Protein uptake by larvae has been observed in the endodermal epithelium. These observations suggest seawater flows through the larval digestive system and that the digestive epithelium can remove DOM from this flow. To test this hypothesis we exposed pluteus larvae of the sea urchin *Lytechinus variegatus* to concentrations of polysaccharides and proteins that reflect their abundance in seawater. Pluteus larvae of varying ages were incubated in filtered seawater containing 264 nM solutions of polysaccharides (rhodamine-dextran, iron dextran) and proteins (FITC-albumin, ferritin) for 1 to 4.5 h. Labeled dextrans were assimilated only by the cells of the larval stomach; rhodamine-dextran was detected in gastric cells after a 1-h exposure. In contrast, labeled albumin was present in cells of the ectodermal ciliary band, the entire gut lining, and the distal end of the pore canal after exposures of 1-h. Ferritin uptake was detected in cells of the stomach and the distal end of the pore canal after 4-h exposures. The assimilation of macromolecular DOM from seawater by the digestive epithelium suggests a flow of water through the gut. The presence of labeled cells at the pore canal terminus is also suggestive of an influx of seawater, but we cannot exclude resorption of the label from primary urine formed by the “larval kidney”. Uptake of proteins by outer epithelium was only seen in cells of the larval locomotory structure. That pluteus larvae can take up both low and high molecular weight forms of DOM suggests that DOM may be a significant nutritional resource.

P2.40 MCIVOR, CC; U.S. Geological Survey; *carole_mcivor@usgs.gov*

Community ecology of mangrove rivulus at two west Florida locations

Mangrove rivulus (*Kryptolebias marmoratus*) were captured from closed canopy mangrove forests in two west Florida locations: along a salinity gradient on the Shark River, Everglades National Park, and along an elevation gradient on a mosquito-ditched peninsula in west central Tampa Bay. In both instances they were the most abundant fish taxon captured in buried aluminum trenches placed flush with the forest floor. Mangrove rivulus were present year-round along the Shark River and occurred across a wide range of salinities from near-fresh to near-marine. If abundance is a valid indicator of habitat quality, mangrove killifish selected habitat based on a combination of distance from the nearest permanent subtidal water and intertidal elevation - and thus depth of flooding (Tampa Bay location). A comparison of size frequency distributions in the two locations indicates that Tampa Bay fish are smaller than those in the Everglades, perhaps because of cooler temperatures and longer winters near their northern distributional limit. Tarpon Bay, our uppermost (and lowest salinity) site along Shark River, is a large tidal embayment with 40 km of narrow, fringing mangrove shoreline. If we assume that the habitat we sampled there with three permanently located nets is representative of the remaining shoreline, then extrapolating the means of our rivulus density estimates (7 years of data) indicate that the Tarpon Bay location might contain 30,400 mangrove rivulus. Clearly, the management and scientific communities require basic ecological data from more locations to better ascertain the true conservation status of this widely-used "model" fish.

P2.129 MCPHERSON, D.R.; SUNY at Geneseo; *mcpherso@geneseo.edu*

Pharmacology of the serotonin-mediated increase of cAMP in Aplysia foot muscle

In the marine gastropod mollusc *Aplysia californica*, serotonin (5-HT) causes a large increase in the cAMP content of foot muscle tissue. This increase of cAMP is believed to underlie much of the strong modulatory effect of 5-HT on foot muscle contraction force and relaxation rate. It is therefore of interest to explore the pharmacology of the 5-HT receptor that mediates the cAMP increase, in order to describe its profile and in hopes of finding selective tools to manipulate it. In this poster I will present the results of experiments using a variety of 5-HT antagonists. The most effective antagonist was mianserin, followed by methiothepin and cyproheptadine. Most other drugs were ineffective. While none of the effective drugs are highly selective, the results do yield a partial profile of the 5-HT receptor and may distinguish it from other receptors in *Aplysia*.

P1.142 MEDLIN , Alexandra/M.*; COLE, Amanda/M.; SHEDLOCK, Andrew/M. ; College of Charleston, College of Charleston ; *amedlincofc@gmail.com*

Global annotation and molecular evolutionary analysis of genomic repeats in the Painted Turtle, Chrysemys picta

The analysis of genome-scale information from the sister group of mammals, Reptilia, is presently closing a large gap in the study of vertebrate biology. Turtles are of central importance to this effort in that they have been difficult to place accurately in the amniote tree of life, they exhibit a number of unique phenotypic and life history traits among vertebrates, and are threatened globally by a variety of human impacts on the environment. Annotating genomic repeats by sequence alignment to a reference database provides a means for testing alternative models of molecular evolution and can thereby describe forces that have shaped our own genomes uniquely as compared to other amniotes. We annotated global repeat content for the full set of genomic sequence reads generated for the painted turtle, *C. picta*, the first turtle species having its complete genome assembled. Sequence divergence values reveal differential age distributions among major repeat subfamilies suggesting relatively young active mobile elements are still driving turtle genomic diversity whereas distributions skewed toward higher mean values suggest the presence of numerous distinct lineages of older inactive repeats that can be viewed as molecular fossils embedded in turtle chromosomes. The present study reveals that alternative modes of evolution are likely operating in different turtle repeat lineages whose proliferation and persistence cannot be easily explained by strict vertical inheritance of single source genes, such as seen for the dominant form of interspersed repeats in the human genome and that contrasts with the largely inactive compact repetitive DNA landscape of birds.

P2.93 MENZEL, Evan J.*; NICHOLAS, Bailey; DENARDO, Dale F.; SECOR, Stephen M.; University of Alabama, Arizona State University; *ejmenzel@crimson.ua.edu*

Adaptive regulation of gastrointestinal form and function for the diamondback rattlesnake.

Snakes exhibit an adaptive interplay between feeding frequency and the extent that they modulate gastrointestinal (GI) performance with feeding and fasting. Snakes that feed relatively frequently in the wild modestly regulate intestinal performance with each meal, whereas infrequently feeding species widely regulate intestinal form and function with the start and completion of digestion. We tested this adaptive hypothesis by examining postprandial responses in GI morphology and function for the western diamondback rattlesnake (*Crotalus atrox*). This rattlesnake feeds relatively infrequently in the wild given its sit-and-wait foraging behavior and hence is predicted to significantly regulate GI form and function with feeding. Luminal pH throughout the GI tract was relatively neutral (6-7.7) for fasting snakes. Rodent meals (25% of body mass) generated significant decreases in gastric pH (2-3) at 12 h and 2 d postfeeding, while other portions of the GI tract did not change in pH. Feeding resulted in a doubling of liver mass, tripling of small intestinal mass, a 76% increase in kidney mass, and a 73% reduction in the mass of the gall bladder. Rattlesnakes experienced with feeding 60%, 100%, and 120% increases in intestinal mucosal thickness, enterocyte volume, and microvillus length, respectively. We found feeding to induce significant increases in the specific activities and total tissue capacities of pancreatic trypsin and amylase and intestinal aminopeptidase and maltase. Western diamondback rattlesnakes experience the predicted wide regulation of gastrointestinal performance common to snakes that feed infrequently.

P3.112 MEYERS, M.L.*; JACOBS, M.W.; GALLAGER, S.M.; CHRISTMAS, A.F.; McDaniel College, Woods Hole Oceanographic Institution, Western Washington University ; *mlm028@mcdaniel.edu*

Living It Up Before Going Down- Vertical Positioning Behaviors of Homarus americanus Larvae in Response to a Thermocline

Vertical positioning of the larvae of the American lobster (*Homarus americanus*) is a critical factor that may influence transport, depth at settlement, and abundance. We hypothesized that vertical positioning behavior of lobster larvae would vary with larval age, and that vertical movements of larvae would be limited by the natural oceanographic barriers, such as thermoclines. Larvae of different stages were released into ten meter columns in one of three environments: (1) a column with an established thermocline, (2) a column with an evenly distributed water temperature undergoing the development of a thermocline, or (3) a column exhibiting a uniform temperature. We used an underwater video camera to profile vertical position as a function of temperature and time of day (day vs. night). Larvae of all three stages positioned themselves at significantly higher depths in the presence of a thermocline. Stage I larvae positioned themselves at higher depths at night than during the day, while stage III larvae and stage IV postlarvae were found at similar depths at night and during the day. Additionally, when larvae were released into an environment as a thermocline was forming, they responded to the formation by positioning themselves at higher depths over time. Postlarvae offered settlement habitats at a range of depths chose to settle above the thermocline if present and at lower depths in the absence of a thermocline. Although they were physically able to cross the thermocline, lobster larvae and postlarvae responded to the gradient by adjusting their vertical positioning. These results suggest that vertical positioning may be strongly influenced by natural barriers present in the open ocean.

P3.18 MIKA, Teresa L.*; REIBER, Carl L.; University of Nevada, Las Vegas; *mikat@unlv.nevada.edu*

Cardiac performance across temperature extremes in the grass shrimp, Palaemonetes pugio.

Metabolic rate increases in poikilothermic animals exposed to increased temperature. The systems responsible for oxygen uptake and distribution must keep pace with this increased rate if these animals are to maintain aerobic metabolism. Analyses were performed on grass shrimp, *Palaemonetes pugio*, acclimated to 20° C exposed to a range of temperatures (5° – 40° C) in both normoxic and hyperoxic environments to determine response of the oxygen delivery system to this increased demand. Animals placed in a hyperoxic environment had a higher CT_{max} than animals in a normoxic environment, suggesting a physical limitation in oxygen delivery. Previous work has indicated a limitation in diastolic filling time may be a main contributor to this limitation in oxygen delivery. Current work investigates the time in cardiac cycle across the range of temperatures to determine if this previously noted relationship is maintained across a wider range of heart rates. Pressure-area loops are also generated to provide an estimate of cardiac work and myocardial oxygen consumption in both normoxic and hyperoxic conditions.

P2.102 MILENKAYA, O.*; WALTERS, J.R.; Virginia Tech; *olm@vt.edu*

Survival of finches is predicted by oxygen carrying capacity, but not by immunological, stress, or condition parameters

While some physiological parameters have been demonstrated to predict reproductive success (eg. MCV) and survival (eg. CORT), others have yet to be validated as indicators of fitness. We investigated whether several such measures were linked to survival probabilities in a population of wild Crimson Finches *(Neochmia phaeton)* at Mornington Wildlife Sanctuary over two breeding seasons. Adults and nestlings were sampled for hematocrit (PCV), hemoglobin (Hb), and total plasma protein. Adults were additionally sampled for heterophil to lymphocyte ratio, scaled mass index, muscle score, and fat score. We included age, sex, breeding stage and year in some of our models of adult survival, and size and year in some of our nestling models. We analyzed survival in Program MARK and ranked the models using an information theoretic approach. The top two models for apparent adult survival included PCV and, combined, had 66% of the model weight. An adult with high PCV is 250% more likely to survive one year compared to an adult with low PCV. With 79% of the weight, the top two nestling models included PCV and Hb, parameters that are highly correlated and reflect oxygen carrying capacity. High PCV nestlings are 200% more likely to survive to independence compared to nestlings with low PCV. These results indicate that oxygen carrying capacity, but not immunological, stress or condition parameters, predict survival in Crimson Finches. None of the birds were anemic, suggesting that the effect of PCV and Hb on survival is not mediated through direct mortality, but is an indirect effect of oxygen carrying capacity. We hypothesize that increased oxygen carrying capacity may improve predator evasion and competitive ability.

P1.224 MILLER, L.*; WATERS, J.S.; HARRISON, J.F.; VANDENBROOKS, J.M.; YAGER, D.D.; XIAO, X.; DE CARLO, F.; SOCHA, J.J.; Virginia Tech, Arizona State U., U. Maryland, Argonne National Lab.; *jjsocha@vt.edu*

The use of SR-µCT for 3D visualization of insect tracheal systems

The morphology of the insect respiratory system consists of an immense network of tracheal tubes and airsacs that range in size from the millimeter to sub-micron scale and permeate the entire body. Gases are exchanged directly from tracheae to the tissues largely without a circulatory component. Because patterns of diffusive or convective air transport depend on network geometry, the structural design of the system is critical to understanding its performance. Despite its importance, the three-dimensional morphology of insect tracheal systems has not been well characterized, largely due to the difficulty of obtaining reliable or accurate data. Here we demonstrate the use of synchrotron radiation microcomputed tomography (SR-µCT) to visualize the three-dimensional tracheal systems of intact insects. Samples were prepared fresh (with no tissue fixation) by sacrificing the insect with ethyl acetate and then securely mounting the sample in x-ray transparent polyimide tubes. In a scan, approximately 1400 projection images are recorded while the sample rotates 180° about the vertical axis, a process that takes on the scale of seconds using a high-speed camera. The 3D morphology of tracheae and airsacs in multiple species was successfully imaged, including samples from ant, beetle, fruit fly, preying mantis, and butterfly taxa. We compare image results to those from other techniques such as confocal microscopy and stereological point-counting. The resolution of confocal microscopy was slightly greater, enabling the visualization of more sub-micron tracheoles in fruit fly muscle tissue, but SR-µCT allowed larger sample volumes to be imaged. We conclude that SR-µCT is a highly effective technique for obtaining three-dimensional tracheal system morphology.

P2.91 MINEO, P.M.*; SCHAEFFER, P.J.; Miami University; *mineopm@muohio.edu*

Thermal acclimation of locomotor performance in the Eastern Newt (Notophthalmus viridescens).

Biochemical acclimation to temperature is evident in some amphibians, but the degree to which this response is associated with locomotor performance is uncertain. Previous studies demonstrate biochemical acclimation of oxidative enzymes in muscle of the Eastern Newt (Notophthalmus viridescens). Our goal is to determine how the acclimation of these metabolic enzymes is correlated with the thermal sensitivity of locomotor performance in these animals. We acclimated N. viridecens to 25°C, 15°C, and 5°C for 12 weeks. Next, we measured burst-swimming speed and swam newts to exhaustion at 5°C, 10°C, 15°C, 20°C, 25°C and 30°C in a temperature-controlled track. The activities of lactate dehydrogenase, citrate synthase, and cytochrome c oxidase in muscle extracted from these animals was measured across the same temperature range as the locomotor tests to determine if thermal sensitivity of enzyme function is matched with the thermal sensitivity of burst and endurance locomotion, as well as whether phenotypic flexibility of enzyme function is associated with phenotypic flexibility of locomotor performance.

P1.41 MIRANDA, RA*; PROPPER, CR; Northern Arizona University; *ram257@nau.edu*

Sexually dimorphic mRNA levels of genes involved in arginine vasotocin and sex steroid signaling in the brain of Xenopus tropicalis

The arginine vasotocin (AVT)/arginine vasopressin neuropeptide system interacts with sex steroids to mediate social behaviors in vertebrates. Additionally, both the expression of behavior and expression of these neuroendocrine signaling systems is sexually dimorphic across clades. The purpose of this study was to compare mRNA abundance of genes important for AVT and estrogen signaling in the brain between adult male and female *Xenopus tropicalis*. Brains from each sex (n=10) were collected and later macrodissected into five areas: hindbrain, thalamus/hypothalamus, preoptic area, lateral telencephalon and medial telencephalon. Total RNA was then extracted from each brain area and cDNA was synthesized from mRNA. Quantitative real-time PCR was used to measure mRNA abundance of AVT precursor peptide (VT), AVT 1a receptor (V1a), estrogen receptor α (ERα) and aromatase (CYP19). A difference in mRNA levels was seen between sexes. Males expressed more V1a mRNA in the medial telencephalon (Student's t-test, $p=0.045$). Males also showed higher transcript abundance in the preoptic area for both VT (Mann-Whitney U test, $p=0.014$) and CYP19 (Mann-Whitney U test, $p=0.022$). Females showed more mRNA abundance for ERα (Mann-Whitney U test, $p=0.05$) and CYP19 (Mann-Whitney U test, $p=0.021$) in the hindbrain. No difference in mRNA levels was seen between sexes for all other genes analyzed anywhere in the brain. Our results demonstrate that there is sexually dimorphic mRNA abundance for genes involved in AVT and estrogen signaling in the brain of *X. tropicalis* and suggest estradiol synthesis may interact with brain AVT signaling pathways.

P1.61 MITCHELL, Reed T*; PINHO, Breanna SH; HENRY, Raymond P; Auburn University; *RZM0015@auburn.edu*

Carbonic anhydrase induction in the euryhaline blue crab, Callnectes sapidus, during low salinity acclimation is rate-limited by protein synthesis

An essential component of the ability of the marine blue crab, *Callinectes sapidus*, to survive in low-salinity environments is an increase in cytoplasmic carbonic anhydrase (CA) activity in the posterior, ion-regulating gills. This is accomplished via a two-step mechanism involving rapid gene activation followed by synthesis of new enzyme. Upon transfer from 35 ppt to low salinity, relative expression of cytoplasmic CA mRNA (CAc) increases 100-fold at 12 hr; however, it is not until 96 hr that new acclimated levels of CA activity are reached. This delay in activity suggests that protein synthesis, not gene activation, is the rate-limiting step. To further test this we measured both CAc expression and CA activity in crabs acclimated to 35 ppt and transferred to 22 ppt, and in crabs transferred from 22 to 10 ppt. In the 22 ppt transfer, crabs did not show an increase in CA activity until 48 hr post transfer. In the 10 ppt group CA activity did not rise until 24 hrs, despite high levels of gene expression at 22 ppt. These results demonstrate that despite the priming of the CA induction mechanism at 22 ppt, increases in CA activity still take on the order of days to occur. This may be due to necessary post-translational modifications such as the insertion of a zinc atom into the active site of the enzyme. Preliminary testing of zinc as a limiter of CA activity has yet to yield conclusive results.

P2.116 MONACO, C. J.; University of South Carolina; *monacocj@email.sc.edu*
Parameterizing a Dynamic Energy Budget Model for the keystone predator Pisaster ochraceus
Ecological literature offers a number of examples revealing the overarching importance of keystone predators on their systems. By driving prey dynamics, these key players can define the structure and functioning of entire communities. Mechanistic studies have shown that the relative importance of predator species on their communities is largely determined by their sensitivity to varying body temperature and food conditions. Despite widespread recognition of keystone predators' critical ecological role, few predictive frameworks have been developed that account for interactive effects of varying prey availability and temperature on their foraging performance. Pure experimental studies are usually unable to capture the interaction of multiple factors. Pure theoretical approaches, in turn, consider inherently complex environments, but are often criticized for lacking realism. By merging these approaches, current efforts are providing a deeper understanding of the ways in which individuals' physiological condition varies under constantly fluctuating environmental signals. Dynamic Energy Budget Models (DEBM) rise as powerful tools, capable of integrating such signals to shed light on the organism's fitness throughout its life-history. I show work-in-progress aimed towards estimating standard DEBM parameters for the sea star *Pisaster ochraceus*, an emblematic keystone predator inhabiting rocky-intertidal shores along the west coast of North America. Besides relying on computer simulations and literature surveys, the model parameterization is strongly supported by empirical observations. Preliminary outputs are shown, where *Pisaster*'s foraging behavior and fitness are contrasted under different temperature and food conditions.

P2.198 MONGEAU, J.-M.; ALEXANDER, T.*; FULL, R.J.; Univ. of California, Berkeley, Morgan State Univ.; *jmmongeau@berkeley.edu*
Neuromechanical Feedback during Dynamic Recovery after a Lateral Perturbation in Rapid Running Cockroaches
When running animals are perturbed, recovery depends on the interplay between mechanical and neural feedback. Low-dimensional dynamic models complemented by kinematic and electromyographic (EMG) experiments of running cockroaches have demonstrated that mechanical self-stabilization can be sufficient to recover from perturbations. While mechanical feedback alone may be sufficient to maintain stability following small perturbations, measurements of instantaneous leg kinematic phase and frequency suggest that neural feedback is required when animals are pushed outside their passive stability basin. To study the interplay of neural and mechanical feedback during dynamic recovery, we perturbed rapid running cockroaches *Blaberus discoidalis* with a lateral impulse of a magnitude nearly twice the running speed (0.67 ± 0.03 m s^{-1}). We hypothesized that the early phase of recovery would be dominated by mechanical feedback followed by neural feedback. To identify the presence of neural feedback, we analyzed the EMG patterns of putative control muscles in the hind leg (178,179). Animals ran at an average, preferred escape speed of 36.2 ± 7.0 cm s^{-1} while experiencing peak lateral impulses of 1.35 ± 0.15Gs on a moving cart. We observed evidence of neural feedback in EMG signals during the second post-perturbation stride (~100 ms after perturbation). Frequency of post-perturbation signals after 2 strides decreased relative to pre-perturbation recordings (median period increase = 4.9 ms; $P = 0.001$). Post-perturbation changes in EMGs support the predictions made by studies of instantaneous leg kinematic phase and frequency that suggest alterations to the animals' neural oscillators.

P3.103 MONTUELLE, S.J.*; WILLIAMS, S.H.; Ohio University Heritage College of Osteopathic Medicine; *montuell@ohio.edu*
Mobility of the mandibular symphysis during feeding in lizards
In jawed vertebrates, the lower jaw is comprised of two hemimandibles that are united in the anterior midline by the mandibular symphysis. In lizards, the symphysis exhibits variable morphology in the extent of connective tissue density, symphyseal width and the morphology of Meckel's cartilage (i.e., fused anteriorly or unfused). Because of these differences, previous studies have suggested functional differences in the role of the mandibular symphysis during feeding. Here, we investigate symphyseal mobility during prey capture and processing in lizards that differ in the morphology of their mandibular symphysis. We compare the intra-mandibular movements in a lizard species characterized by an un-fused Meckel's cartilage, *Gerrhosaurus major*, with one characterized by a fused Meckel's cartilage, *Pogona vitticeps*. Both species, however, have dense connective tissue in the symphyseal joint. We use high speed fluoroscopy in lateral and dorsoventral views to reconstruct the movements of the two hemimandibles in three dimensions. Our observation indicates that despite an unfused Meckel's cartilage, the hemimandibles of *G. major* do not move independently during feeding. These results suggest that fiber density may be more important for restricting movements of the hemimandibles than Meckel's cartilage in lizards.

P1.127 MOOI, R.*; BURNS, C.; California Academy of Sciences, San Francisco; *rmooi@calacademy.org*
Tic tacs from the Eocene of the Pacific Northwest: Significant clypeasteroids from unexpected places
Recent discovery of specimens of the sand dollar relative, *Fibulariella*, from the Yellowstone Hot Spot-derived middle Eocene Crescent Formation (50ma) at Tongue Point, Clallam County WA, represents the first northeastern Pacific occurrence of this genus. These extremely miniaturized laganine clypeasteroids (<5 mm test length) are found serendipitously preserved in sediments lodged in crevices between basalt pillows and breccia associated with possible black sand beach deposits. Associated fauna include warm water corals, bryozoans, mollusks, brachiopods and at least 3 other species of echinoids. The geographically closest Eocene relative of this likely new *Fibulariella* species is a Gulf of Mexico form presently and incorrectly known as a *Fibularia*, *F. texana*. *Fibulariella* is only now emerging as a taxon significantly different from *Fibularia* in many respects. The two genera are superficially similar due to their small size and apparent paedomorphosis, but differ greatly in overall plate architecture, basicoronal arrangement, petaloid shape, and details involving the apical system. The discovery of this new *Fibulariella* from the northeastern Pacific sheds new light on the origins, affinities, and distribution of these very early clypeasteroids.

P1.167 MOORE, S.J.*; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *mooresj@hendrix.edu*
Do prenatal steroids affect the oxidative capacity of the guinea pigs rectus thoracis muscle?
Prenatal steroids are administered to mothers when they are going into premature labor, in order to accelerate the development of their fetus' lungs. The effect of glucocorticoids on the lungs is known. However, the effects of the steroids on breathing muscles are not well understood. Based on the results of a study in our lab, we hypothesize that the breathing muscles of treated guinea pigs will have higher oxidative capacities, and thus, higher fatigue resistance than untreated muscles. To test this hypothesis, pregnant guinea pigs were injected with the glucocorticoid, betamethasone, or sterile water twice a week, 24-hours apart for three weeks, at 65%, 75%, and 85% gestation. Samples of the rectus thoracis (RT) muscle were then collected from the fetuses, sectioned, stained for their myosin ATPase or NADH-TR (tetrazolium reductase) activities, and digital images of the stained sections were taken. The staining densities of the slow- and fast-twitch fibers in the treated and control RT muscles were measured using Scion Image, and these densities were converted into Z-scores. If it is discovered that the glucocorticoids lead to an increased oxidative capacity in the RT, the steroids have had a positive effect on the development of this muscle. Therefore, if the steroids are administered to a mother before she goes into labor, her fetus will have RT muscles that will be more resistant to fatigue, giving the ventilatory system the ability to respond to any breathing challenges faced by the premature infant.

P2.50 MOORE, A.L.*; BARNES, C.J.; LEE, D.V.; Univ. of Nevada, Las Vegas; *moorea3@unlv.nevada.edu*
A new 3D system for measuring burrowing biomechanics
Subterranean digging behaviors provide opportunities for protection, access to prey, and predator avoidance to a diverse array of vertebrates, yet studies of the biomechanics of burrowing have been limited by the technical challenges of measuring kinetics and kinematics of animals moving within a substrate. Previous studies of burrowing typically use 2D X-ray video and 1D force measurements, however, empirical observations show that burrowing mechanics are not restricted to a single axis or plane. Here we present a new system for simultaneously measuring 3D kinematics and kinetics of burrowing animals by combining 3D X-ray motion analysis with an innovative 'tunnel-tube' for measuring 3D burrowing reaction force together with outward pressure on the tunnel walls. The tunnel-tube is a rigid acrylic cylinder supported at each end by six-axis load cells for measuring net reaction forces and the lengthwise center of pressure during burrowing. To measure the outward pressure on the walls of the tunnel, a nitrogen-pressurized inner-tube separates the rigid outer wall of the tunnel-tube from the substrate filled interior. A pressure transducer in this nitrogen-filled space records the outward pressure due to soil compaction against the rubber inner-tube. Separate vertical and horizontal forces during burrowing strokes may also be measured independently using flex-sensitive resistors arranged in concentric bands along the length of the inner-tube. Measured simultaneously, 3D X-ray kinematics 3D reaction force and dynamic pressure data will provide a more complete view of burrowing biomechanics in a diversity of vertebrates.

P2.122 MORA-KEPFER, F*; SIASSIPOUR, AH; STUMP, J; BROWNE, WE; University of Miami, Coral Gables; *floriamk@bio.miami.edu*
Anatomy of the brain in the crustacean model system, Parhyale hawaiensis: sexual dimorphism and an examination of the amphipod hemi-ellipsoid body
Recent molecular phylogenetic inference places the lineage giving rise to insects squarely in a paraphyletic crustacean clade. This suggests that insects are derived crustaceans. A suite of morphological characters also supports the close relationship between crustaceans and insects including similarities in the basic architecture of the brain. In well-studied insects, the brain is subdivided from anterior to posterior into protocerebral (PC), deutocerebral (DC), and tritocerebral (TC) neuromeres. A similar, and presumably homologous, tripartite ground plan for the brain is shared with all arthropods including the amphipod crustacean *Parhyale hawaiensis*. Here, we characterize *Parhyale* brain morphology via serial section series. These serial sections are the basis for our 3D volume reconstruction of the brain. Our morphological data suggest similarities between the mushroom bodies of insects and the hemi-ellipsoid bodies of *Parhyale*. Additionally we examine sexual dimorphism between the antennal lobes of sexually mature adults In contrast to females, males have more robust antennae with numerous sensory pits, which may reflect differential neural development of the antennal lobes. We are using our morphological data to explore the potential relationship between structural plasticity of the brain and sexual dimorphism in antennal structures. Our results provide critical anatomical information required to understand the basic organization of the brain in the model crustacean *Parhyale hawaiensis*. This detailed neuroanatomical dataset will contribute to experiments aimed at exploring the interplay between sexual dimorphism and neural plasticity in crustaceans.

P1.130 MORENO, Pamela*; ARACENA, Jimena; Southwestern Oklahoma State University ; *morenop@student.swosu.edu*
Differential starvation survival of field collected and laboratory wild type fruit flies (Drosophila melanogaster)
Most popular strains of wild type fruit flies (Drosophila melanogaster) used in genetic and behavioral tests have low genetic variation, due to environmental homogeneity and genetic drift caused by the small culture vials that are used to maintain them. We compared the starvation survival of field-collected flies (GG) to laboratory flies (Oregon R). Field collected females (GGF) survived significantly longer than males (GGM) and also longer than Oregon R flies of both sexes (WF and WM). However, the size of the flies was not significantly different. These results suggest that female flies in the field are under selection to increase fat storage.

P1.84 MORGAN, H.E.*; EDWARDS, T.M.; Louisiana Tech University, Lousiana Tech University; *hem009@latech.edu*

Phytoestrogen Variation among Organs of Soybeans

We collected tissue samples from different organs of reproductive soybeans to examine how phytoestrogen concentrations vary throughout the plant. The activity of phytoestrogens have been most heavily researched within herbivores where they act as exogenous hormones upon being hydrolytically cleaved in their digestive tract. Phytoestrogens emulate the effects of estradiol by binding to estrogen receptors alpha and beta (ESR1 and ESR2), but with a much lower affinity than endogenous estrogens. Additionally, they act as selective estrogen receptor modulators (SERMs) by activating the receptors in some cells and inhibiting the receptors in other cells. The ability of phytoestrogens to interact with estrogen signaling can lead to altered gene expression in body cells; these interactions have been linked to various health benefits such as increased heart health and reduced chance of osteoporosis. In this study, our objective was to better understand the significance of phytoestrogens in plants. Soybeans have high phytoestrogen concentrations relative to other common vegetables, making them a good model for the study of phytoestrogen variation. For phytoestrogen analysis, fresh plant tissues from leaves, roots, stems, seed pods, and seeds were disrupted using a blender or mortar and pestle and extracted for 24 – 48 hours in 55% ethanol. Extracts were filtered, concentrated by evaporation under nitrogen, and reconstituted to a known concentration. Extracts were tested for estrogenicity using a yeast reporter gene system expressing human ESR1 and ESR2. Our results suggest that phytoestrogen concentrations vary among plant organs, which allows us to speculate that phytoestrogens may play a significant role in the activities of organs where they are found in highest abundance.

P1.105 MORHARDT, A.*; RIDGELY, R.; WITMER, L.; Ohio University; *am159410@ohio.edu*

Gross Anatomical Brain Region Approximation (GABRA): a new technique for assessing brain size and structure in extinct archosaurs

Studying brain evolution in extinct taxa is difficult due to the potential lack of close correspondence between the brain and its bony braincase. Cranial endocasts may be good proxies in certain groups (mammals, birds), but the brain does not fill the endocranial cavity in many reptiles, making their endocasts less reliable indicators of brain size and morphology. Thus, assessments of relative brain size and brain-region evolution often require untested assumptions. We propose the use of a new technique known as Gross Anatomical Brain Region Approximation (GABRA), which involves importing a digital endocast derived from CT scanning and 3D visualization software into modeling software (Maya). Brain regions underlying the digital endocast are modeled as ellipsoids, the limits of which are based on the osteological correlates of soft-tissue structures visible on endocasts, as identified by comparison with extant taxa. These discernable structures (neurovascular canals, dural sinuses, fossae produced by the brain itself, etc.) provide limits on the location and size of major brain regions (e.g., cerebral hemispheres, cerebellum, optic lobes, olfactory bulbs). GABRA criteria were validated in extant archosaurs (birds, alligators) with gross dissection, CT scanning of Lugol's-iodine-soaked specimens, and MRI data. Preliminary GABRA brain results of dinosaur taxa are credible. Ultimately, GABRA allows moving beyond studying the cranial endocast as a singular entity to studying the evolution of the brain and its different parts, allowing hypotheses of neurological mosaic evolution to be better tested. Moreover, revised estimates of brain and brain-region dimensions will provide a better basis for quantitative analyses of relative brain size.

P2.109 MORTIMER, SA*; PACE, CM; NISHIKAWA, KC; Northern Arizona University; *sam395@nau.edu*

Implications of hind limb scaling across mouse mdm genotypes

The mouse mdm genotypes are an excellent model to study effects of variation in titin on locomotion. Previous work from our lab has shown that *mdm* genotypes vary in their kinematics. However, mutant mice are identified by their smaller size and it is possible that changes in titin also affect growth and development. If mutant hind limb segments are not proportioned the same as the other genotypes this needs to be accounted for when interpreting locomotor data. Therefore, the goal of this project was to determine if the *mdm* genotypes vary in the lengths of their limb elements and if that variation persists as they grow. We measured hind limb segments of each genotype ranging in age from 24 to 100 days old. For all genotypes, the longest limb segment is the calf, followed by the thigh, the metarasals, and the toes. Differences between wildtypes and heterozygotes are small, whereas mutants differed more. Across the entire age range, mutant body lengths and limb segments are smaller than the other genotypes. However, when body size is accounted for the hindlimbs of mutants are slightly longer than the other genotypes and their feet are larger. As there is no difference between heterozygous and wildtype limb segments, differences in locomotion may be driven by differences in titin function in muscle. While there are small differences in mutant leg segments, the fact that their legs are relatively longer while their stride length is relatively shorter, indicates that differences in titin function drive these locomotor differences, not differences in limb scaling. Given the utility of the *mdm* genotypes for elucidating the role of titin in muscle, understanding how the limb elements may differ is an important step to fully understanding the effect of titin on locomotion in these animals. Supported by NSF IOS-1025806.

P1.14 MOURABIT, S*; KUDOH, T; Univ. of Exeter, Exeter, UK; *t.kudoh@exeter.ac.uk*

The mangrove killifish as a model for environmental embryology

The mangrove killifish, *Kryptolebias marmoratus*, is a self-fertilizing vertebrate offering vast potential as a model species in many biological disciplines. Previous studies have defined developmental stages but lacked visual representations of the various embryonic structures. We offer detailed photographic images of *K. marmoratus* development with revised descriptions. An improved dechorionation method was developed to provide high resolution photographs, as well as a microinjection technique enabling cell marking. Using *K. marmoratus* in conjunction with the zebrafish, a popular model species, we examined the differential stress response of embryos exposed to high temperatures. In situ hybridisation was performed for oxidative stress related genes (*hmox1, gstp, fth1*), and regulation of these genes in response to heat stress was compared between both species. In addition, microinjections of two constructs were carried out allowing for visualisation of promoter activity, via fluorescent proteins, for the heat-shock protein 70 and the electrophile responsive element (which activates gene expression in response to oxidative stress). The comparative data allows us to discuss the conserved and species specific mechanisms of the heat-shock response in different fish species from different thermal habitats. Our data also suggest that *K. marmoratus* embryos are easily used and manipulated, supporting the use of this hermaphroditic vertebrate as a strong comparative model system in embryology, evolution, genetics, environmental and medical biology.

P3.74 MOUSTAKAS, Jacqueline E*; CEBRA-THOMAS, Judith; HÄKKINEN, Teemu; JERNVALL, Jukka; GILBERT, Scott F; Institute of Biotechnology, University of Helsinki, Finland, Department of Biology, Millersville University, Millersville, PA, Department of Biology, Swarthmore College, Swarthmore, PA; *jacqueline.moustakas@helsinki.fi*

The Dynamic Network of Scute Formation

The turtle shell, a classic case of morphological novelty, is composed of endochondral axial skeletal elements overlain by plates of dermal bone and keratinous scutes. Previously, we have shown that, as in the development of several other ectodermal organs, the keratinous scutes form by an epithelial-mesenchymal interaction that is regulated by *Shh-Bmp2* signaling. Here we examined the growth dynamics of the turtle shell in an ontogenetic series using genetic markers for scute placodes as landmarks. We used the expression of these genes in the placodes to construct a distance map in a time-series of embryonic development in the red-eared slider turtle *Trachemys scripta* to visualize the growth of the shell. We then constructed distance maps of developing scute placodes in a population of embryos at the same stage of development to measure their coefficient of variation and thereby examine variation, stability, and the development of anomalies in turtle scutes.

P1.43 MOVIUS, Morgan A.*; AUBIN-HORTH, Nadia; RENN, Suzy CP; Reed College, Laval University; *momovius@reed.edu*

Decreased Aggression without Loss of Territory Following Cortisol Injection in Male Cichlids.

In group-living species, an individual's dominance rank in the social group influences all crucial aspects of its life, including reproduction and survival. The social environment dramatically impacts the expression of complex behaviors. Males of the African cichlid species *Astatotilapi burtioni*, have served as a model system to study the neural, endocrine, and molecular basis of socially plastic phenotypes that encompass male dominance, reproduction capacity and growth. Multiple lines of research suggest that increased expression of the neuropeptide AVT is correlated with social dominance, however recent pharmacological experiments revealed an increased probability of territory loss following injections with AVT. In order to test the possibility that this effect was mediated through activation of the stress response we increased systemic cortisol levels in dominant males with repeated injections. We found that while cortisol injections caused a significant decrease in aggressive behavior, it did not cause social descent from the dominant to subordinate phenotype. This result suggests that while cortisol plays a role in the behavioral regulation of aggression, it is not sufficient to determine the phenotype of cichlid males

P1.220 MUIR, T.J.*; DISHONG, B.D.; COSTANZO, J.P.; LEE, R.E.; Augustana College, Miami University; *timmuir@augustana.edu*

Energy use in terrestrially hibernating hatchling turtles (Chrysemys picta) is extremely sensitive to overwintering temperature

Many animals across diverse taxa endure extended bouts of dormancy during which they are aphagic and thus, must rely on endogenous energy stores to survive long-term dormancy and, when food is not immediately available, fuel post-arousal activities. Because temperature directly influences metabolic rate in ectothermic animals, the thermal environment during dormancy may have profound effects on energy use and conservation for dormant ectotherms. To better understand those effects, we quantified energy storage and use by hatchling painted turtles (*Chrysemys picta*) during a 5-mo simulated hibernation at 4, 10, or 15°C (n=8 for each group). All turtles survived hibernation and those held at 4°C appeared healthy, whereas those held at 10 and 15°C appeared debilitated. Dry yolk mass at the end of hibernation did not vary among groups, but dry carcass and dry liver mass each varied ($P<0.05$) inversely with hibernation temperature. Likewise, total remaining energy, determined by bomb calorimetry, was inversely related ($P<0.05$) to hibernation temperature. Rates of oxygen consumption (VO_2) measured during hibernation showed an extreme temperature effect with an overall $Q_{10}=9.0$. Predicted energy use, which was calculated based on our VO_2 data, matches well with our calorimetric data suggesting that the large differences in VO_2 we measured among groups were sustained throughout hibernation. Low winter temperature enhances energy conservation by hatchling turtles, and the high Q_{10} implies that even a modest increase in overwintering temperature, which may occur over the next several decades of climate change, could cause a large increase in energy use leaving turtles with less energy reserved to fuel emergence and post-emergence activities.

P1.109 MULLER, LJ*; STAAB, KL; HERNANDEZ, LP; George Washington University; *larajmuller@gmail.com*

Comparative adductor mandibula architecture and muscle fiber type composition within Cyprinidae

The adductor mandibula complex of fishes has long been of interest to functional morphologists interested in feeding. In basal teleosts this muscle serves only to close the jaws, while in more derived species (characterized by the evolution of separate divisions) the adductor mandibulae may also serve an important role in premaxillary protrusion. Indeed previous research has shown that contraction of the A1 division of cypriniform fishes is important in kinethmoid-mediated premaxillary protrusion. Thus given the importance of this division of the adductor mandibula in cypriniform feeding there may be greater variation in architecture of this division as compared with that of the other divisions. Significant research effort has been expended in examining the comparative morphology of this muscle mass within perciform fishes, however less data exist for cypriniform fishes. Moreover, very little comparative data exist for muscle fiber type distribution for many fish groups. Muscle fiber type is inherently related to muscular function, so muscle fiber type composition may be an important determinant of feeding ecology. Here we examine not only the relative architecture of the divisions of the adductor mandibulae, but also determine muscle fiber composition and distribution patterns within ten genera of cypriniform fishes. Using standard immunohistochemistry with a number of discrete myosin antibodies we have characterized fiber type composition within a number of cypriniform species with greatly differing trophic habits. We were especially interested in testing whether there was greater variation in fiber type in the A2 division (responsible for lower jaw adduction, and thus biting) versus the A1 division (responsible for premaxillary protrusion, and thus suction feeding).

P1.80 MURDOCK, C*; DEBRO, L; Jacksonville State University, Jacksonville, AL, Jacksonville State Univeristy, Jacksonville, AL; *murdock@jsu.edu*

Mycobacteriophage Isolation and Characterization as a Model to Promote Undergraduate Research in the Freshman Curriculum

Jacksonville State University (JSU) participates in the Howard Hughes Medical Institute (HHMI) sponsored National Genomics Research Initiative (NGRI) of the Science Education Alliance (SEA). This HHMI program is focused on improving undergraduate science education through the implementation of novel research. Specifically, this program has utilized the isolation and characterization of mycobacteriophage as a model to promote undergraduate research. The specific aim of the JSU project is to test the hypothesis that participation in research will promote learning across the curriculum. We describe here the implementation, impact, and results from the experience. The experimental group (i.e., HHMI-SEA students) consisted of fourteen students representing a cross-section of the freshman class. These students enrolled in the traditional biology lecture, along with the control group. However, the HHMI-SEA students replaced the traditional laboratory component with an experimental laboratory course. Students were assessed by comparing academic performance and by measuring changes in attitudes toward science. We observed no significant difference in academic performance. However, the HHMI-SEA students demonstrated a measurable difference in gains in the student attitudes about science and in research productivity. Although none of the participants in the experimental course had any prior laboratory experience, preliminary results support the concept that beginning students can become fully engaged in novel scientific research. We conclude that participation in the research experience had no measurable effect on academic performance (i.e., assessment scores), but made a significant impact on student interest in science.

P3.127 MURRAY, Kendall B.*; DEMKO, Alyssa M.; WARD, Bridget K.; DELILLO, Cynthia A.; BALAZADEH, Keyvan; BOURQUE, Bradford D.; RHYNE, Andrew L.; Roger Williams University, Roger Williams University; New England Aquarium; *kmurray742@g.rwu.edu*

The absence of male features and functionality in the monotypic shrimp genus Lysmatella, a simultaneous hermaphrodite

Protandric simultaneous hermaphroditism is ubiquitous in the caridean shrimp genus *Lysmata*. *Lysmata* have external morphology that is characteristic of caridean shrimp. The most common method of identifying male phase shrimp is the presence of the appendix masculina on the second pleopod. It has been well established that all members of this genus can undergo sex change from male to euhermorphodites, sometimes dependent on group size. Additionally, the male phase in *Lysmata* is functional, allowing for successful fertilization between hermaphrodites and primary males. Given results from recent molecular phylogenies *Lysmatella*, a sister genus to *Lysmata*, is also expected to be a simultaneous hermaphrodite. The objective of this study was to investigate and document the sexual system of this monotypic genus. To accomplish this, *Lymatella prima* were maintained in pairs, observed, and resultant larvae reared in the laboratory. Newly metamorphosed shrimp were separated into individual containers and observed for three months. Breeding experiments were also conducted between mature hermaphrodites and immature individuals. Live samples in addition to excuvaie were collected to document development from the juvenile form to adult. Results indicate that *Lysmatella* lack features common in *Lysmata* and immature individuals cannot successfully fertilize mature hermaphrodites. Therefore, it appears that there is no functional male phase present in this monotypic genus prior to maturation.

P3.85 MUSSER, Jacob M*; WAGNER, Gunter P; PRUM, Richard O; Yale University; *jacob.musser@yale.edu*

The role of beta-catenin in the early development of archosaur skin appendages

Beta-catenin, a key component of the wnt signalling pathway, is important in the development of many vertebrate epidermal appendages and has been linked to the formation of a thickened epidermis in the initial stage of hair and feather development. In the canonical wnt pathway, binding of the wnt ligand to its receptor results in the translocation of beta-catenin to the nucleus, where it acts as a transcriptional cofactor and regulates the expression of genes important in later stages of hair and feather development. However, while the role of beta-catenin has been explored in hair and feathers, its expression and use in the early development of other epidermal appendages is poorly understood. Here, we examine the role of beta-catenin in scale and claw development in birds and alligators to shed light on the developmental decisions being made in skin development and to understand the extent of homology in the early development of different epidermal appendages.

P3.152 NAHM, A.C.*; BELL, G.; KUZIRIAN, A.M.; HANLON, R.T.; CRONIN, T.W.; University of Maryland, Baltimore County, Marine Biological Laboratory, Woods Hole, MA; *anahm1@umbc.edu*

Dermal opsins of the summer flounder, Paralichthys dentatus

Like other fishes, summer flounder, *Paralichthys dentatus*, are hypothesized to have dermal opsins that are potentially photoreceptive. These potential photoreceptors are thought to detect light, possibly playing a role in regulating patterns of camouflage. We examined this possibility, using reverse transcriptase polymerase chain reaction (RT-PCR) to amplify any opsin genes expressed in several regions of skin, as well as those of the retina. We identified four opsins in the eye of *P. dentatus*. BLAST analysis determined that these were from the vertebrate rhodopsin classes RH1 (rhodopsin), RH2 (middle wavelength sensitive), LWS (long wavelength sensitive) and SWS2 (short wavelength sensitive). Several regions of skin had more than one opsin present in a single sample. RH1 and SWS2 are present on the ventral side, dorsal side, and dorsal fin. The amino acid sequences of these opsins match the predicted amino acid sequences of the opsins found in the eye. Future work will include *in situ* hybridization to determine the cell types in which the opsins are expressed, as well as continuing attempts to identify the presence of other opsin classes in both the retina and in the skin cells.

P2.160 NAIR, D.T.; MILLER, B.M.; ZIGLER, A.M.; FARRELL, W.J.*; Franklin and Marshall College; *williamfarrell9@gmail.com*

Behavioral profile and predictors of social status for male green anole lizards (Anolis carolinensis) during two weeks of cohabitation

Green anole lizards (*Anolis carolinensis*) have long served as a model organism for the study of aggression and social status. We collected and analyzed video records (2 hrs/day) documenting the behavior of 12 size-matched, male green anole dyads during two weeks of cohabitation in an attempt to precisely document the stability of the dominant/subordinate relationships formed and to identify early indicators (from the first two hours of interaction) of social dominance. The aggressive displays exhibited by male anoles have been well documented and include lateral compression of the body (LC), pushups (PU), and extensions of the red dewlap beneath the throat (DE). The dyads examined established stable dominant/subordinate relationships with one animal always displaying more PU than his opponent during observations conducted on alternate days from Day 2 to 14 of cohabitation. These presumably dominant animals frequently chased and displaced opponents from established cage locations while rarely, if ever, being chased or displaced themselves. Contrary to previous reports, a shorter initial latency to darkening of the postorbital eyespot failed to reliably predict dominance (7/12 correct), and similar results were obtained for latency to LC, PU and DE (8/12, 6/12 and 7/12 respectively). In contrast, higher numbers of PU and DE during the first two hours of interaction and greener body color during the second hour of interaction correctly predicted future dominance in 11/12 dyads. These results suggest that vigor of aggressive response is a better predictor of social status than initial reactivity.

P2.85A NAPIER, K.R.*; MCWHORTER, T.J.; MARTINEZ DEL RIO, C.; FLEMING, P.A.; Murdoch Univ., Western Australia and Univ. of Wyoming, Laramie, Murdoch Univ., Western Australia and Univ. of Adelaide, South Australia, Univ. of Wyoming, Laramie, Murdoch Univ., Western Australia; *knapier@uwyo.edu*

A comparison of pharmacokinetic methods for in vivo studies of non-mediated glucose absorption

Two pharmacokinetic methods are primarily used to assess systematic bioavailability (f) of orally dosed water-soluble compounds *in vivo*. The 'area under the curve' (AUC) method employs a single oral dose of probe compounds followed by multiple blood sampling to obtain plasma concentration time curves. Fractional elimination rate (K_{el}) and distribution pool space (S) are estimated from multiple blood samples following a separate injection of probes. The 'steady-state feeding' method relies on *ad libitum* feeding of a marked diet, with the concentration probes during steady-state feeding measured with one blood sample. K_{el} is estimated from the decline in probe concentration in excreta with S estimated from one blood sample. We compared these methods in the Australian red wattlebird measuring absorption of ^{3}H-*L-glucose*. K_{el} values estimated using the steady-state feeding protocol were significantly higher, and estimates of S and f consequently lower, compared with the AUC protocol. The steady-state feeding method appears sensitive to disruptions of steady-state feeding. Higher K_{el} values may also reflect differences in renal function, since animals fed *ad libitum*. The AUC method relies on fewer assumptions and allows simultaneous comparisons of absorption by mediated and non-mediated (i.e. paracellular) mechanisms, but cannot be easily applied to freely-feeding animals. The steady-state feeding method allows work with smaller species and exploration of the effects of feeding on nutrient uptake, but requires careful attention to the validity of assumptions.

P2.189 NAPPIER, AL*; MCBRAYER, LM; MCELROY, EJ; College of Charleston, Georgia Southern University; *alnappie@g.cofc.edu*

Computational morphological model and biomechanical analysis of acceleration in the Florida scrub lizard, Sceloporus woodi

Discerning the function of individual joints for an organism engaged in ecologically relevant behavior is important for understanding musculoskeletal function. We use an inverse dynamics approach to estimate joint moments and powers generated during burst locomotion in the Florida scrub lizard, *Sceloporus woodi*. First, we generated a three-dimensional morphological model using multiplanar reconstruction of micro-computed tomographies (microCTs) in OsiriX. Joint moments and powers were then computed using Matlab's SimMechanics by driving the three-dimensional models with experimentally measured ground reaction forces and joint kinematics. Finally, dissections of preserved specimens were performed to compare the calculated joint moments and powers to the available muscle mass.

P3.33 NATER, O.H.A.*; BRUNO, J.R.; DILLON, M.E.; University of Wyoming, Laramie; *onater@uwyo.edu*

Effects of climate on seasonal abundance of native bees and flowers - Implications for plant-pollinator communities in the face of climate change

Discerning the role of climate in shaping the relationship between pollinator and floral abundance is crucial for developing conservation strategies to address a potential 'pollination crisis'. However, for most systems we lack even rudimentary data on the relationship between climate and population fluctuations of pollinators and flowers. Here we present preliminary data from an ongoing census of native bees and their floral resources. We sampled bees and plants weekly throughout the growing season (late May to mid-September) at two sites in southeastern Wyoming. We collected bees in standardized "bee cups" as well as by fixed-effort netting, and counted all flowers in 100 1-m^2 quadrats in each of the sites. Native bee abundance tracked mean temperature for the first half of the growing season (late May to early July). Beginning in July, mean temperature and bee abundance diverged, with bee numbers decreasing and temperatures continuing to rise. A sharp drop in floral resources at this time likely played a role in this divergence. While bee numbers peaked in mid-June, floral abundance was highest in mid-July. Given the strong dependence of bee abundance on spring climate, the duration of the lag between peak bee and floral abundance may be driven by climate, suggesting that current and future climate change could lead to phenological mismatch between plants and their bee pollinators in this community. Further investigation of the drivers of plant-pollinator interactions and network structure will be required to predict and mitigate the potentially disruptive effect of climate change on plant-pollinator communities.

P2.135 NATHANIEL , Thomas *; HUBER, Robert; PANKSEPP, Jaak; University of South Carolina School of Medicine-Greenville , Dept of Biological Sciences, Bowling Green State University, OH , Dept of Veterinary and Comparative Anatomy, Pharmacology, and Physiology, Washington State University, Pullman ; *tinathaniel@gmail.com*

Specific locomotion behavioral patterns associated with drug; Cocaine alters active multifarious behavior in crayfish.

A common misconception holds that only humans possess susceptibility for the reward phenomenon. This may explain why evolutionary factors have received little consideration in drug addiction research. We have previously shown that morphine or cocaine targets brain neural pathways in crayfish that serve as powerful rewards in a place preference paradigm. The current study represents an extension of our efforts to develop crayfish into a new model of drug addiction research. In the current study, we developed a crayfish model of unconditioning locomotion responses. We used this model to explore the neurochemical basis of drug unconditioned responses by exploring the effect of repeated cocaine treatments on multifarious unconditioned locomotor activity of crayfish. Our results indicate that injected cocaine wielded its effects at a number of neural sites, including the distinct alteration of circuits for active locomotion behaviors, suggesting the presence of selective effects towards specific locomotion behavioral patterns associated with the drug instead of a global effect. Our findings indicate that locomotion as a unitary phenomenon comprised of assemblage of multifarious components, which can be manipulated and separated by cocaine. Neuronal simplicity combined with the potential for elegant neuroanatomical and behavioral analyses further support the notion that the crayfish model is highly suited for comprehensive, experimental analyses of specific locomotion responses that characterized drug properties at the behavioral level.

P3.161 NAVARA, KJ; ANDERSON, EM; EDWARDS, ML*; Univ. of Georgia; *megedw11@uga.edu*

Comb Size and Color are Honest Indicators of Sperm Quality in Male Broiler Breeder Chickens

In many avian species, males display dramatic and conspicuous ornaments that may serve as honest signals of quality to females. The phenotype-linked fertility hypothesis suggests that the honesty of these signals may be maintained through a link with fertility. Indeed in some recent studies, bright coloration has been linked with better fertility, and also indicates semen characteristics that influence fertility, such as sperm performance and levels of oxidative stress in semen. However, most of these studies were performed on species with ornamental feather coloration, in which the ornament is produced months prior to reproduction. We tested the phenotype-linked fertility hypothesis in the domestic rooster, a species where comb characteristics fluctuate on a short-term basis according to environmental and physiological conditions and thus may serve as immediate signals of quality to hens. We examined the relationships of comb size and color with measures of sperm quality, including sperm concentration, mobility, and viability. We found that comb size was inversely correlated while comb color was positively correlated with sperm viability. Thus, males with the smallest, reddest combs had the highest percentage of viable sperm, suggesting that comb size and color may act as honest signals of sperm quality in domestic roosters.

P2.130 NELSON, M.*; ADAMS, T.; OJO, C.O.; CARROLL, M.A.; CATAPANE, E.J.; Medgar Evers College, Brooklyn, NY, Kingsborough Community College, Brooklyn, NY; *margie@mec.cuny.edu*

Adenylyl Cyclase Inhibitors Reverse the Neurotoxic Effects of Manganese on Post-Synaptic Dopamine D2 Receptors

Manganese (Mn), a neurotoxin causing Manganism, a Parkinsons-like disease, disrupts dopaminergic systems. The mechanism is not fully resolved. Gill lateral cilia of *Crassostrea virginica* are controlled by serotonergic-dopaminergic innervations from their ganglia. Dopamine (DA) is cilio-inhibitory, serotonin cilio-excitatory. Previously we showed post-synaptic DA receptors in gill lateral cells are D2 type, G protein-coupled (Gai/o) metabotropic receptors. Gai inhibits adenylyl cyclase (AC). Gβγ opens K^+ and closes Ca^{2+} channels. We showed Mn blocks DA post-synaptic receptor activity. Here we observed membrane potentials of gill lateral ciliated cells of *C. virginica* with a fluorescent dye while measuring cilia beating rates. Applying serotonin to gill caused prolonged membrane depolarization and increased cilia beating rates. Applying DA after exciting cilia repolarized the membrane and decreased beating. Mn prevented the cilio-inhibitory response and repolarization. Applying ATP (10^{-4}M) or forskolin (10^{-6}-10^{-5}M), an AC activator, to control or Mn treated gills increased beating without changing membrane potential. Applying MDL or SQ (10^{-5}-10^{-2}M, AC inhibitors, to controls or Mn treated gills decreased beating without affecting membrane potential. The study shows a correlation between membrane potential and cilia beating rates; that actions initiated by activation of D2 post-synaptic receptors can be differentiated to effects on AC and membrane potential; and neurotoxic effects of Mn can be overcome by AC inhibitors. This information is helpful to understand causes and treatments of Manganism.

P3.43 NETH , Leinson; University of Hawaii; *leinson@yahoo.com*

Oxidative stress in two coral species, Porites lobata and Pocillopora damicornis, from Enipein, Micronesia

Coral reefs are often affected by a suite of processes that are becoming increasingly influenced by land-use practices and related terrestrial activities. As a result, the survival and persistence of coastal coral reefs are at risk. The need for increased monitoring of coral health is necessary to address stressors prior to coral mortality. Our current study measured levels of DNA damage in corals located in the coastal reef of Enipein, Federated States of Micronesia. Two coral species, Pocillopora damicornis and Porites lobata, were sampled over a gradient from shore to determine if a correlation exists between DNA damage and distance from shore. No significant differences in levels of DNA damage with increased distance from shore were found for either Pocillopora damicornis and Porites lobata. However, relative levels of DNA damage were lower in the P. damincornis species compared to P. lobata. This study is the first to record DNA AP damage levels in corals in the Enipein and provides a baseline of DNA AP damage for corals in the Micronesian islands.

P3.93 NEWEL, M.S.*; BOURNE, G.B.; University of Calgary, Alberta, Bamfield Marine Sciences Centre, British Columbia; *bourne@ucalgary.ca*

Factors affecting the drilling and feeding behavior of Lewis' moon snail, Euspira lewisii (Gastropoda: Naticidae)

Euspira lewisii, the largest extant naticid gastropod, displays a stereotypical naticid feeding behavior while preying almost exclusively on bivalves. After capturing a clam, *E. lewisii* drills a beveled hole through the clam's shell using its radula. Typically the drill hole is found near the umbo. Our previous experiments on snails collected from Barkley Sound, British Columbia, maintained in our Calgary laboratory together or in isolation and fed 'littleneck' clams (native *Protothaca staminea* or introduced *Venerupis philippinarum*), which are natural prey species that have also been used by other researchers. We found that in many instances without completing the drill hole snails smothered their prey within the envelop of pedal mucus used to restrain them, and then fed on the 'gaping' clam. Recently, others have reported that given a choice, *E. lewisii* appear to select thinner-shelled clams. Yet another report suggested that a related species (*E. fortunei*) preferentially drills the left valve of its prey. Using our extensive collection of post-feeding clam shells (primarily *V. philippinarum*), we conducted a morphometric analysis of the shells and their respective drill holes. We also examined a representative sample of live clams. We found that drill holes were relatively equally distributed among the left and right valves. However, drill-hole site fidelity decreased as the snail's health declined and in some cases when different clam species were provided. Since prey capture requires extensive manipulation, certain aspects of morphology (*e.g.*, relative density) may provide *E. lewisii* with cues of the profitability of their potential prey.

P3.190 NGUYENBA, Andrew*; BORDA, Elizabeth; ALVARADO, Jaime R.; SCHULZE, Anja; Texas A&M University at Galveston; *majora52@yahoo.com*

Delineating cryptic species and populations of the cosmopolitan fireworm genus Eurythoe (Annelida: Amphinomidae) using High-Resolution Melting Analysis (HRMA).

Fireworms of the genus *Eurythoe* (Annelida: Amphinomidae) are represented by the circumtropical morpho-species *Eurythoe complanata*, which shows a broad geographic distribution and low morphological variation. Recent work, by others, of over 240 specimens yielded no clear diagnostic phenotypic characters to differentiate populations from coastal Brazil, Panama (Caribbean, Pacific), the Indian Ocean, and Mozambique. Within the same survey, evaluation of genetic data (mitochondrial COI and allozymes) revealed at least three cryptic species from specimens collected in Panama (Caribbean, Pacific), south Atlantic Islands and coastal Brazil. In this study, we explore the genetic variation and phylogenetic relationships of *E. complanata* populations from the Gulf of California, western coastal Mexico, and coastal Caribbean (Belize, Mexico, Panama) using nucleotide sequence data from two nuclear and two mitochondrial genes, and assess the utility of High-Resolution Melting Analysis (HRMA) as a rapid and inexpensive genotyping method to establish unambiguous genetic diagnostic characters to delineate *Eurythoe* species and infer population structure.

P3.8 NIELSEN, M.E.*; PAPAJ, D.R.; University of Arizona; *nielsenm@email.arizona.edu*

Change in thermal refuge seeking behavior during development of Battus philenor larvae.

Temperature is an often highly variable component of any organism's environment, and such variation can strongly impact an organism's physiology and thereby its fitness. Because of this, organisms have evolved a wide range of mechanisms for coping with temperature change. Effective thermoregulation is particularly crucial for larvae of the Pipevine Swallowtail, *Battus philenor*, in the Southwestern US because their host plant grows close to the ground and thus reaches extremely high temperatures on summer days. One way *B. philenor* deals with these high temperature extremes is by leaving their procumbent host and seeking a thermal refuge higher up in the vegetation. Although size and developmental stage have been found to influence thermoregulation in other lepidopterous species, previous studies of thermal refuge-seeking in *B. philenor* have only examined large, late instars. Here, we investigated how refuge-seeking behavior changed over the course of larval development, specifically assessing the temperature at which caterpillars of different instars would leave the host plant and seek a thermal refuge. Since the cost of leaving a host plant is likely greater for earlier instars due to their smaller size and more limited dispersal abilities, we reasoned that earlier instars would leave the plant at higher temperatures than later ones. Such instar-dependent responses would have implications for the evolution of other traits, such as heat tolerance. It would also have implications for how caterpillar body coloration, a temperature-dependent, phenotypically plastic trait in this species, varies during development under different temperature regimes.

P1.102 NYGAARD, K.R.*; HUND, A.K.; RAND, M.S.; Carleton College, Northfield, MN; *mrand@carleton.edu*

Genetics and color development in a rare melanized and pterin-less morph of a North American lizard (Sceloporus)

In certain Colorado populations, male prairie lizards (*Sceloporus consobrinus*) exhibit one of three discrete chin-color morphs (orange, yellow, or white). Orange and yellow coloration is qualitatively pterin based, seasonally labile, quantitatively testosterone dependent, and correlated to male agonistic behavior. Pterin-based chin coloration is absent from the rare white morph. In addition, these males are heavily melanized; the dorsal coloration is significantly darker and much of the blue belly and throat patches are suffused in black. Numerous studies in mammals and birds have shown that variation in degrees of pelt and plumage melanization are attributable to sequence variation in the melanocortin-1 receptor (MC1R) gene. We hypothesized that the variation in degree of melanization we observe in these lizards was due to sequence differences in the MC1R gene. We sequenced *MC1R* in 40 individual lizards, including four pterin-less melanized morphs and found no sequence variation in this gene. Additionally, unlike the orange and yellow morphs, testosterone administration failed to induce pterin-like color development. We also tested the effects of ultraviolet (UV) light stimulation and dietary carotenoid supplementation on color development and found that neither the addition of UV light, nor dietary carotenoids, with or without testosterone, either enhanced or diminished color development in any morph. Our findings are consistent with the hypothesis that these color morphs are genetically determined and we continue to look for the candidate genes responsible for these pigment differences.

P1.119 O'BRIEN, Haley D.; Ohio University, Athens; *haley.d.obrien@gmail.com*
Ontogeny and Phylogeny of Cranial Vascular Patterns in the Tragulidae (Artiodactyla: Ruminantia)
Most extant even-toed ungulates possess a highly specialized cranial vascular structure known as the carotid rete. The carotid rete is an intracranial thermoregulatory arterial meshwork capable of selectively cooling the brain. As such, the carotid rete is hypothesized to be selectively advantageous for artiodactyls. Within Artiodactyla, one of the most successful clades is the Ruminantia. All currently sampled ruminants possess a carotid rete except for *Tragulus javanicus*, a species within most basal ruminant family. Is the lack of a carotid rete a basal condition for ruminant cranial vascular patterns, or is there a secondary loss within Tragulidae? This study elucidates the evolutionary history of the carotid rete within the Tragulidae by examining phylogenetic and ontogenetic patterns of cranial vasculature.

Osteological correlates for cranial vascular patterns, including external cranial foramina and intracranial impressions (i.e. carotid canal), were scored for four species of tragulids: *Hyemoschus aquaticus, Tragulus javanicus, Tragulus napu*, and *Tragulus stanleyanus*. Osteological correlates and ancestral state reconstruction reveal a secondary loss of the carotid rete within Tragulidae. Neonate and juvenile crania of *H. aquaticus* and *T. javanicus* were studied to identify any ontogenetic patterns that may inform how this character is lost. The expansion of cartilaginous structures within external cranial foramina of *T. javanicus* indicates that the carotid rete is lost late in embryonic development, corroborating pre-existing evidence that an intracranial meshwork develops in early *T. javanicus* embryos, only to diminish significantly in neonates. These results strengthen the possibility that basal ruminants possessed this evolutionarily advantageous cranial vascular pattern.

P1.52 OBI, I.*; STERLING, K.M.; SIMMONS, T.; AHEARN, G.A.; U of North Florida, Jacksonville; *gahearn@unf.edu*
K-dependent 3H-D-glucose transport by hepatopancreatic BBMV of the marine shrimp, Litopenaeus setiferus.
This study reports the occurrence and properties of K-dependent 3H-D-glucose transport across hepatopancreatic brush border membrane vesicles (BBMV) of the marine shrimp, L. setiferus, and speculates on the possible biological relevance of this phenomenon. Vesicles loaded with 300 mM mannitol and incubated in 0.1 mM 3H-D-glucose and either 150 mM NaCl or 150 mM KCl both exhibited 3H-D-glucose uptake overshoots at 1 min of incubation that were approximately twice equilibrium, suggesting that both cations could equally drive sugar accumulation. 3H-D-glucose influxes (1 min uptakes; 0.1 mM D-glucose) in the presence of inwardly-directed 150 mM KCl or 150 mM NaCl gradients were significantly ($p < 0.05$) stimulated by an inside-negative membrane potential (pHi = 5.0; pHo = 7.0; 50 micro-M CCCP), and significantly ($p = 0.05$) inhibited by 0.25 mM phloridzin. Certain sugars at 0.1 mM significantly ($p = 0.05$) reduced influx of 0.1 mM 3H-D-glucose in 150 mM KCl (e.g., D-mannose and 2-deoxy-D-glucose), while others (e.g., D-galactose, alpha-methyl-D-glucoside, D-fructose) were without effect. In the presence of an imposed inside negative membrane potential, 3H-D-glucose (0.1 mM) influx was a hyperbolic function of variable external [KCl] (25 to 400 mM), and had a lower Km and higher Jmax than a similar curve displayed by vesicles without a membrane potential. Membrane potential had the greatest effect on the apparent binding affinity (e.g., Km) of the D-glucose transport system. Results suggest the presence of a brush border K-D-glucose cotransport system in these largely herbivorous shrimp which uses dietary K to stimulate sugar uptake. Project supported by USDA agriculture and food research initiative competitive grant no. 2010-65206-20617.

P3.183 OLSZEWSKI, JM*; HARPER, CJ; BRAINERD, EL; Brown University, Providence, RI; *Julia_Olszewski@brown.edu*
High-throughput method for measuring muscle ultrastructure
Traditionally, myofilament lengths have been measured using Transmission Electron Microscopy (TEM). This method is a time intensive process, making it difficult to use TEM for comparative research. The goal of this study is to develop a high-throughput, accurate method for measuring myofilament lengths that can be applied to vertebrates and invertebrates. Larval zebrafish (*Danio rerio*) muscle was processed for TEM using the traditional approach developed by Page and Huxley (1963); J Cell Biol 19(2):369-390. These authors established that myosin thick filament length is consistently 1.6 µm in diverse slow and fast vertebrate muscles. Here, myosin was immmunohistochemically labeled, and the muscle was optically sliced, then rendered three-dimensionally with a confocal microscope. Thick filament lengths were measured in the confocal images and compared to measurements from the electron micrographs. A preliminary analysis reveals that zebrafish thick filament lengths were 1.58 µm on the TEM micrographs and 1.54 µm on the confocal images. The accuracy of these measurements may be enhanced with the use of super resolution microscopy, which is becoming more common in bioimaging facilities. Because confocal microscopy is efficient, this method can be used to measure myofilaments lengths in a variety of organisms. In invertebrates, thick filament length is variable, even within the same animal. With this method, thick filament length could be measured across a wide range of invertebrate species and give insight into how muscle ultrastructure predicts muscle function.

P2.82 OOKA, Shioh*; WANG, Lingyu; WIKRAMANAYAKE, Athula; Univeristy of Miami, FL; *sooka@bio.miami.edu*
Expression pattern of flamingo during sea urchin early development.
Wnt signaling pathways are implicated in numerous developmental processes. The Wnt/PCP pathway plays an important role in cell polarity rather than in cell fate decisions. It has been reported that convergent-extension (CE) movements driving gastrulation are regulated by the Wnt/PCP pathway. Flamingo (Fmi) is known as a core member of the Wnt/PCP pathway. It has been reported that Fmi is an atypical cadherin, and that Fmi plays a critical role in CE movements in vertebrates during gastrulation. In addition to the cadherin repeats in extracellular region, Fmi contains a seven-pass transmembrane domain, and a SE/D domain which is highly conserved sequences in the intracellular region. In sea urchin, extension of the archenteron is driven by CE, but molecular mechanisms which regulate this process are not well understood to date. Thus, in the present work, expression pattern of flamingo homolog of the sea urchin, Strongylocentrotus pupuratus (Spfmi), was analyzed during the early development in order to begin to study its role in sea urchin gastrulation. Spfmi mRNA was broadly seen in the unfertilized eggs and cleavage stages. By hatched blastula stage, Spfmi mRNA was restricted to the vegetal plate, which is the region initiating future primary invagination. Subsequently, Spfmi accumulates around the blastopore and the archenteron. These results suggest that Spfmi may play a role in regulating CE during gastrulation. Hence, a morpholino antisense oligonucleotide (MO) against Spfmi was injected into zygotes to investigate how SpFmi is implicated in gastrulation. MO-mediated Spfmi knockdown resulted in failing to elongate the archenteron, suggesting that SpFmi appears to be essential for elongating the archenteron during sea urchin gastrulation.

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Combined effects of social stress and an agricultural pesticide on tadpole growth and development

Human impacts on the environment pose a threat to natural populations. Environmental contaminants such as pesticides can negatively affect growth, development, reproductive success and survival in a wide range of species. Stress from contaminants may produce even more severe outcomes when coupled with normal biotic stressors. Intraspecific competition is a widespread source of biotic stress, particularly when resources are limited. We predicted that the stress of being an inferior competitor would increase an individual's vulnerability to environmental toxins. We tested this idea by exposing size-structured groups of southern toad (*Anaxyrus terrestris*) tadpoles to a common insecticide (carbaryl) or a no-pesticide control. We found that size-advantaged tadpoles generally metamorphosed earlier. However, tadpoles that were initially smaller ultimately grew to larger sizes at metamorphosis. Once the larger competitors metamorphosed, the smaller individuals were apparently released from competition and grew rapidly. Food limitation intensified competition, leading to a greater delay in metamorphosis for small individuals. The pesticide inhibited growth for all size classes. However, the outcome of competition was affected by pesticide exposure. Under food-limited conditions, the competitive suppression of smaller individuals was less pronounced when tadpoles were exposed to the pesticide, suggesting that the larger individuals were less effective competitors in the presence of carbaryl. Understanding how stressors interact allows us to better assess the risks faced by amphibian populations in human-impacted environments, and simple laboratory studies may underestimate the effects of contaminant exposure under realistic ecological conditions.

P3.95 PAIG-TRAN, EWM*; KLEINTEICH, T; SUMMERS, AP; Univ. of Washington; *mpaig@uw.edu*

Exploring the filter morphology and filtration mechanics in Mobulidae

Filter feeding has evolved independently four separate times in three lineages of cartilaginous fishes (Lamiformes: *Megachasma* and *Cetorhinus*, Orectolobiformes: *Rhincodon*, and Mobulidae: *Manta* and *Mobula*). The independent evolution of filtering structures in elasmobranchs resulted in morphologically different filtering structures and presumably very different mechanisms for filtering food particles. Elasmobranch filter feeders have traditionally been predicted to use some form of sieve filtration; however, new mechanisms of particle capture in the filtering sharks have been proposed including engulfment filtering and cross flow filtration. The structure of *Manta* and *Mobula* filtering pads are very different compared to the filtering sharks. *Manta* and *Mobula* filter pads are chevron shaped structures composed of many rows of filtering lobes located on both sides of the gill filaments, facing toward the incoming flow of water and also toward the posterior buccal cavity. We performed scanning electron microscopy to examine the filtering pads of *Manta birostris*, *Mobula tarapacana*, and *Mobula thurstoni* and have found evidence that the surfaces of the lobes are covered with a blanket of cilia, which likely serve as a surface for capturing particles by hydrosol filtration. Using histology, we identified mucosal cells on the distal edge of the epithelium, presumably to provide a sticky coating for capturing food particles and for transferring to the esophagus. Finally, we identified the presence of denticles along the leading edge of the lobes, presumably to prevent degradation of the pads by large, fast-moving particles.

P1.88 PAITZ, RT*; BOWDEN, RM; Illinois St. University; *rpaitz@ilstu.edu*

A mechanistic understanding of yolk steroid effects

In oviparous vertebrates, egg yolks contain numerous steroids of maternal origin at the time of oviposition and manipulations of these yolk steroids have been shown to influence the phenotype of the resulting offspring. To date, most research has focused on the phenotypic effects of these maternal steroids while less attention has been paid to the underlying mechanisms. In this poster, we present a series of experiments conducted in red-eared sliders (*Trachemys scripta*) that characterize the physiological mechanisms underlying yolk steroid effects. First, endogenous levels of yolk progesterone (P), testosterone (T), and estradiol (E2) decline rapidly during the early stages of embryonic development. Second, tritiated P, T, and E2 are all converted to water-soluble metabolites during these same early stages. Using E2 as an example, we demonstrate that these water-soluble metabolites are estrogen sulfates and that they primarily reside outside of the embryo in the extraembryonic fluids and yolk for most of development. During the final stages of development, we observe a decline in levels of E2 metabolites in the extraembryonic fluids and yolks and an increase in the levels found in the embryo. Finally, we show that exogenous estradiol sulfate is capable of inducing sex reversal in embryos suggesting that these sulfonated steroids can produce phenotypic effects. Together, these data illustrate the complex nature of the mechanisms underlying yolk steroid effects and highlight the importance of addressing embryonic processes when attempting to interpret the evolutionary consequences of maternal steroids.

P3.162 PALMER, MS; HANKISON, SJ*; Ohio Wesleyan University; *sjhankis@owu.edu*

UV and mate choice in the sailfin molly, Poecilia latipinna

There is growing evidence that the ultraviolet (UV) spectrum plays an important role in social communications for numerous vertebrates. Prior studies have demonstrated that UV characteristics in some fishes are influential during social behaviors such as courtship. However, not all fish possess UV markings or the ability to perceive UV wavelengths (300-400 nm). We sought to discover whether UV features were present in the sailfin molly, *Poecilia latipinna*, and to determine whether UV plays a role in female mate preference. UV-reflective areas were spectroscopically detected on the bodies of male and female mollies. We then conducted behavioral experiments, exposing females to males whose visual appearance was manipulated by filters that either transmitted or blocked UV wavelengths. Female mollies significantly preferred males displaying UV traits. Our results suggest that sailfin mollies rely on information in the UV as well as visual wavebands when making visual mate choice decisions.

P1.138 PANHUIS, Tami M.*; BROITMAN-MADURO, Gina; UHRIG, Jarrod; MADURO, Morris; REZNICK, David N.; Ohio Wesleyan Univeristy, University of California, Riverside, Ohio Wesleyan University; *tmpanhui@owu.edu*

Expressed Sequence Tag analysis of the Poeciliopsis placenta

Several species in the *Poeciliopsis* fish genus are highly matrotrophic live-bearers that exhibit a placental-like structure used for maternal provisioning of embyros. The *Poeciliopsis* placenta consists of two main tissues - a highly specialized maternal follicle that encases individual embryos and acts in nutrient transport, and the embryonic pericardial membrane (or sac), which is highly vascularized during development. To better understand the *Poeciliopsis* placenta we derived cDNA libraries from the maternal follicular placenta of two matrotrophic *Poeciliopsis* sister species, *P. turneri* and *P. presidionis*. Putative function of expressed sequence tags was determined with BLASTX homology searches and Gene Ontology (GO) annotation. These analyses revealed putative genes whose products may be involved in specific transport functions of the maternal follicle. One gene, alpha 2 macroglobulin (A2M), is highlighted here and discussed in light of the parent-offspring conflict theory of placental evolution.

P3.42 PARRILLA, Leah*; OWERKOWICZ, Tomasz; STEELE, Erin; MORI, Miki; LEE, Amber; HICKS, James; ROURKE, Bryan; California State University, Long Beach, University of California, Irvine; *leah.parrilla@student.csulb.edu*

Effects of Hypoxia and Hyperoxia in Alligator mississippiensis

Oxygen levels have fluctuated between 16% and 36% as shown from burial rates of organic carbon over the past 500 million years (my). This cyclical pattern has been associated with animal extinction and implicated as a driving force for physiological adaptation. We use *Alligator mississippiensis (A.M.)* as a model species of longevity and adaptability over the last 100my. Incubated A.M. eggs were raised in oxygen conditions of 16%, 21%, 26%, 31%, and 36% representative of oxygen levels over the last 500my. We hypothesized that A.M. raised in hypoxic environments would have constraints on growth, cardiovascular load, metabolic protein expression and possible myosin heavy-chain (MyHC) plasticity related to cardiovascular demands. AM reared in hyperoxia were expected to show plasticity in cardiac isoforms and increased oxygen dependent gene expression. Heart and metabolic activity in the liver were examined at embryonic, hatchling and post-hatchling time points as indicators of phenotypic plasticity to differing oxygen environments. MyHC isoform expression was examined in all chambers. Proteomic analysis was used to identify differentially expressed liver proteins from each oxygen group using two dimensional gel electrophoresis and MALDI-TOF/MS for protein identification. Quantitative PCR was used to measure cardiac gene expression for each oxygen group in the oxygen dependent HIF-1α gene, E3 ubiquitin ligase gene MAFbx involved in the atrophy signaling pathway, and Myostatin involved in hypertrophy. Funded by NSF grant:IOS-0922627 NSF RUI

P2.62 PARROTT, B.B.*; HUDSON, A.; BRADY, R.; SCHULZ, C.; Medical University of South Carolina, Dept. of Obstetrics and Gynecology, University of Georgia, Dept. of Cellular Biology; *benbparrott@gmail.com*

Environmental and Genetic Control of Stem Cell divisions in the Drosophila Testis

To realize the full therapeutic potential of stem cells, we must uncover the fundamental properties that govern their behavior in normal tissues as well as in those tissues affected by disease. In contrast to our understanding of the cell fate dynamics in tissues maintained by adult stem cells, we know relatively little regarding how organisms control the number of terminally differentiated cells they produce. Here, we report that in the Drosophila testis, the frequency of Germline Stem Cell (GSC) divisions depends on the levels of sexual activity that an animal experiences. These findings suggest that stem cells respond to the demand for the terminally differentiated cells they replenish by modulating their division frequency (positive or negative – does the frequency increase or decrease?). Furthermore, GSC division frequency depends on genetic factors. Mutations in an EGF encoding locus, spitz, result in the accumulation of early-stage, undifferentiated germ cells resembling a germ cell tumor. We observed that GSCs in animals, with attenuated EGF signaling, display a two-fold increase in their division frequency, suggesting a mechanism by which stem cells contribute to tumorigenesis. In addition, we show that two novel genetic suppressors of the spitz phenotype, seven-up and homothorax, specifically suppress the cell fate component of the phenotype without suppressing the hyper-proliferation of GSCs. These data provide evidence that EGF functions in two genetically distinct pathways to regulate cell fates and GSC divisions. Thus, this work provides a fundamental link between stem cell biology and the role they can play in various cancers.

P2.111 PATIL, Y.N.*; BOSWELL, L.; MARDEN, B.; HAND, S.C.; Louisiana State University, Baton Rouge, LA 70803, Louisiana State University, Baton Rouge, LA, 70803, Great Salt Lake Artemia LLC, Ogden, UT, 84401; *ypatil1@lsu.edu*

Metabolic Downregulation in Embryos of Artemia franciscana during Diapause

Artemia franciscana embryos characteristically display a low metabolic rate in the diapause state. We have confirmed this observation for embryos released from ovigerous females collected from the Great Salt Lake, Utah. Metabolic rate as judged by respiration is depressed acutely across a 26-day time course. We measured selected metabolic intermediates in diapause and post-diapause embryos in order to identify sites of inhibition in the metabolic pathway from trehalose to acetyl-CoA. Based on the values obtained for product to substrate ratios, we calculated a strong negative crossover point for hexokinase in diapause (glucose-6-phosphate/glucose; 0.045 ± 0.0009; ± SE, $n = 6$) as compared to the post-diapause state (0.759 ± 0.005). A second inhibition point was observed at pyruvate kinase in diapause (pyruvate/phosphoenol pyruvate; 0.150 ± 0.009; ± SE, $n = 4$) versus the post-diapause state (0.624 ± 0.048). Finally, a third inhibition was observed at pyruvate dehydrogenase (PDH) in diapause (acetyl CoA/pyruvate; 0.013 ± 0.0012; ± SE, $n = 6$) as compared to the post-diapause state (0.042 ± 0.0028). These inhibitions are consistent with a restriction of carbohydrate fuel to the mitochondrion. We quantified the phosphorylation state of site 1 for PDH subunit E1 α (pPDH) in diapause and post-diapause embryos. The relative amount of pPDH was higher in diapause embryos as compared to post-diapause embryos, which suggests that the PDH in diapause may be inhibited. Taken together, the findings indicate that substrate availability for oxidative phosphorylation plays a crucial role in downregulating metabolic rate during diapause. (Supported by NSF grant IOS-0920254)

P1.226 PENDAR, H.*; BERINGER, D.; SOCHA, J.J.; Virginia Tech; *hpendar@vt.edu*

Collapse patterns of insect tracheal tubes under pressure

Rhythmic tracheal compression is a form of active ventilation known to occur in the respiratory system of some insects. During compression, segments of the tracheal system collapse and reinflate on the time scale of seconds. In-vivo x-ray imaging has demonstrated that tracheal compression occurs by the formation of local dimples, but the biomechanical mechanism of tube collapse is not known. One hypothesis suggests that an increase in hydrostatic pressure of the surrounding hemolymph induces tube collapse by buckling. To investigate the collapse properties of tracheae in the American cockroach (*Periplaneta americana*), sections of large (diameter, ~500μm) tracheal tube were excised and tested ex-vivo in a custom-made pressure chamber. Each tracheal section was sealed at one end and connected to ambient air via a microtube at the other end, and then was compressed by increasing the pressure in the surrounding fluid. Video and pressure data were recorded simultaneously and analyzed to characterize collapse patterns. In a typical trial, the tracheal tube remained fully inflated during the initial pressure ramp, but when a threshold pressure was reached (range, 0.15—0.55 kPa), instantaneous buckling occurred. The observed range of collapse pressures is congruent with the magnitude of in-vivo pressure pulsations previously measured in the hemolymph of a carabid beetle, suggesting that changes in pressure may play a prominent role in tube collapse in insects.

P1.65 PENNOYER, Kelly*; FREDERICH, Markus; University of New England; *kpennoyer@une.edu*

Differential whole animal and cellular level response to salinity stress in two color morphs of Carcinus maenas

The green crab, *Carcinus maenas* is polymorphic in ventral carapace coloration. Crabs are green after molting and become dark red after prolonged intermolt. Previous studies have shown changes in the organismic physiology of these crabs, showing that the red morphs are less tolerant to environmental changes. Cellular data to complement the differential whole animal response is lacking. We tested the hypothesis that the cellular response to salinity stress reflects the whole animal response. Red and green morphs were incubated in 10ppt salinity for 24, 48 and 72 h. On the whole animal level oxygen consumption, reaction time, running endurance on a treadmill, reaction time and hemolymph osmolarity were measured. These data align with previous studies stating the red morphs are less tolerant to low salinity. On the cellular level changes in mRNA expression, protein levels, and/or activity were measured for ion transporters and associated enzymes (Na^+/K^+-ATPase, membrane bound and cytoplasmic carbonic anhydrase, Na^+-K^+-$2Cl^-$-cotransporter, Na^+/H^+ exchanger, and NH_3H^+-cotransporter) and the cellular stress markers AMPK and HSP70. Preliminary results show differential gene and protein expression and activity levels in the two color morphs. For most measured parameters red morphs showed lower mRNA, protein and activity levels at control conditions and changed more than green morphs during salinity stress. This indicates that also on the cellular level the red morphs are less tolerant to low salinity exposure than the green morphs. These findings represent the first data on differential cellular response to salinity stress in the two color morphs of *Carcinus maenas*. Funded by NSF IOB0640478 and DGE0841361.

P2.126 PERES, R.*; MARQUES, A.C.; CIPOLLA-NETO, J.; University of SÃ£o Paulo, SÃ£o Paulo - Brazil; *peresrafaperes@aol.com*

Melatonin in Cnidarians

Melatonin, the main secretory product of the vertebrate pineal gland is suspected to be a ubiquitous molecule principally involved in the transduction of photoperiodic information and protection against free radicals. Besides vertebrates, melatonin has been detected throughout phylogeny in numerous non-vertebrate taxa. In the present study, the occurrence of melatonin in the cnidarian *Olindias sambaquiensis* and its possible pathway of production was evaluated. Melatonin was evaluated by HPLC with a electrochemical detector. Presence of isoforms of the genes tryptophan hydroxylase and arylalkylamine N- acetyltransferase from the pathway of melatonin's production was evaluated by PCR. Activity of the enzyme arylalkylamine N- acetyltransferase was checked by radio assays. Our results indicate the presence of melatonin in the cnidarian *Olindias sambaquiensis*, with a circadian pattern of production. This pattern is sustained even in constant darkness, indicating that this melatonin's production is the manifestation of a endogenous clock. We also have find isoforms of the gene of the enzyme tryptophan hydroxylase and arylalkylamine N- acetyltransferase. Together with the results of the activity of the enzyme arylalkylamine N-acetyltransferase, in a rhythm near of the melatonin's production, these data indicate that the melatonin's pathway of production in *Olindias sambaquiensis* is similar to the one observed in vertebrates. Taken together, our results show, for the first time, the presence of melatonin in an cnidarian. More than that, we have demonstrated that the classical pathway of production of the hormone is probably the one used in this marine invertebrate. More research are necessary to evaluate possible functions of the melatonin in this specie.

P1.17 PERKINS, Samantha L.*; JENNY, Matthew J.; University of Alabama; *mjjenny@bama.ua.edu*

Comparative Transcriptomics of Two Freshwater Mussels, Villosa nebulosa and Villosa lienosa, in Response to Heat Shock

The impact of stress related to global warming of surface waters has been studied extensively on multiple levels of biological organization. However, the impact of warming on freshwater mussels (Bivalvia: Unionidae), keystone species in many of the worlds freshwater systems, is poorly understood. A next generation sequencing approach was undertaken to identify genes that were differentially expressed in response to temperature stress. Two species of mussel native to Alabama (USA), *Villosa nebulosa* and *Villosa lienosa*, were chosen for study because of the differences in habitat range and conservation status. *V. nebulosa* is restricted to a relatively narrow range and is of moderate conservation risk, while *Villosa lienosa* has a large geographic range and is currently stable. Both species were subjected to heat shock (3°C above ambient 22°C) and tissue samples were collected at 3 and 6 hours post shock to produce the RNA template for sequencing. ~330,000 sequence reads (mean length of 100 base pairs) were generated for each species. Sequence assembly yielded 17,637 and 21,657 contigs for *V. nebulosa* and *V. lienosa*, respectively. Contigs were blasted against the NCBI nonredundant database and further annotated by assignment of gene ontology categories. BLAST results confirmed a significant number of genes related to heat shock, oxidative stress and general cellular stress. Seventeen genes were chosen as potential molecular biomarkers across multiple functional categories (heat shock, oxidative stress, growth, metabolism and reproduction) for comparative expression profiling via quantitative real time-PCR. Future work will involve quantitatively modeling the effects of global warming on freshwater mussels by integrating molecular, metabolic, and physiological parameters the determine the effects of heat stress on life history characteristics.

P2.147 PERRAULT, Justin R*; MILLER, Debra L; WYNEKEN, Jeanette; Florida Atlantic University, Boca Raton, Center for Wildlife Health, Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville; *jperrau2@fau.edu*

Physiological measures of health and reproductive success in leatherback sea turtles (Dermochelys coriacea)

The leatherback sea turtle (*Dermochelys coriacea*) exhibits the lowest and most variable hatching success of the sea turtle species. We explored physiological measures of maternal health as correlates of low success in this species. We evaluated several metrics of maternal condition from blood for Florida’s nesting leatherback population, established a large sample of baseline health parameters, and correlated these values with hatching success of the nesting females' eggs. We found that several measures of maternal condition correlated with hatching success: alkaline phosphatase, calcium, phosphorus, calcium:phosphorus ratio, cholesterol, gamma globulin protein, and total erythrocyte count. These physiological metrics are the first quantitative indicators that maternal health is important to reproductive success. While maternal health has been documented to impact several vital rates in other species, this is the first study of any sea turtle showing that some aspects of health may explain at least annual vital rates. Because turtles are physiologically resilient animals, it is likely that sublethal effects on health may manifest in reproductive compromises that we detected. Long-term and comparative studies are needed to determine if certain individuals historically and consistently produce nests with lower hatching success than others and if leatherback turtles with evidence of chronic suboptimal health consistently have lower reproductive success.

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Predator-prey interactions between decapod crustaceans and polynoid polychaetes

Predator-prey studies can lead to a better understanding of why animals evolved specific traits, and help us better comprehend how the ecological community functions as a whole. Numerous studies report that the size of both predator and prey strongly influence predation success; predators may shift prey preference with size, while prey may reach a size refuge. We examined the correlation between predator and prey size to survival of two intertidal scale worms. A luminescent species, *Harmothoe imbricata*, is often found on the same rock as a nonluminescent species, *Lepidonotus squamatus*. The decapod crustaceans *Carcinus maenus*, *Cancer irroratus*, *Hemigrapsus sanguineus*, and*Homerus americanus* were collected from the same habitat areas, and transported to separate flow-through tanks. All were regulated on a 12-hour light cycle so that it was dark during normal daylight hours. One worm and one crustacean were placed in a 10-cm square tank separated by a divider in darkness. After 10 minutes, the divider was removed and their interaction was filmed via low-light cameras with an infra-red (IR) light source. Luminescence was recorded via both by a night vision device and a photomultiplier. Three of the four predators consistently attacked the worms, with *H. sanguineus* only attacking a worm once. The two species of worms showed drastically different behavior when pursued by a predator. Prior to an attack, *H. imbricata* often swam quickly away, on occasion flashing if threatened. Under attack, they almost always luminesced while trying to escape via scale loss or autotomization. In contrast, *L. squamatus* latched on to the bottom of the tank without moving, dropping scales, or autotomizing. To date, it appears that all sizes of both worm species have more success evading smaller predators. Thus, predator size may have a stronger influence on survivability than prey size.

P2.44 PERRY, J.L.*; RING, B.C.; Valdosta State University; *jlperry@valdosta.edu*

Cloning and Characterization of the Vasa Gene in the Mangrove Killifish, Kryptolebias marmoratus

The mangrove killifish is unique among vertebrates because it reproduces by self-fertilization, primarily as hermaphrodites. It is a powerful research model because isogenic lineages can be produced by continual self-crossing in the laboratory. The molecular and environmental factors that control sex determination in this species are unknown. Here, we describe the cloning and characterization of the primary germ cell marker gene, vasa. The cloned transcript *Kmvas* is 2.1 Kb and encodes for a 642 aa protein. Based on protein homology, *Kmvas* is most closely related to the pacific blue-fin tuna. Whereas nucleotide alignments of the highly conserved DEAD-box domain of *Kmvas* demonstrate the mangrove killifish is most closely related to Medaka and the Japanese jack mackerel. Further, we are analyzing the spatial and temporal patterns of *Kmvas* expression during embryogenesis and within the developing ovotestis.

P2.66 PERRY, KL*; RAMIREZ, A; BROWNE, WE; University of Miami, Coral Gables; *k.perry3@umiami.edu*

Investigation of the cis-regulation of the FoxB Gene in Nematostella vectensis

The process of establishing and maintaining discrete cell fates is essential to the proper development of multicellular organisms. The basic mechanisms controlling the development of neuronal cell fates arose early in Metazoan evolution. Yet little is known about the *cis*-regulation of gene expression during neurogenesis in early diverging lineages of Metazoans such as the cnidarian *Nematostella vectenesis (Nv)*. *Nematostella* possesses a simple radially organized body plan in which the nervous system develops as a diffuse nerve net with regionally organized pharyngeal and oral nerve rings. The *Forkhead (Fox)* gene family is known to play an important role in regulating neural cell fates. The *NvFoxB* gene is expressed at the oral pole of the pharyngeal ectoderm, suggesting a role in regulating neural cell fates in the developing pharyngeal nerve ring. Here we characterize aspects of *NvFoxB cis*-regulation during neurogenesis in developing embryos and polyps by *in vivo* time-lapse microscopy. Our preliminary expression data from a 3.5kb region of upstream genomic DNA driving an orange fluorescent protein (OFP) gene confirm that this genomic region contains sufficient regulatory information to drive restricted OFP expression in *Nematostella*. We are manipulating our construct to define a minimal promoter required to drive OFP expression in a distinct set of neurons in the pharynx. These results, along with other experiments, will provide key information required to elucidate the basic structure and mechanism of action for *cis*-regulatory sequences during neural development in *Nematostella*. We are also gaining useful tools for exploring gene function. These regulatory sequences can be used to drive genes of interest in discrete cell populations at defined times during development in *Nematostella*.

P2.55 PETERS, JP*; WOLF, N; STRICKER, CA; COLLIER, TR; MARTINEZ DEL RIO, C; Univ. of Wyoming, U. S. Geological Survey, Fort Collins Science Center, Denver Federal Center; *jpeter50@uwyo.edu*

Trophic and metamorphic discrimination of hydrogen isotopes in cabbages (Brassica oleracea) and cabbage loopers (Trichoplusia ni): Implications for stable isotope ecology

The use of stable isotopes in ecological studies requires that we know the magnitude of discrimination factors between consumer and element sources. The causes of variation in discrimination factors for carbon and nitrogen have been relatively well studied. In contrast, we know very little about the incorporation of hydrogen isotopes. Understanding these processes in hydrogen isotopes is essential to the study of animal migrations with stable isotope analysis. We reared cabbage looper moths (Trichoplusia ni) on cabbage (Brassica oleracea) plants irrigated with four treatments of deuterium-enriched water. δD values of plants, caterpillars, and moths were linearly correlated with the isotopic composition of irrigation water. However, the δD values of plants did not show a 1 to 1 relationship to irrigation water, suggesting that ambient water vapor (which did not vary in δD across treatments), contributes a large fraction of the hydrogen incorporated into leaves (c. 40%). We also documented a substantial trophic enrichment of deuterium between plants and caterpillars (c. 32‰) and metamorphic depletion of deuterium between moths and caterpillars (c. 14‰). We believe that accounting for the effects of exchange of hydrogen between plants and ambient hydrogen sources, trophic enrichment and metamorphic depletion on hydrogen signatures will greatly improve the use of hydrogen isotopes in the study of migratory movements.

P1.133 PETERSON, M.P.; ATWELL, J.W.; MILA, B.; ABOLINS-ABOLS, M.*; KETTERSON, E.D.; Indiana University, Bloomington, Museo Nacional de Ciencias Naturales, Madrid; *mabolins@indiana.edu*

Candidate genes and rapidly evolving migratory behavior in the genus Junco.

Avian migration has fascinated behavioral biologists for generations, yet much remains to be learned about the genetic and neural bases for variation in its timing and occurrence. Greater insight into the molecular and neural mechanisms associated with migratory behavior will help to explain rapid evolution of migration and allow for more informed approaches to problems in conservation. A recent study by Mueller, Kempenaers and colleagues demonstrated that repeat length polymorphism in the gene *ADCYAP1* explains part of population variation in migratory behavior of the old-world warbler *Sylvia atricapilla*. To test the generality of this finding, we are investigating whether polymorphisms in *ADCYAP1*, as well as other candidate genes, help to explain variation in migratory behavior of the North American sparrow genus *Junco* (*J. hyemalis & J. phaeonotus*). Additional candidate genes were selected by surveying the recently completed *J. hyemalis* transcriptome for genes that contain repeat length polymorphisms and regulate key physiological or behavioral aspects associated with migration. We are examining DNA from 6 sub-species of *Junco* that are thought to have diverged from one another in the past 10,000 years. These subspecies represent a full spectrum of migratory variation, including sedentary populations and altitudinal, regional, and long-distance migrants. Our goals are to determine whether repeat length polymorphisms of candidate genes co-vary with migratory behavior of the different sub-species and to evaluate whether similar genetic mechanisms underlie behavioral diversity within different avian lineages.

P2.171 PETERSON, J.D.*; RILEY, K.L.; APPEL, A.; MENDONCA, M.T.; Auburn University; Troy University, Montgomery, Auburn University; *peterj1@auburn.edu*

Exogenous corticosterone elevates metabolic rate in an amphibian

The vertebrate stress response is a suite of physiological changes that help organisms cope with environmental perturbations. One component of the stress response is the hypothalamic-pituitary-adrenal (interenal) axis, which secretes glucocorticoids to modulate the organism’s energetic response to a stressor. Acute glucocorticoid secretion functions in freeing energy stores, increasing metabolism, and reducing non-immediate energy consuming processes. However, chronic elevated glucocorticoid secretion results in an increased resting metabolic rate that can potentially lead to weight loss and unsustainable tissue catabolism. Although this effect has been documented in several vertebrate groups, there are no studies verifying it in amphibians. However, given recent global population declines, this is the very group to explore the relation between environmental stressors, chronically elevated baseline levels of corticosterone and their effect on metabolic rate, body condition, and tissue catabolism. We treated *Litoria caerulea* with exogenous glucocorticoids (400ug/20ul DMSO), which mimicked elevated baseline levels. Treated individuals consumed significantly more oxygen than those treated with vehicle ($p=0.0002$), representing a 1.8 fold increase in oxygen consumption. Time course of elevated oxygen consumption and effects on baseline plasma corticosterone will also be discussed.

P2.5 PETZOLD, J.M.*; SMITH, G.T.; Indiana University, Bloomington; *jpetzold@indiana.edu*

Chirp parameters signal sex but not male quality in the weakly electric fish Parapteronotus hasemani

Apteronotid electric fish produce a continuous electric organ discharge (EOD) that functions in communication. The frequency and amplitude of the EOD can be modulated during reproductive and agonistic interactions to produce chirps. In several species, EOD frequency and chirping are sexually dimorphic traits that are regulated by steroid hormones. However, the signal parameters that differ between the sexes vary greatly among species. We tested how EOD frequency and chirping vary between and within sexes in *Parapteronotus hasemani*, a species of South American electric fish with extreme morphological sexual dimorphism in body size. *P. hasemani* males also show a great degree of within-sex variation in jaw morphology that may indicate age or social status (Cox Fernandes, 2010). We measured circulating concentrations of testosterone (T) and 11-ketotestosterone (11KT) as well as jaw length, body length, and body mass. We also performed playbacks of species-typical EODs to sixteen *P. hasemani* to quantify EOD frequency and chirping. The duration of chirps was longer in males than in females, although EOD frequency, chirp rate, and chirp amplitude modulation were sexually monomorphic. Circulating concentrations of T and 11KT were not correlated with jaw morphology, body size, or EOD frequency within males. Thus, chirp duration, but not EOD frequency, is a sexually dimorphic trait that may be used as an honest indicator of sex in *P. hasemani*. The lack of a correlation of EOD and chirp parameters with hormone levels or morphological traits within males, however, suggests that these signals may not necessarily serve as reliable indicators of male quality. Supported by NSF IOS 0950721.

P1.60 PHAM, D.; CHARMANTIER, G.; BOULO, V.; GROUSSET, E.; WABETE, N.; CHARMANTIER-DAURES, M.*; Ifremer New Caledonia, Univ. Montpellier 2, France; *mireille.charmantier@univ-montp2.fr*

Osmoregulation in the peneid shrimp Litopenaeus stylirostris: Ontogeny and localization of transporters

The ontogeny of osmoregulation was investigated in *L. stylirostris* by studying salinity tolerance, osmoregulatory capacity and the localization of Na/K-ATPase (NKA) in the branchial chamber organs throughout development. Shrimps at different larval and postlarval stages were exposed to a range of salinities (0 to 45 ppt). Survival rates exceeded 80% at salinity over 25 after 24 hours at all stages. At salinities below 25, salinity tolerance was higher in nauplii and zoeae than in mysis. Postlarvae were able to withstand lower salinities, e.g. 6 at PL9, but they were more sensitive than larvae to salinities over 35. Zoea and mysis slightly hyper-regulated at all tested salinities. After metamorphosis, postlarvae progressively acquired the adult pattern of hyper-hypo-osmoregulation. Immunolocalization of NKA showed a sequential involvement of the different branchial organs: first, pleurae in zoeae, then branchiostegites in mysis and finally the epipodites in postlarval stages. No immunoreactivity was observed in the developing gills at any stage. In late juveniles immunolocalization of NKA, co-transporter NKCC1 and CFTR was assessed in gills, epipodites and branchiostegite at two salinities (12 and 30). NKA was present at 12 and 35 in all organs. CFTR was mostly localized in the branchiostegites at 35. NKCC1 was detected in the gills at both salinities, but in cells different from those with NKA. In conclusion the gills are involved in osmoregulation later than metamorphosis and a cellular complex may be involved in their osmoregulatory function.

P3.4 PIERCE, C.T.*; CONTRERAS , H.L.; DAVIDOWITZ, G; Univ. of Arizona; *pierce91@email.arizona.edu*

Environmental Humidity Effects on M. Sexta Foraging Behavior

Manduca sexta is a common model system used in biological studies. Although a lot is known about this insect's behavior and underlying physiology, there are still many behavioral and physiological factors that remain unresolved. *Datura wrightii* is the main host plant for *M. sexta*. However, this moth also feeds from *Agave palmeri* flowers which provide a more dilute nectar compared to *Datura wrightii*. It is unclear when these insects choose to feed from a particular type of nectar. In this study, we hypothesized that *M. sexta* feed from a dilute nectar when environmental humidity is low in order to diminish the effects of dehydration. In order to determine if preference for a particular nectar is driven by differences in environmental humidities, we examined *M. sexta* at 20, 40, 60, and 80% RH and provided nectar varying in sucrose concentration (0 [water], 12 and 24%). Individual moths were placed in separate cages the first day after emergence. Daily consumption of nectar and changes in weight were recorded until each moth died. Our results show a threshold in the response to changes in RH for *M. sexta*. We saw that at low RH (20, 40%) a higher percentage of moths fed from nectar, regardless of sucrose concentration. These moths consumed more nectar overall than moths placed in higher RH (60 and 80%). There was no real difference in the preference for nectar containing sucrose in relation to changes in RH. However, moths drank more water when placed at lower RH than when placed at higher RH.

P1.15 PINKERTON, Mark*; TAPLEY, Jeffrey; CUNNINGHAM, Charles; JENNY, Matthew J; University of Alabama, University of New Mexico; *mjjenny@bama.ua.edu*

Identification of Several Glutathione S-transferase and Multixenobiotic Resistance Transporter Genes from the American Oyster, Crassostrea virginica

Estuarine systems along the Gulf of Mexico were severely impacted by the ~5 million barrels of crude oil released from Deepwater Horizon oil spill in the Spring-Summer of 2010. Although biomarker genes indicative of hydrocarbon exposure are well characterized in vertebrate models, invertebrate responses are poorly understood. In an effort to identify novel invertebrate biomarkers of oil exposure, we chose the American oyster (*Crassostrea virginica*) as our model organism because of their sessile nature and capacity for bioaccumulation of pollutants. To identify candidate genes, oysters were exposed to crude oil (100 ppm) or crude oil and dispersant (1 ppm) for four days prior to tissue dissection (digestive gland and gill) used to produce the RNA template for next generation sequencing with the 454 Genome Sequencer. ~700,000 sequences reads were generated from each tissue, assembled into contigs and further annotated by comparison to the NCBI nonredundant database using the blastx algorithm. From these results we were able to identify several candidate members (cytoplasmic, and microsomal classes) of the glutathione S-transferase (GST) family, classic phase II metabolism genes involved in the biotransformation of xenobiotics. We also found several candidate multixenobiotic resistance (MXR) transporters that confer resistance by functioning as efflux transporters. These data represents the first extensive identification of these important detoxification genes from a mollusk. Gene expression studies with both controlled oil exposures (0.1 to 100 ppm) and oysters collected from oil-impacted reefs are currently underway to assess the feasibility of these genes as potential biomarkers of crude oil exposure.

P2.146 PINSON, SE*; NAVARA, KJ; University of Georgia; *sbmoore@uga.edu*

Sequence position, but not age, significantly influences sex ratios in the domestic chicken

Birds have demonstrated a remarkable ability to bias sex ratios prior to hatch in relation to a variety of social and environmental conditions. Several studies have found relationships between age or sequence position and biased sex ratios in wild and captive bird populations. There is little information with regards to the influence of these factors on sex ratios of domestic chickens, which are often used as the study species in experimental sex ratio studies. The purpose of this study was to determine if there is variation between the proportion of males produced at different ages or sequence positions in commercially available birds. We collected fertile eggs from randomly selected hens when they were 32, 35, 53, 56, 59, and 63 weeks of age. We also collected fertile eggs from randomly selected hens and assigned the appropriate sequence position to each egg. We incubated the eggs for 8 days and quantified the sexes using a molecular sexing technique. In our study, laying hens produced statistically similar proportions of males for all sampled weeks of age, so age does not appear to be a factor influencing primary sex ratios in chickens; however, there was significant variation between sequence positions. A significantly greater proportion of male offspring was produced from the third egg in the sequence compared to the earlier ($\chi 2=5.085$, $p=0.02$) and later ($\chi 2=3.734$, $p=0.05$) sequence positions. Results of this study suggest that sequence position can influence sex ratios in hens, so it is a factor that should be considered when designing and executing manipulative sex ratio studies in domestic chickens.

P1.129 PIRTLE, Elia/I*; TRACY, C/Richard; University of Nevada Reno; *tigerhobbs@att.net*

Why dinosaurs went extinct: A species-centered analysis

The mass extinction at the end of the Cretaceous, 65 Ma, resulted in the loss of all non-avian dinosaurs. Our species-level analysis of 555 dinosaur species reveal a gradual decline in species richness throughout the last two ages of the Cretaceous, which is a pattern inconsistent with the "asteroid impact" hypothesis as the leading cause of dinosaur extinction. A more likely explanation for the late Cretaceous dinosaur extinctions is that large-bodied species of dinosaurs, which were confined to small habitat fragments, went extinct due to stochastic population dynamics (or Gambler's Ruin) exacerbated by top-down control by ferocious predators. Similar extinctions of large-bodied dinosaurs occurred three times during the Mesozoic followed by re-radiations of dinosaur species after each extinction event. In the final Cretaceous extinction, occurring 6-19 million years before the K/T boundary, the surviving small-bodied dinosaur species were the ancestors of modern birds.

P1.55 PITTS, NL*; HOKE, KL; MYKLES, DL; GHALAMBHOR, CK; Colorado State University; *natalie.pitts@colorado.edu*

Differences in the Expression of Muscle Related Genes in Response to Predation Cues in the Trinidad Guppy; Poecilia reticulata

Poecilia reticulate, are found throughout a variety of stream drainages on the Caribbean Island of Trinidad. Guppies are found in both high predation and low predation environments that differ in the predation species with which the guppies co-exist with. High predation and low predation drainages often exist in close proximity to one another separated only by a waterfall barrier. This sharp contrast between populations with different predation cues provides a unique opportunity to study how the stress of predation effects gene expression, morphology, and behavior. Plastic differences in predation cues can also be created in the lab by breeding wild caught fish for two generations then separating the F2 generation into tanks with pred+ or pred- water. Differences in predation cues have been shown to cause significant differences in the depth of the caudal peduncle, the location of the majority of a guppy's muscle mass. The purpose of this experiment was to examine the effects of predation on gene expression of mTOR signaling pathway and muscle related genes. Two populations were examined, Guanapo (GH), a high predation population and Taylor (TY), a low predation population. Two treatments, pred+ and pred- where examined within both of these populations. qPCR was used to examine differences in Myostatin, FKBP12, elF2, myosin heavy chain, myosin light chain 2, and TnT. In most cases, expression levels of the analyzed genes differed between populations and treatments. These data indicate that differences in body morphology caused by predation cues may be attributed to changes in gene expression in the muscle.

P2.131 PLYLER, Jennifer*; SATTERLIE, Richard; University of North Carolina Wilmington; *jbp7588@uncw.edu*

Organization of the Pedal Serotonergic Cluster Neurons in the pteropod mollusc Clione

Symmetrical clusters of serotonergic neurons are found in the pedal ganglia of the pteropod mollusc Clione limacina. Some of these cells innervate the swim musculature of the wings, and serve a modulatory function rather than a direct motor function. The neurons are active during swim accelerations and serve to increase muscle contractility. They produce no central alteration of swimming activity. At least two of these neurons do not innervate the wings but have axons in nerves that run to the body wall. The innervation target is not known for these cells. Our data suggest the body wall neurons innervate the longitudinal musculature of the body wall, and likely enhance muscular contraction to increase body stiffness and hydrostatic pressure in the fluid skeleton during swim acclerations.

P1.216 PORTER, W. R.*; WITMER, L. M.; Ohio University; *wp298308@ohio.edu*

Vascular patterns in iguanas: blood vessels and cephalic sites of thermal exchange

Reptilian physiological research has shed light on the behavioral and physiological components of thermoregulation, yet no modern anatomical investigation has mapped vascular anatomy onto areas of potential thermal exchange. Archosaurs and mammals have been shown to use these sites to support selective temperature regulation, indicating that blood vessels are used in a similar manner across clades. Our understanding of similar concepts in reptiles, however, is incomplete. Vascular anatomy was investigated in the green iguana, with special attention to known sites of thermal exchange. Blood vessels were injected with a latex/barium solution of differing concentrations to discriminate arteries from veins in CT scans. Specimens were scanned using the OUμCT scanner at 90-micron slice thicknesses and analyzed using Avizo. The palatal plexus was less extensive than the archosaur plexus. The tongue was found to be highly vascularized, with vessels concentrated just ventral to the choana, possibly exposing blood vessels to airflow from the nasal cavity. Blood supply to the nasal cavity is from the supraorbital and ethmoid arteries with collateral supply via the palatal and maxillary arteries. These arteries anastomose around the nostril to form a narial plexus, exposing blood to ambient temperatures. A similar vascular pattern was found in the narial regions of archosaurs. The veins of the nasal cavity empty into the orbital sinus along the rostroventral border of the frontal bone. The orbital sinus surrounds the globus oculi and then coalesces into the jugular vein along the caudal aspect of the orbit. These results indicate that iguanas use similar sites of thermal exchange as archosaurs, suggesting that an ability to finely regulate cephalic temperatures may characterize all diapsids.

P1.19 PORTER, Danielle*; PERKINS, Samantha; PRITCHETT, Jazmine; TARRANT, Ann M. ; JENNY, Matthew J.; Univ. of Alabama, Woods Hole Oceanographic Institution; *mjjenny@bama.ua.edu*

Induction of Cell Death in Nematostella vectensis by Environmentally Relevant Concentrations of Macondo Crude Oil from the Deepwater Horizon Oil Spill

The Deepwater Horizon spill released ~5 million barrels of crude oil (Macondo Prospect) into the Gulf of Mexico in the Spring-Summer of 2010 posing a serious threat to marine and estuarine organisms. Although much is known regarding hydrocarbon toxicity in vertebrates, comparable knowledge regarding the sublethal physiological responses of estuarine invertebrates to hydrocarbon-based pollutants is lacking. To further investigate these mechanisms, we have chosen the starlet sea anemone, *Nematostella vectensis*, as our model organism. As a cnidarian, *N. vectensis* is part of a sister group to the Bilateria and thus provides an evolutionary context for elucidation of conserved pathways in cellular and molecular responses to hydrocarbon exposure. To determine if environmentally relevant concentrations of Macondo crude oil were capable of causing cellular stress, sea anemones were exposed to various concentrations of oil (5-20 ppm) or oil and dispersant (2 ppm dispersant) in equilibrated seawater and sampled after periods of 3, 5 and 7 days for histological assessment. Whole animals were embedded in paraffin and cross-sectioned for staining and assessment of cell damage using the TUNEL method to detect fragmented DNA characteristic of apoptosis. 5 to 7 days of exposure to 20 ppm of crude oil was sufficient to cause widespread cell death. Additional analyses are underway to determine if dispersant enhances the toxicity of oil as determined by the prevalence of apoptotic cells. The current data support the observation that environmentally relevant concentrations of crude oil are capable of causing severe cellular damage to *Nematostella* via water-borne exposures.

P3.178 PORTER, ME; GROTMOL, S; KRYVI, H; TOTLAND, GK; LONG, JH*; Vassar College, University of Bergen; *jolong@vassar.edu*

The Vertebral Column of Sharks: Functional Morphology of the Intervertebral Joint

The primary task of the vertebral column of fish – being conspicuous as a repeating pattern of vertebral bodies alternating with intervertebral joints – is as a stiffening element that supports axial oscillations of the trunk and tail during swimming. Here we describe the anatomy of the intervertebral joint of the spiny dogfish *Squalus acanthias* . Most structures that comprise the joint are derived from the notochord. These include a prominent intervertebral ligament made up of separate layers of lamellar elastin and type II collagen. Within the lumen of the joint there are vacuolated cells and a central fluid-filled canal that runs through the core of vertebral body, thus forming anastomoses between adjacent joints. How these morphologies may correlate with mechanical properties such as storage of elastic energy, dampening of oscillations, and stiffness of the bending joints, will be discussed. This work was funded, in part, by the National Science Foundation (IOS-0922605).

P1.145 PORTER, M.L.*; HAYNES, B.; CRANDALL, K.A.; OAKLEY, T.H.; CRONIN, T.W.; Univ. of Maryland Baltimore County, MD, Brigham Young Univ., Provo, UT, Univ. of California, Santa Barbara; *porter@umbc.edu*

Evolutionary Genomics of Visual System Complexity: Expressed Opsin Diversity in Stomatopod Crustaceans

Stomatopod crustaceans have complex and diverse visual systems, containing unique features that exist in no other animals. These features include a specialized ommatidial region (the midband), intrarhabdomal filtering of photoreceptors used in color vision, and receptors devoted to the detection of polarized light. The most complex stomatopod eye type contains 6 midband rows, 4 intrarhabdomal filters, and 16 physiologically different photoreceptor classes. However, there are also species with variations in the number of midband rows, photoreceptor classes, and filters present. Previous studies of retinal opsins found significantly more transcripts than predicted in all species investigated thus far, and characterizing all of the expressed opsins in any particular species has been a difficult task. To understand the complete diversity of opsins expressed in stomatopod retinas, transcriptomes have been sequenced from four species representing different superfamilies and exhibiting variations in eye design: *Neogonodactylus oerstedii* (6 midband rows, 4 intrarhabdomal filters); *Pseudosquilla ciliata* (6 rows, 3 filters); *Hemisquilla californiensis* (6 rows, 2 filters); and *Squilla empusa* (2 rows, 0 filters). Using a combination of directed searches of the assembled transcriptome and annotation approaches, a large diversity of opsin transcripts was recovered from all species, including transcripts similar to arthropod visual system opsins. Unexpected opsins were also recovered, including transcripts similar to the vertebrate peropsins.

P3.131 POTVIN, J.*; GOLDBOGEN , J. A.; SHADWICK, R. E.; Saint Louis University, Cascadia Research Collective, Univ. of British Columbia; *potvinj@slu.edu*

The very high metabolic costs of engulfment by lunge-feeding Rorquals, as revealed by computer simulations

Lunge feeding by rorqual whales represents one of the most extreme feeding methods among aquatic vertebrates. The strategy requires the momentary abandonment of the body-streamlining that make their non-feeding locomotion so energy-efficient, in favor of a high-drag, mouth-open configuration aimed at engulfing the maximum amount of prey-laden water. Over the past three years the Basic Lunge Feeding model (BLF) (Potvin et al. 2009 J. Roy. Soc. Interface & 2010 J. Theor. Biol) has been used to calculate for the first time the energetic cost of engulfment in comparison with the energetic gain from food (Goldbogen et al. 2011 J. Exp. Biol.), and with losses incurred during prey-approach and while purging the water out of the cavity post-engulfment (Goldbogen et al. 2011 Funct. Ecol.). The BLF has been used also as part of a new foraging model of blue whales (*Balaenoptera musculus*) in the specific ecology of the Southern Ocean (Weidenmann et al. 2011 Ecol. Model.). Here the BLF (V3.0) is used to show how demanding engulfment is metabolically, in comparison with (non-feeding) swimming and diving. The simulations reveal that the rate of engulfment metabolic energy expenditures (EMEE) is larger by factors of up to 40 in comparison to the basal metabolic rate (BMR). Most interestingly, EMEE are ten times greater than what is expected from the standard field and active metabolic rates (FMR and AMR, respectively) associated with a variety of marine mammal species. The BLF is also used to explore the scaling of EMEE over the body sizes of humpback (*Megaptera noveaangliae*), fin (*Balaenoptera physalus*) and blue whales. The result is that EMEE are significantly lower for the smaller adults of each species, and as such could have represented an important driver for the evolution of filter feeding in (small) archaic whale species.

P3.24 POWERS, M.L.*; HADDOCK, S.H.D; Univ. of California, Santa Cruz, Monterey Bay Aquarium Research Institute ; *mpowers@mbari.org*

Cloning, expression, and characterization of a photoprotein from the luminescent ctenophore Bathocyroe fosteri

Calcium-binding photoproteins have been discovered in a variety of luminous marine organisms. Light emission occurs when calcium binds to a photoprotein-substrate-oxygen complex where the substrate, usually coelenterazine, is oxidized to produce blue light. This group of photoproteins has been widely studied in hydrozoans which use the same general mechanism and have similar spectral properties. However, to further understand the evolution of these proteins and their potentially unique properties, more primary sequence information is needed. Recent interest in this area has led to the identification of several ctenophore photoproteins. Here we report the cloning, expression, and purification of the photoprotein responsible for luminescence in the deep-sea ctenophore *Bathocyroe fosteri*. This animal was of particular interest due to its unique dual color spectrum observed in live specimens. Full-length sequences were identified using known photoprotein sequences to BLAST *Bathocyroe* expressed sequence tags (ESTs) obtained from 454 transcriptome sequencing. Primary structure alignment of the *Bathoocyroe* photoprotein with both mnemiopsin 1 and 2, berovin, and bolinopsin showed very strong sequence similarity and conservation of Ca2+ binding sites. Preliminary results from spectral characterization of regenerated photoprotein show a maximum emission wavelength at 489nm, and spectra do not indicate bimodal distribution as was previously observed.

P1.174 POWERS, S.D.*; MAINE, A.R.; LUTTERSCHMIDT, D.I.; Portland State University, Oregon; *sepowers@pdx.edu*

Seasonal variation in neurogenesis in red-sided garter snakes (Thamnophis sirtalis)

Seasonal variation in neurogenesis (i.e., cell proliferation, migration, differentiation) is widespread across diverse taxonomic groups. However, the functional significance of such changes in the adult brain is often unknown. We examined if seasonal differences in neurogenesis occur in a population of red-sided garter snakes (*Thamnophis sirtalis*) in Manitoba, Canada. We also addressed whether seasonal neurogenesis is correlated with changes in courtship behavior. We collected male snakes from the den site during the spring mating season or fall pre-hibernation period. Snakes were treated with bromodeoxyuridine (BrdU; a thymidine analog that is incorporated into the DNA of newly proliferating cells) and housed in outdoor arenas. In the spring, courtship behavior was measured before males were euthanized at 1, 5, 10, 15, 20, or 28 days post-BrdU treatment. During the fall, neurogenesis was assessed at days 1, 5, and 10 post-treatment. Brains were processed for BrdU immunohistochemistry to visualize newly proliferated cells and data were analyzed by two-way ANOVA. We found that fall snakes had significantly more proliferating cells ($F = 20.279$; $P < 0.001$) and migrating cells ($H = 15.604$; $P = 0.001$) in the nucleus sphericus than spring males. In addition, the number of proliferating cells increased over time ($F = 3.712$; $P = 0.047$), while male courtship behavior decreased significantly during spring ($H = 15.962$; $P = 0.007$). Further research is necessary to determine if increased cell proliferation regulates seasonal transitions in behavior (e.g., the transition from courtship behavior to migration and summer foraging). Our results also suggest that increased neurogenesis during the fall may play a role in preparing for winter dormancy (e.g., neuroprotection).

P1.32 PRADHAN, DS*; SOLOMON-LANE, TK; WILLIS, MC; NAUDE, PW; GROBER, MS; Georgia State Univ., Atlanta, Univ. of Georgia, Athens; *dpradhan1@student.gsu.edu*

Brain injection of an androgen synthesis inhibitor rapidly affects recovery from anesthesia and androgen levels in males

In many fishes, 11-Ketotestosterone (KT) activates male breeding phenotype. Bluebanded gobies are fish in which brain KT levels are several fold higher than the gonads. Synthesis of KT occurs via the sequential action of 11β-hydroxylase (converts testosterone to 11-Hydroxytestosterone, 11-OHT) and 11β-hydroxysteroid dehydrogenase (11β-HSD, converts 11-OHT to KT). In males, systemic implants of carbenoxolone (CBX), a specific 11β-HSD inhibitor that does not cross the blood brain barrier, decreases KT levels by 48% one day after treatment. These effects are gone in 4 d, suggesting that KT inhibition in testis may be compensated by KT synthesis from the brain. To test whether local changes in brain KT synthesis affect systemic changes, we intracerebroventricularly (icv) injected males (N=24) with three doses of CBX or vehicle. To establish basal physiological effects of CBX, we measured parameters of recovery from anesthesia. Males treated with the medium (24.7 mg/mL) and high (49.4 mg/mL) CBX doses took significantly longer to initiate ventilation and regain equilibrium compared to low doses (4.94 mg/mL) and controls (0 mg/mL). Medium and high doses also increased respiration in the first 5 min following initiation of ventilation. There was no effect of CBX on brain KT levels after 1 h. In contrast, systemic KT was decreased by the medium and high dose (75 % and 90 % respectively), and there was no effect of the low dose. The absence of local CBX effect suggests that the brain recovers rapidly from the inhibition of 11β-HSD. Systemic effects of CBX suggest there may be a lag between effects in the brain and KT accumulation in water.

P2.137 PREZIOSO, Kristen*; FURIMSKY, Marosh; Westminster College; *preziokk@wclive.westminster.edu*

Behavioral effects of the Parkinsonism inducing neurotoxin, 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine on zebrafish larvae

Parkinson's disease (PD) is the second most common neurodegenerative disorder characterized by dopaminergic neuron degeneration and a manifestation of debilitating motor symptoms. Currently, the etiology and pathogenesis is poorly understood, and it is unclear whether genetic or environmental factors are responsible for most cases. 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP) is a contaminant of the synthetic heroine, meperidine, and has implicated along with the pesticides paraquat and rotenone, as PD causing agents. MPTP causes severe and irreversible motor abnormalities and a depletion of dopaminergic neurons in human and animal models, suggesting a link between patients with idiopathic Parkinson's disease and those exposed to the neurotoxin. The purpose of this study was to examine the effect of MPTP on development and locomotor behavior of zebrafish. Fish were exposed to MPTP (45 µg/L and 245 µg/L) at an early developmental stage (24 hpf), and at a post developmental stage (5 dpf). At 7 dpf, locomotor activity and response to tactile stimulation were observed. Half of the embryos were manually dechorionated prior to the early exposure to study the capacity of the chorion's protective barrier. The results of this study showed that MPTP exposure significantly affected locomotor activity in larval zebrafish.

P1.163 PRINCE, S.C.*; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *princesc@hendrix.edu*

Effects of betamethasone on myosin light chain expression of fetal Cavia porcellus intercostals

Corticosteroids stimulate lung development in growing fetuses. These benefits of corticosteroids are being utilized in modern medicine to attempt to increase fetal survival in mothers that are expected to go into pre-term labor. Corticosteroids are known to improve lung function; however, less is known about their effects on the ventilatory system as a whole, particularly in regards to breathing muscles. Previous studies in our lab have shown that a multi-course exposure to betamethasone, a corticosteroid, leads to changes in myosin heavy chain (MHC) isoform expression in fetal guinea pig intercostal muscles. To more fully understand the functional consequences of prenatal exposure to corticosteroids, it is necessary to also examine the effects on myosin light chain (MLC) expression in fetal guinea pigs, because both MLC and MHC regulate the rate of muscle contraction and may be affected by steroid treatment. Pregnant guinea pigs were injected twice weekly, twenty-four hours apart at 65%, 75%, and 85% gestation. Twenty-four hours after the last betamethasone or sterile water injection, the females were euthanized, and samples of the fetal intercostal muscles were collected. Extracts of the fetal muscle samples were prepared and separated in SDS-polyacrylamide (12%) gels for □3 hours (30 mA/gel) at 18° C. These gels were silver stained, and Scion Image software was used to determine the proportions of MLC1 and MLC2 relative to actin in the treated and control intercostal muscles. Based on any changes we see in MLC1 and MLC2 expression in the treated muscles, we will be able to predict the effects on ventilatory system function in premature newborns.

P3.166 PRIOR, NH*; HEIMOVICS, SA; SOMA, KK; Unv. British Columbia; *nhprior@zoology.ubc.ca*

Effects of Water Restriction on Zebra Finch Reproductive Physiology and Pair-maintenance Behavior

Zebra finches *(Taeniopygia guttata)* are desert-dwelling birds that form long-term pair bonds. Natural droughts and experimental water restriction affect breeding in this species. Sex steroids can regulate courtship and behaviors associated with pair-maintenance in breeding condition zebra finches. However, pair-maintenance in non-breeding condition zebra finches has not been studied. Here, we used water restriction (1mL/subject/week) to bring zebra finch pairs into non-breeding condition. Control pairs were provided with water ad libitum. We examined the effects of water restriction on (1) reproductive physiology (number of eggs laid, gonad size, oviduct length, and sex steroid levels) and (2) pair-maintenance behaviors. Baseline affiliative behaviors were recorded before and after water restriction. After water restriction, we conducted two behavioral tests, (1) a "partner preference test" and (2) a "partner reunion test," and scored a variety of affiliative behaviors. In females, water restriction strongly decreased the number of eggs laid, follicle size, and oviduct length. In males, however, water restriction did not affect testis size. We are currently measuring plasma and brain steroid levels. In baseline behavioral observations, water restriction decreased time in the nestbox but did not affect other affiliative behaviors. Furthermore, water restriction did not affect behavior during the partner preference test or partner reunion test. These data indicate a sex difference in the physiological effects of water restriction and suggest that pair maintenance behaviors are maintained in non-breeding zebra finch pairs. Future studies will examine the role, if any, of systemic and neurally-synthesized sex steroids in zebra finch affiliative behaviors.

P1.83 PRIYAMVADA, L.; GARCIA, J.*; HECKMAN, K.; SCHREIBER, A.M.; St. Lawrence Univ.; *aschreiber@stlawu.edu*

The estrogen-disrupting compounds bisphenol-A (BPA) and atrazine inhibit thymus gland growth in amphibian (Xenopus laevis) tadpoles

High levels of endogenously-produced or exogenously-administered estrogen are known to cause the thymus to atrophy in vertebrates, presumably via interaction with nuclear-localized estrogen receptors. The herbicide, atrazine, has been shown to increase estrogen synthesis by inducing the cytochrome p450 aromatase enzyme, and has also been shown to cause thymic involution in mammals and in adult frogs. The polycarbonate plastic monomer, BPA, is a well-known estrogen receptor agonist that has been shown to inhibit thymus development in birds and mammals. Here we show that treatment of young tadpoles (7 days-post fertilization; Nieuwkoop and Faber stage 50) for 5-7 days with BPA (10 uM), atrazine (200 uM), estradiol (10 uM), or dexamethasone (2 uM) significantly reduces thymus gland size by 11%, 20%, 35%, and 67%, respectively. Differences in thymus size were independent of tadpole somatic size, which did not differ among treatments. In contrast, treatment with thyroid hormone (7 uM triiodothyronine, T3) caused a significant increase (20%) in thymus gland size. Interestingly, compared to tadpoles treated with estradiol alone, concurrent treatment with estradiol (10 uM) + fulvestrant (25 uM; an estrogen receptor antagonist) produced tadpoles with significantly larger (30%) thymus glands. However, the thymuses of estradiol+fulvestrant treated tadpoles were still significantly smaller (23%) compared with untreated controls, suggesting that some of the effects of estradiol and its endocrine-disrupting agonists may circumvent the estrogen receptor pathway.

P1.171 PROKOP, J.A.*; MONZON, R.I.; KROHMER, R.W.; St. Xavier University, Chicago; *j.prokop@mymail.sxu.edu*

Using the Spinophilin Protein as a Method of Assessing Regional Neuronal Plasticity in the Brain of the Male Red-Sided Garter Snake

In many seasonally breeding species, alteration of dendritic spine density and/or morphology appears to be an active process within neural regions regulating reproductive behaviors. Dendritic protrusions, known as dendritic spines, receive much of the incoming excitatory signals from associated contacts with surrounding neurons. In addition, these dendritic spines also appear to be somewhat transient and have the ability to mobilize, relocate and emerge from the dendritic shaft enabling a certain level of synaptic plasticity. In the male red-sided garter snake (Thamnophis sirtalis parietalis), dendritic spines on neurons within the anterior hypothalamus preoptic area (AHPOA) a region critical for the control of reproductive behaviors are dramatically denser during spring mating than in fall non-mating individuals. In addition, spine density appeared to be greater in animals treated with estrogen compared to testosterone. However, since the numbers of actual dendritic spines/synapses are immense, determining changes in spinophilin, a specific scaffold, cytoskeletal protein that is vital for the proliferation of novel spines and increased density, has been used as a method of quantifying regional changes. Therefore, using western immunoblots, this study was designed to examine regional variations in the concentration of spinophilin. Our data indicate that the concentration of spinophilin varies among the regions critical to the expression of reproductive behaviors depending on season, hormonal and reproductive status.

P1.180 PROVINE, SR*; O'MALLEY, H; KROCHMAL, AR; ROTH, TC; Kenyon College, Washington College; *rotht@kenyon.edu*

Memory use as a possible mechanism for over-land movements in Eastern Painted turtles (Chrysemys picta picta): behavioral and neurological evidence

Aquatic turtles leave the water and traverse terrestrial habitats during oviposition, nesting or when the aquatic habitat becomes degraded. Though overland movements are central to the biology of aquatic turtles, few studies have been devoted to the documentation and the possible mechanism of such movements. Here, we report the results of an ongoing investigation into the terrestrial movements of Eastern Painted turtles (Chrysemys picta picta), where successful overland movement between water sources hinges on familiarity with the surrounding upland habitat. Briefly, the movement patterns of resident (N=19) and translocated (N=10) turtles were examined in ephemeral ponds at Chesapeake Farms, Kent Co., MD. We found that while resident turtles successfully located far-off permanent bodies of water quickly and easily, all translocated turtles failed to do so. This work suggests the possibility of spatial memory use or other cognitive factors during these navigations. Relative to their resident counterparts, translocated individuals traveled greater distances at slower rates, changed direction more frequently, and moved in irregular, non-linear patterns, failing to avoid navigation barriers. In a subset of animals, we examined the neurological correlates of space use that may provide an understanding of the mechanisms behind these differences in movement (e.g., spatial memory). We report volumetric data for the medial and dorsal cortices and discuss these results in light of observed movement patterns.

P2.144 PUENGYAM, Peerapong*; UTARABHAND, Prapaporn; TSUKIMURA, Brian; Prince of Songkla University, Thailand, California State University, Fresno; *peerapong_18@yahoo.com*

Histological structure and mRNA in situ hybridization in the ovary of the banana shrimp (Fenneropenaeus merguiensis de Man)

Vitellogenin (Vg) is the precursor to yolk protein that supplies nutrients for embryonic development. Thrombospondin (TSP) is a major component of the cortical rod proteins in the ovary of penaeid shrimps. In this study, the histochemistry and in situ hybridization analysis were used to examine the structure and localization of Vg and TSP mRNA in the ovarian tissue of the banana shrimp, *Fenneropenaeus merguiensis*. Mature ovaries show high accumulation of yolk granules and the rod-like bodies of cortical protein at the periphery of the yolky oocytes. The crypts became elongated and extended to the nucleus. The localization of mRNA transcripts in the ovary was visualized with RNA probes by in situ hybridization. The Vg mRNA was only detected in the follicle cells of vitellogenic ovaries, whereas the TSP mRNA was found in primary oocytes including previtellogenic and early vitellogenic oocytes, (and not in oogonia, mature oocytes, follicle cells and connective tissues). In the banana shrimp, the Vg mRNA may be transcribed and subsequently translated into the Vg precursor in follicle cells, and then taken up into oocytes for yolk accumulation. The TSP was expressed in the early stages of ovarian development and may be important for cortical rod formation in the oocytes. These results suggest that the expression of Vg and TSP gene may play an important role in ovarian maturation but their expression regulation mechanisms are different. Further study of mRNA expression of Vg and TSP is necessary to understand ovarian maturation in penaeid shrimps.

P1.221 QUINLAN, B.A.*; STEVENSON, T.J.; BUCK, C.L.; DUDDLESTON, K.N.; Univ. of Alaska Anchorage; *brian_2008@hotmail.com*

Post-weaning dynamics of the fecal microbial communities of arctic ground squirrels

Mammals participate in a mutualistic relationship with their gut microflora characterized by complex reciprocal interactions that influence both host physiology and microbial community dynamics. There is evidence that the gut microflora plays an important role in host fat deposition. The arctic ground squirrel (*Urocitellus parryii*) is a hibernator that rapidly gains considerable fat in preparation for hibernation. It is likely they host a gut microflora efficient in energy extraction that contributes to pre-hibernation fattening. To date, no studies have examined the gut microflora of arctic ground squirrels. Our objective was to assess changes in diversity of the gut microbiota of juvenile squirrels across their first active season with particular attention paid to the rapid fattening phase. Fecal samples were collected bi-weekly from captive-born squirrels from weaning until hibernation. Microbial diversity was determined using T-RFLP analysis of bacterial 16S rDNA. Differences in microbial communities were determined using Additive Main Effects and Multiplicative Interaction (AMMI) and Interactions Principal Component Analysis (IPCA) using T-REX software. Clone libraries were constructed from fecal samples collected at 0, 4, and 8-weeks post weaning in order to phylogenetically characterize microbial communities. The gut microbial community was comprised primarily of members of the phyla *Firmicutes* and *Bacteroidetes*. T-RF richness, a measure of total diversity, declined from week 4 (125.22) to week 10 (60.56). T-RF patterns varied with time and among animals, and variation among animals decreased over time. Combined, these data show that the gut microbiota shifted as the squirrels developed and prepared for hibernation.

P1.111 RADE, CM*; HERNANDEZ, LP; George Washington University; *cristinarade@gmail.com*

Morphological variation in the pharyngeal jaw apparatus of Cypriniformes

Cypriniformes is a morphologically diverse order of teleosts characterized by a novel pharyngeal jaw apparatus (PJA). While perciform pharyngeal jaws of various fish groups, including cichlids, haemulids, and labrids have been studied, morphological diversity within cypriniform pharyngeal jaws has been largely neglected. This is an especially glaring omission given that the cypriniform PJA consists of a significantly hypertrophied ceratobranchial 5 and loss of the upper pharyngeal jaws, a character seen only at the base of this group. Here we provide a detailed description of the musculoskeletal differences characterizing the cypriniform PJA. Using both cleared and stained specimens and fixed specimens we examine inter- and intra-familial morphological variation. Cypriniform families examined exhibit either patterns of conserved morphology or significant variation at the familial level. Within Balitoridae and Gyrinocheilidae, interspecific variation is minimal. Alternatively while Cyprinidae and Cobitidae show common features at the subfamilial level, there is significant variation in PJA across these families. While significant hypertrophy of the pharyngeal jaws characterizes most cypriniform fishes, gyrinocheilids tend to have smaller and more slender pharyngeal jaws; this is in strong contrast to the thicker and broader pharyngeal jaws of several of the examined cyprinids. Overall, this comparative study identifies various morphological features, including some that are potentially correlated with tropic niches; for instance, gyrinocheilids, which predominantly feed on algae, have slender pharyngeal jaws with a great number of small comb-like pharyngeal teeth. Results here will be important to elucidating the importance of the PJA in relation to cypriniform fishes' trophic diversity and ecological success.

P1.71 RADER, J.A.*; NEWSOME, S.D.; MARTINEZ DEL RIO, C.; Univ. of Wyoming, Laramie; *jrader@uwyo.edu*

Of Isotopes and Ovenbirds: Seeking phenotype-environment correlations in South American Cinclodes ovenbirds

Adaptive radiation is a fundamental concept in ecology, and a primary source of biodiversity. Identifying and describing new examples of adaptive radiation allows us to expand our view of how the process occurs, and to predict its outcomes. *Cinclodes*, a genus of South American songbirds, is a recent and rapidly diverging taxon that has diversified along several ecological axes. This group of 15 species provides an ideal system in which to study ecological and morphological covariation. *Cinclodes* species inhabit lowland coastal and riparian zones, as well as very high elevation (>4000 m) riparian habitats, with some species displaying seasonal elevational migration. Other species have adapted to utilize marine resources either seasonally or permanently, and to cope with the concomitant salt loads. These marine *Cinclodes* may be the most marine adapted of all passerines. Preliminary morphological data suggest that *Cinclodes* can be divided into two functional groups, or morphotypes, based on bill dimensions: a long, stout-billed morph and a short, gracile-billed morph. The data also suggest morphological convergence among the species C. *fuscus*, C. *albiventris* and C. *albidiventris*. Until a recent molecular study identified that these species are not monophyletic, they were considered subspecies of C. *fuscus*. Our study also uses carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes as indicators of reliance on marine and terrestrial resources, and deuterium (δD) and oxygen ($\delta^{18}O$) isotopes to assess patterns of elevational residence and movement. Our study takes a novel approach in the use of morphological and stable isotope covariates to address the challenge of characterizing phenotype and environment, and highlights the value of established museum collections for studies of this variety.

P1.195 RADZIO, T.A.*; TUCKER, C.; STRICKLAND, J.T.; LIGON, D.B.; DELANEY, D.K.; Drexel University, Missouri State University, US Fish and Wildlife Service, US Army Corps of Engineers; *tar55@drexel.edu*

Can Automated Radio Telemetry Quantify Ornate Box Turtle Activity and Nesting Patterns?

Miniature data loggers and transmitters allow biologists to efficiently study wary or cryptic animals in their natural habitats with minimal disturbance. We investigated whether automated radio telemetry and the signal change method could be used to quantify the activity and nesting patterns of ornate box turtles (Terrapene ornata) inhabiting a sand prairie in northwestern Illinois. The signal change method relies on the principle that any movement of a radio transmitter (including minor changes in orientation) can strongly affect the intensity of the transmitter's signal at a stationary receiving station. Using video recordings of radio-monitored turtles, we confirmed that transmitter signal strength values can be analyzed to generate accurate indices of box turtle activity patterns. Notably, between late May and mid-June 2010, most radio-monitored females exhibited substantial activity on 1 or more nights. Previous reports indicate that ornate box turtles nest at night, but are otherwise inactive after dark. Based upon this information, relatively little indication of night activity by males, and other patterns present within the radio signal recordings, we hypothesized that night activity corresponded to nesting. In 2010, we tracked 4 night-active females and visually confirmed nesting in 3 of these individuals, but observations of the fourth female were inconclusive. In 2011, a single researcher found 13 box turtle nests at the site by tracking night-active females, providing further support for this method. In conclusion, we demonstrate that the signal change method can be used to generate accurate indices of box turtle activity that can potentially be used to identify nesting activity in this species.

P1.207 RAFFEL, TR; HERBIG, E*; KOBASA, C; VENESKY, M; MCMAHON, TA; ROHR, JR; Dickinson College, University of South Florida, University of South Florida; *tomraffel@gmail.com*

Climate variability reduces frog resistance to parasitic infection

Climate change is expected to change the distribution and abundance of important diseases of humans and wildlife. Most studies of climate and disease have focused on changes in mean temperature and precipitation, but have ignored potentially important effects of climate variability on host-parasite interactions. In a previous study, we showed that frogs were more susceptible to the pathogenic fungus *Batrachochytrium dendrobatidis* (*Bd*) following an unpredictable shift in temperature. In this study, we tested whether this effect is generalizable to two additional amphibian parasites: the bacterium *Aeromonas hydrophila* and the nematode parasite *Rhabdias*. Using 40 replicate incubators, we acclimated Cuban treefrogs (*Osteopilus septentrionalis*) to 15°C or 25°C for four weeks. Half were then switched to the other temperature, at which point, one frog in each incubator was exposed to *Bd*, *Aeromonas*, or *Rhabdias*. A fourth frog was subjected to control inoculations. The frogs were monitored for an additional 6 weeks in their incubators. *Bd* infection was measured at 2 and 4 weeks post-exposure using quantitative PCR; *Rhabdias* infection levels were assessed at 1, 2, 3, and 6 weeks by examination of frog feces. *Rhabdias*-infected frogs were killed and dissected at the end of the experiment for quantification of adult *Rhabdias* worms in their lungs. We found that all three parasites grew faster in frogs that were subjected to an unexpected temperature shift, supporting our hypothesis. Given that many frog populations are thought to be in decline due to disease, this result has potential implications for the effects of climate change on amphibian declines and extinctions worldwide.

P1.125 RAMIREZ, M. Desmond*; OAKLEY, Todd H.; Univ. of California, Santa Barbara; *ramirez@lifesci.ucsb.edu*

Uncovering the molecular basis of dispersed photoreception in the cephalopod, Octopus bimaculoides

Where do the molecular components of complex traits come from? Do they arise *de novo*, or are they co-opted from existing systems? Photoreception is excellent for exploring these questions, as we understand both the molecular basis and evolutionary histories of animal phototransduction cascade genes. Cephalopod molluscs possess three distinct photoreception systems; most have camera-type eyes, light-sensitive brain regions, and likely some dispersed photoreception (Mathger et al., 2010, reviewed in Ramirez et al., 2011). The cuttlefish *Sepia officinalis* expresses r-opsin in the skin (Mathger et al. 2010). We have identified five r-opsin phototransduction genes expressed in the skin of the octopus, *Octopus bimaculoides*, including r-opsin and G-protein α-q. Although these data are limited, they suggest a common origin of dispersed phototransduction genes for these two cephalopod groups. The sequences of dispersed r-opsins in both *S. officinalis* and *O. bimaculoides* are highly similar to the sequences of eye r-opsins, and the same cascades may mediate both photoreception systems. However, this may not be the case at broader taxonomic scales; dispersed photoreception responses in the gastropod snail *Lymnea stagnalis* are abolished by a pharmacological agent that affects cyclic nucleotide gated (CNG) ion channels (Pankey et al., 2010). CNG is typically associated with the c-opsin pathway, rather than the r-opsin cascade we have identified in octopus skin. Thus, dispersed photoreception may have evolved multiple times within different molluscan lineages. Overall these results suggest that dispersed photoreception genes may have been co-opted from existing systems in cephalopods, but that this is likely not true of all dispersed photoreception systems in molluscs.

P2.86 RAMIREZ, Matthew*; SKIBIEL, Amy; HOOD, Wendy; Auburn University; *mdr0001@auburn.edu*

Lactating Columbian ground squirrels increase nutrient absorption without altering digesta retention

During lactation, a mother must support the nutritional demands of both herself and her dependent offspring. To meet this demand, mothers often increase food intake. However, without changes in gastrointestinal morphology, mean digesta retention time and relative digestibility will decrease and ultimately, intestinal capacity may limit reproductive performance. During reproduction, an increase in mass and length of the small intestine can compensate for increased nutrient intake and a change in handling of solute versus particle phases of digestion may improve nutrient absorption. The purpose of this study was to examine the functional changes in the gastrointestinal tract during lactation in Columbian ground squirrels. Digestibility of dry matter, fiber, and nitrogen was compared between early and late lactation females, and between lactating and non-reproductive females. Food and feces were analyzed for dry matter fiber content and nitrogen. To examine mean retention time, the passage of two digesta markers (Co and Cr) was quantified at peak lactation. Food intake and digestion of fiber components and nitrogen in the diet was significantly greater in lactating females over non-reproductive individuals. This improved digestibility by reproductive individuals was not associated with an increase in the amount of time that solutes or small particles were retained in the gastrointestinal track. However, within each group, solutes were selectively retained over particles, an adaptation previously thought to be limited to small species (<100 g). These findings suggest that greater absorption efficiency in lactating females is most likely achieved with an increase in the efficiency of passive and active absorption rather than with changes in gross morphology.

P3.41 RAYMOND, W.W.*; DUGGINS, D.O.; DETHIER, M.N.; Oregon State University, Friday Harbor Laboratories, University of Washington; *raymondw@onid.orst.edu*

Fresh vs. Aged Kelp: Feeding Preferences of Red Urchins

Kelps create a large amount of biomass in nearshore temperate marine ecosystems. Kelps also provide structure, habitat and food to many organisms. However, attached kelps are only minimally consumed by large herbivores. When kelps detach from the rock their biomass is transported elsewhere in the ecosystem, providing a spatial subsidy of carbon to consumers in other habitats. One consumer is the red urchin, *Strongylocentrotus franciscanus*, which occurs from the intertidal to 120m depth. Urchins are known to feed on kelps transported as drift, and due to their low assimilation efficiency, urchin waste becomes a viable food source to other benthic organisms. Drift kelps gradually degrade as they are transported into deep water, but the effect of degradation or aging on kelp palatability to urchins is not well known. I investigated the feeding preferences of red urchins to fresh or aged kelps: *Nereocystis luetkeana*, *Agarum fimbriatum*, and *Saccharina subsimplex*. I simultaneously offered a fresh and aged sample of each kelp species to urchins and recorded which sample was bitten first. My results show strong preferences for aged *N. luetkeana* but for fresh *A. fimbriatum* and *S. subsimplex*. Due to their preferential feeding behavior, urchins act as a biological filter in the spatial subsidy, therefore serving a critical role in determining the rate at which kelps are integrated into the food web.

P1.168 REDO, A.R.*; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *redoar@hendrix.edu*

Determining the effect of prenatal steroids on the rectus abdominis of Cavia porcellus

Glucocorticoid steroids are widely used as a precaution for women who risk premature labor. These steroids accelerate lung development in babies born premature, but may come with side effects like weight loss and lung problems later in life. The focus of this research project is to determine the effects of prenatal steroid treatment on the glycogen storage in the fast- and slow-twitch fibers of the guinea pig rectus abdominis muscle. Based on work completed in our lab, which showed a higher oxidative capacity in a breathing muscle exposed to prenatal steroids, we hypothesize that more glycogen, the fuel of muscle contraction, is stored in the fibers of fetuses that are exposed to the steroids. To test this hypothesis, pregnant Hartley guinea pigs were injected with betamethasone or sterile water at 65%, 75%, and 85% gestation. Twenty-four hours after the last injection, each female guinea pig was humanely euthanized and her fetuses extracted. The rectus abdominis muscle was removed from each fetus and prepared for histochemistry. Once the tissue was cut in a cryostat and mounted onto slides, it was stained for myosin ATPase activity and glycogen content using the Periodic Acid Schiff reaction. Digital images of the stained tissue were taken, the fast- and slow-twitch fibers were identified, and their glycogen staining densities measured using Scion Image. Z-scores will be calculated and used to determine the percentages of fast- and slow-twitch fibers staining darkly or lightly for glycogen. If we find a greater storage of glycogen in treated breathing muscles, the breathing muscles of babies exposed to these steroids may be capable of contracting for extended periods of time, because of the larger fuel reserves in their fibers.

P2.4 REICHARD, D/G*; HAHN, T/P; KETTERSON, E/D; Indiana Univ., Bloomington, Univ. of California, Davis; *dgreicha@indiana.edu*

Female release of luteinizing hormone (LH) in response to short- and long-range song in a songbird, the dark-eyed junco (Junco hyemalis)

Male courtship signals and displays can have strong stimulatory effects on female reproductive physiology. In songbirds, males use vocal signals, or songs, both to attract and stimulate females into a copulation or lasting pair bond. Previous research has shown that hearing male song can activate the hypothalamic-pituitary-gonadal (HPG) axis leading to the production of sex steroids that drive reproductive development in both sexes. However, studies of the physiological impacts of male song have focused exclusively on high-amplitude, long-range songs (LRS) that project over long distances and overlooked low-amplitude, short-range songs (SRS) that occur during directed courtship. To test the effect of SRS on female physiology, we captured free-living, female dark-eyed juncos (*Junco hyemalis*), brought them into captivity and played 45 minutes of LRS or SRS, or left them in silence as a control. After an additional 15 minutes of silence, we collected plasma samples that were later assayed for luteinizing hormone (LH), the hormonal link between the pituitary gland and the gonads in the HPG axis. When focusing only on females with LH levels detectable by the assay, females hearing song had significantly higher circulating LH than controls. Also, a higher proportion of females hearing SRS exhibited LH levels above the minimum detection limit of our assay than did females receiving LRS or the silent control. These results suggest that females can rapidly elevate their circulating LH in response to male song and highlight the potential for SRS to elicit a larger release of LH and possibly sex steroid production than LRS. We conclude by arguing that future research on male vocal signals should focus on both LRS and SRS.

P1.132A RENN, Suzy CP*; CARLETON, Julia; CROTTEAU, Emily; Reed College; *renns@reed.edu*

Molecular modules of maternal aggression in the African cichlid Astatotilapia burtoni

Thirty years of research have contributed to our understanding of the molecular, hormonal, and physiological mechanisms of the socially regulated switch between dominant and subordinate phenotypes among males of the African cichlid species *Astatotilapia burtoni*. Meanwhile, the female phenotypes have been largely ignored by all but a few studies regarding the reproductive cycle and affiliative behavior. Females of a recently collected A. burtoni wild stock from Zambia display a "good mother" phenotype that includes defensive aggression to protect free-swimming fry for up to 15 days post-release, whereas labstock females show similar aggression but eat their fry within 2-3 days post-release. The behavioral difference is likely due to inadvertent artificial selection in the lab, as suggested by good-mother phenotype observed in F1 wildstock that have been reared under standard lab conditions. Our current research employs a systems biology approach to investigate the neuroendocrine and genomic contribution to the novel phenotype of maternal aggression in A. burtoni. We describe the behavior in detail through repeated, ten-minute focal observations. We use cross-fostering experiments to demonstrate that the differing level of maternal care is possibly induced in part by differences in the behavior of the fry. We use a cDNA microarray to identify differences in gene expression between stocks and between timepoints along the reproductive cycle. A module of gene expression, specific to the wild stock in the post-release, maternal stage contains some genes previously identified as important in male territorial behavior and also a novel set of genes potentially related to maternal aggression.

P3.22 REYNOLDS, A.M.*; GATLIN, J.C.; Miami University, University of Wyoming ; *reynola5@muohio.edu*

Determining the effects of chromatin-derived signals on dynein motor function during mitosis

In order to segregate chromosomes accurately during division, a cell must first assemble a bipolar mitotic spindle. This process is regulated in part by chromatin-mediated signaling cues that affect microtubule dynamics and microtubule motor function. The best characterized and arguably most important chromosome-mediated signaling pathway involves the small GTPase Ran and the nuclear receptor protein importin β (the Ran pathway). In these experiments we tested the hypothesis that the Ran pathway regulates the function of cytoplasmic dynein, a microtubule motor protein known to be critical for bipolar spindle assembly. We first investigated the possible interaction between importin β and dynein by adding recombinant, his-tagged importin β to mitotic cell-free extracts derived from *Xenopus* eggs. Ni-NTA agarose magnetic beads were then used to separate importin β and associated proteins from the rest of the extract. Western analysis confirmed the presence of dynein in the eluted fraction, suggesting that importin β interacts either directly with dynein or indirectly via dynein-associated proteins. Although more studies are needed to determine whether activation of the Ran pathway affects this interaction and/or dynein motor function, our preliminary data are the first to indicate a mitotic link between the Ran pathway and dynein.

P3.153 RICE, J L*; CAIN, S D; Eastern Oregon University; *ricejl@eou.edu*

A Comparison of the Brain and Rhinophores of Tritonia diomedea and Armina californica

It is known that many species of animals are able to use multiple sensory cues for orientation and navigation. For example, birds have been shown to use magnetic fields, polarized light, and odors to navigate throughout their habitat. Similarly, two species of marine invertebrates, *Tritonia diomedea* and *Armina californica*, use multiple sensory cues to navigate. The neurobiological processes that underlie this behavior are not well-understood. Both species are found in sea pens bed located in near-shore and sheltered waters of the northeastern Pacific. However, their behavior in the sea pens is rather different; *A. californica* burrows while *T. diomedea* crawls and swims. Both of these animals have nervous systems that are amenable to single cell investigations of nervous system function. Here we report on the morphology and neuroanatomy of the brain and rhinophores, the primary sensory organs in these animals. The tissue morphology was investigated using standard histological techniques both for general morphology and nervous system structure.

P1.146 RICE, C.D.; Clemson University, Clemson SC; *cdrice@clemson.edu*

THE GULF KILLIFISH, FUNDULUS GRANDIS, AS A KEY MODEL FOR DETERMING THE EFFECTS OF ENVIRONMENTAL STRESSORS ON IMMUNE FUNCTION IN GULF OF MEXICO ESTUARINE FISH

The Gulf killifish, Fundulus grandis, occupies a key ecological position in high marsh habitats along the entire Gulf of Mexico of USA, with an extended range towards southeastern Florida. As with the Atlantic killifish, Gulf killifish have a small home range fidelity, and thus are confined to local physical and environmental factors. These two killifish are popular models in developmental biology and environmental toxicology. High marsh habitats are subject to highly fluctuating environmental factors, including contaminants, on immune functions that may impact disease susceptibility. A cell-based method was used to generate mAbs against IgM and eosinophilic granular cells (EGC) of F. grandis by immunizing mice with lymphoid cells. F. grandis were immunized with V. anguillarium and bled for immune plasma. Resulting hybridomas were screened for antibodies specific to both cell-surface (B-cells) and plasma IgM. Hybridomas were also screened for mAbs specific only to EGC. This all-at-once approach to mAb production resulted in mAb 2C11 for EGCs, and mAbs D58 & IC9 for IgM heavy and light chains, respectively. Our lab previously generated mAb M24-2 which is specific to pan-fish lysozyme. Together, these mAbs allow for detailed studies on the immunobiology of F. grandis. mAbs D58 and IC9 allow us to co-localize splenic germinal centers and CYP1A (mAb C10-7), and allow us to quantify B-cell #s and distribution, and also allow us to quantify antibody responses. mAbs 2C11 and M24-2 allow us to quantify EGC cells and phagocytes. Moreover, these mAbs are highly cross-reactive with Atlantic killifish, thus extending the use of killifish in environmental immunotoxicology within estuaries of both the Atlantic and Gulf of Mexico.(NIH R15-ES016905-01; R15-ES010556-01)

P1.169 RILEY, L.A.*; SCIORTINO, A.; WALKER, R.A.; DEAROLF, J.L.; Hendrix College, Conway, AR; *rileyla@hendrix.edu*

The effect of prenatal steroids on the fatigue resistance of the fetal guinea pig diaphragm

Glucocorticoids are administered to mothers at risk of preterm birth to accelerate fetal lung maturation. Though the application of these steroids has increased viability in premature births, little is known about the effects of glucocorticoids on the development of breathing muscles. Studies in our lab have shown that exposure to prenatal steroids results in an increase in the oxidative capacity of breathing muscles. Also, a positive correlation exists between oxidative capacity and fatigue resistance in the adult diaphragm. Thus, an increase in oxidative capacity in steroid-treated fetal muscles may lead to an increase in fatigue resistance. We hypothesize that the administration of betamethasone during muscle fiber differentiation will increase the fatigue resistance of the diaphragm in fetal guinea pigs. To test this hypothesis, we removed the diaphragm from fetal guinea pigs that were treated with two injections per week of betamethasone or sterile water (control). These injections occurred twenty-four hours apart at 65%, 75%, and 85% gestation. We then measured the contractile abilities of these muscles using a standard two-minute fatigue test. Results that support our hypothesis would indicate that a multi-course exposure to betamethasone leads to a more developed, fatigue-resistant diaphragm. Therefore, premature infants given this treatment may be better able to sustain ventilation during times of stress than untreated infants.

P3.140 RIVERA, A.R.V.*; RIVERA, G.; BLOB, R.W.; WYNEKEN, J.; Florida Atlantic University, Boca Raton, Iowa State University, Ames, Clemson University, South Carolina; *arivera@g.clemson.edu*

Whole-body acceleration and inertial effects of flippers during swimming in the green sea turtle (Chelonia mydas)

Sea turtles swim using synchronous, dorsoventral movements of elongate flipper-shaped forelimbs to propel themselves through water. These patterns resemble the flapping motions of flight and have been shown to produce thrust during both the upstroke and downstroke phases of the limb cycle, although thrust production during upstroke is less than half of that during downstroke. While thrust has been examined, drag and the cumulative effects of drag and thrust on whole-body acceleration during upstroke and downstroke remains unknown. Furthermore, it is unknown if the lower thrust produced during upstroke is able to overcome the effects of drag. To compare the relative contributions of upstroke and downstroke to forward motion in swimming sea turtles, we analyzed high-speed video of rectilinear swimming by juvenile green sea turtles (*Chelonia mydas*). Our results show that maximum whole-body acceleration is considerably higher during downstroke than during upstroke. In addition, maximum acceleration during upstroke is not significantly greater than zero, thus indicating that positive acceleration is primarily limited to downstroke. These patterns are likely related to the production of greater average and peak accelerations of the flipper during downstroke, which are facilitated by the hypertrophied pectoralis muscles of sea turtles. Finally, we also calculated the acceleration of the true center of mass and used these data to evaluate the inertial effects of flipper motion.

P1.117 RIVERA, G*; HANSEL, MM; ADAMS, DC; Iowa State University, Ames; *grivera@iastate.edu*

Evolutionary rates and patterns of sexual shape dimorphism in the shells of emydid turtles

Sex-based differences in shell shape have been identified in many species of turtle. Despite the functional importance of shell shape in turtles, sexual shape dimorphism (SShD) has received considerably less attention than sexual size dimorphism (SSD). In addition, most studies of SShD have focused on specific species rather than evolutionary patterns. In this study we examined sexual dimorphism in carapace shape from a broad sampling of emydid turtles. Three-dimensional coordinates were collected for landmarks from the shells of museum specimens and superimposed using the generalized Procrustes method. Multivariate techniques were used to quantify the magnitude and direction of differences in shell shape between sexes. We also used the comparative phylogenetic method to map SShD and SSD magnitudes onto an existing phylogeny of emydid turtles. This approach provided insight into several evolutionary patterns related to SShD in emydid turtles, including: (1) strong phylogenetic patterns in the direction and magnitude of SShD; (2) significant correlations between the magnitudes of SShD and SSD in the Deirochelyinae, but not the Emydinae; and (3) significantly greater rates of evolution for SSD compared to SShD. Implications of findings will be discussed.

P2.108 ROARK, AM*; BAST, RL; SáNCHEZ, J; BOLTEN, AB; BJORNDAL, KA; Hood College, Frederick, MD, Univ. of Florida, Gainesville, FL; *roark@hood.edu*

Intake and growth rates modulate bone structure in juvenile green turtles (Chelonia mydas)

The availability of resources early in life regulates rates of growth and development. It may also entrain subsequent performance through effects on morphology, physiology, and/or life history. The purpose of this study was to determine whether resource availability during early development affects bone structure in green turtles (*Chelonia mydas*). Juvenile turtles were fed on one of three treatment schedules over a period of twelve weeks: continuous ad libitum feeding (AL), continuous food restriction (R), or food restriction for five weeks followed by a switch to ad libitum feeding (R-AL). We previously reported that R-AL turtles demonstrated rapid growth upon a return to ad libitum feeding but allocated proportionally less mass growth to mineral gains than turtles that did not experience a diet switch. We predicted that this effect would manifest as differences in bone morphology and/or extent of mineralization. In this study, bone structure of AL, R, and R-AL turtles was evaluated using measurements of external bone morphology, microcomputed tomography (microCT), and histology of excised humeri. Our results suggest that intake and growth rates affect bone structure, even when corrected for body size. This finding suggests that food availability early in life modulates bone structure in juvenile green turtles, thereby potentially affecting performance later in life.

P3.21 ROBBINS, K.A.*; SHERO, M.R.; STEVENSON, T.; DUDDLESTON, K.; BUCK, C.L.; BURNS, J.M.; Univ. of N. Carolina, Wilmington, Univ. of Alaska, Anchorage; *kar9291@uncw.edu*

Hematological development in young arctic ground squirrels: a model for natural resistance to iron deficiency?

In many mammals, postnatal development is accompanied by an anemia that persists until after independent foraging begins. This "physiological anemia of infancy" is attributed to rapid growth and expansion of heme stores during a period when iron intake rates are low. Since anemia and iron deficiency (ID) negatively impact development and performance, adaptations that reduce their magnitude or persistence may offer selective advantages. In Alaska, arctic ground squirrel (AGS; *Urocitellus parryii*) pups must mature rapidly during the short summer active season in order to prepare for their long overwinter hibernation. We therefore hypothesized that AGS pups would not suffer from developmental anemia. To test this hypothesis, we measured the blood and iron stores of 70 pups at 2 week intervals from birth until hibernation, and compared values to adult females. Pups grew rapidly across the entire period (11 g/d). However, while nursing and weaned pups had significantly ($p < 0.05$) lower hematological parameters (HCT, Hb, MCHC) than adults, anemia did not develop; rather all variables increased postweaning and reached adult values by the time pups were 2 months old. The increase in circulating heme stores was accompanied by significant new RBC production (reticulocytes). Liver iron stores declined even after pups began feeding; two month old pups had stores <50% those of adults. Together these findings suggest that endogenous and ingested iron is preferentially allocated toward rapid development, but that the apparent resistance to ID is only possible due to significant losses of iron reserves. Therefore, foraging on a nutritionally adequate diet once weaned is likely critical for proper growth and survival.

P2.75 ROBERTSON, J.C.; Westminster College, PA; *robertjc@westminster.edu*

Structure and Growth of the Paddlefish Rostrum: Investigating Vertebrate Postembryonic Morphogenesis

Paddlefish (*Polyodon spathula*) are native to North American river systems and are known for the prominent rostrum that extends from their head. As chondrosteans, paddlefish exhibit other interesting adaptations - including a derived cartilaginous skeleton. Interestingly, paddlefish hatch with no rostrum; under good growth conditions, the rostrum is first evident at about 30 days post-hatching and quickly grows to represent a third of the total body length of the fish. As such, the paddlefish rostrum offers a remarkable case of postembryonic morphogenesis in a vertebrate. This report describes studies of the structure and growth of the rostrum of juvenile paddlefish. Internally, the rostrum is characterized by a medial hyaline cartilage element that is continuous with the skull and features a lipid-filled medullary cavity. Extending laterally from the cartilage core are fibrous connective tissue wings rich in randomly oriented collagen-like fibers. The shape and relative areas of these three major compositional elements (cartilage, cavity and wings) changes along the length of the rostrum. Superficially, the lateral wings are sites of high concentrations of the well-described ampullary electroreceptors that are involved in prey detection. A single "U"-shaped lateral line canal running the length of the rostrum is located in the medial wing in a ventral position. This water-vibration sensing structure is continuous with the head lateral line canal system and makes a turn near the rostrum tip. Neuromasts, a "C"-shaped surrounding support structure, and accessory canals open to the external environment are significant features of the rostrum lateral line. Results of this work contribute to our understanding of the anatomy of this species and reaffirm that the paddlefish rostrum may be a subject of interest in studies of chondrogenesis and developmental sensory neurobiology.

P3.15 ROBERTSON, J.J.*; DEAROLF, J.L.; Hendrix College, Conway, AR; *robertsonjj@hendrix.edu*

The role of the diaphragm and scalenus in the ventilation of striped and spotted dolphins (Stenella spp.)

The major ventilatory muscle in most mammalian ventilatory systems is the diaphragm, yet its role in dolphin ventilation seems to be diminished. Research on the diaphragm of the bottlenose dolphin has shown that it is composed of mainly slow-twitch muscle fibers. The low number of fast-twitch fibers suggests that there are other muscles involved in dolphin ventilation that possess the contractile speed needed to power their explosive exhalation and rapid inhalation. Previous studies have shown that muscles that work together to drive inspiration have similar fiber-type profiles and levels of oxidative and glycolytic enzymatic activities. Thus, this experiment used histochemical analyses to calculate the fiber-type profiles of the scalenus and diaphragm of striped and spotted dolphins to determine if these muscles work jointly or independently to drive ventilation. Tissue samples were cut and stained for their myosin ATPase activity to distinguish fiber-types. Digital images of the stained tissues were taken and printed in order to count and calculate the percentages of fast-twitch fibers in the scalenus and diaphragm from each specimen. The samples were also stained for their NADH-TR (tetrazolium reductase) activities, an indicator of oxidative activity. Scion Image was used to measure the NADH-TR staining density in slow- and fast-twitch fibers. These measurements were converted to Z-scores and used to calculate the percentages of slow- and fast-twitch fibers staining lightly or darkly for NADH-TR. If the striped and spotted dolphin scalenus and diaphragm muscles are found to have similar fiber-type profiles and percentages of fibers staining darkly for NADH-TR, than these results strongly support the idea that the diaphragm and scalenus muscles of these cetaceans work jointly to drive ventilation.

P1.56 ROBINSON, AM*; MACLEA, KS; CHANG, ES; MYKLES, DL; Colorado State Univ., UC Davis Bodega Marine Lab; *amr0125@gmail.com*

Effects of molting on expression of FKBP12, an inhibitor of mTOR-regulated protein synthesis, in crustacean skeletal muscle

During premolt, the claw muscle in crustaceans must atrophy to successfully withdraw the claws from the old exoskeleton. In the blackback land crab, *Gecarcinus lateralis*, the rate of global protein synthesis in atrophic claw muscles is correlated with hemolymph ecdysteroid titers. This increased protein turnover is associated with extensive remodeling of the contractile structure as muscle fibers are reduced in size. These data suggest that ecdysteroids, either directly or indirectly, stimulate metazoan Target Of Rapamycin (mTOR), a protein kinase complex that promotes translation. We hypothesize that FKBP12 (FK506-binding protein, 12 kDa), an inhibitor of mTOR, is down-regulated in atrophic claw muscle. cDNAs encoding *G. lateralis* and green shore crab (*Carcinus maenas*) FKBP12 were cloned. Real-time PCR was used to quantify the effects of eyestalk ablation (ESA) on FKBP12 expression in claw and thoracic muscles of *C. maenas* (green and red morphs). Both morphs were refractory to ESA, causing only a small increase in hemolymph ecdysteroid level. ESA had a transient effect on FKBP12 expression in green morphs, but not red morphs. There was no correlation of FKBP12 mRNA with hemolymph ecdysteroid titer. We will quantify the effects of molting on FKBP12 expression in *G. lateralis* muscles. Supported by NSF (IBN-0618203).

P2.72 ROCK, K.*; GREER, E.; MAYER, M.; SCHREIBER, A.M.; St. Lawrence Univ.; *aschreiber@stlawu.edu*

Methylmercury uptake and tissue distribution in metamorphosing Xenopus laevis tadpoles fed a swordfish diet

Methylmercury (MeHg) is a toxic form of Hg known to bioaccumulate in organisms, particularly in aquatic wildlife. MeHg's sub-lethal adverse effects include neurotoxicity, endocrine disruption, and immune suppression. Although many studies have measured MeHg levels from wild vertebrates, few controlled laboratory studies on dietary MeHg uptake and tissue distribution have been conducted using amphibian models, partly due to the challenge of effectively administering MeHg. Here we describe a simple and effective method to elevate MeHg loads of lab-raised tadpoles (Niewkoop & Faber stages 54-57) to levels comparable to those found in wetland environments known to contain high MeHg. Tadpoles were raised for 1 month on a diet of powdered swordfish, a top marine predator known to have elevated MeHg content. Compared with controls fed a Pacific salmon diet low in MeHg, pre-metamorphic tadpole (NF 57) tissues were significantly elevated (average tail values: 0.29 vs. 2.20 ppm; average body values: 0.011 vs. 1.570 ppm). Tails from swordfish-fed tadpoles contained almost one-and-one-half times the MeHg concentrations found in the body, likely due to the high muscle content of the tail compared with the body. Interestingly, following either spontaneous metamorphosis or metamorphic induction with exogenous thyroid hormone treatment (30 nM thyroxine, 7 days beginning at NF 57) the concentration of MeHg in the body abruptly doubled, even though the tadpoles were not fed during this period. We attribute the rapid rise in body MeHg levels to transference from the resorbing tail. Therefore, metamorphosis may represent a critical period when tadpoles living in environments containing elevated MeHg are particularly susceptible to its toxic effects.

P3.99 RODRIGUEZ, D.; FRANCIS, JR., A.W.*; Armstrong Atlantic State Univ., Savannah, GA; *austin.francis@armstrong.edu*

Asymmetrical Dentition Observed in the Flounder Paralicthys albigutta

Type, size, and number of teeth in fishes correlates with their feeding habits and diets. Little is known, however, about the teeth of the bilaterally asymmetrical flatfishes (Order Pleuronectiformes). To better understand the dentition of flatfishes, we investigated whether there was a significant difference in the number and distribution of teeth between the ocular and blind sides of the gulf flounder, *Paralicthys albigutta*. Ninety-seven gulf flounder were caught off the coast of Florida with either a seine net or hook and line. They were preserved on site in a 10% formalin solution and later transferred to a 70% ethanol solution. By removing and examining the premaxilla, maxilla, and dentary, we were able to determine the number and position of teeth for four sections of the jaws: upper blind side, upper ocular side, lower blind side, and lower ocular side. The premaxilla of both sides was determined to possess a greater number of teeth, ranging from 15-32. The maxilla of both sides possessed fewer teeth, ranging from 10-20. Between the ocular and blind sides, the ocular side consistently displayed more teeth. As a result, there was a significance difference in the dentition between ocular and blind sides of the gulf flounder. This asymmetrical difference in dentition may be correlated with their benthic and epibenthic feeding habits.

P1.201 ROSENDALE, A.J.*; COSTANZO, J.P.; LEE, R.E.; Miami University, Oxford OH; *rosendaj@muohio.edu*

Importance of a Putative Glucose Transporter during Physiological Stress in the Wood Frog, Rana sylvatica

Survival of physiological stresses such as freezing and dehydration by the terrestrial wood frog, *Rana sylvatica*, involves accumulation of high levels of glucose in tissues and body fluids. Stresses *R. sylvatica* is able to tolerate due in part to increased glucose levels include dehydration, freezing, and anoxia. Hyperglycemia is achieved by the production of large quantities of glucose in the liver, and the rapid export of glucose from the liver to the body fluids. The latter process is thought to involve facilitative glucose transporters, specifically GLUT2; however, little is known about how changes in GLUT2 expression in response to physiological stress may contribute to the survival of anurans during physiological stress. To elucidate the importance of GLUTs during physiological stress, we first identified a GLUT2 homolog from *R. sylvatica*. The GLUT2 cDNA cloned from liver encodes a 498 amino acid protein which has a high degree of identity to GLUT2 proteins from other taxa. GLUT2 expression in response to organismal dehydration and freezing, as well as exposure to anoxic conditions, was analyzed using quantitative PCR. Preliminary findings suggest that physiological stress results in changes in GLUT2 expression in *R. sylvatica*; therefore, GLUT2 abundance in liver may mediate stress-induced glucose accumulation. Results of this study begin to clarify the importance of GLUTs in the physiological regulation of glucose in amphibians.
Supported in part by NSF IOS1022788.

P2.177 ROSS, AM*; THOMPSON, JA; VALVERDE, RA; Southeastern Louisiana University; *Ashley.Ross-2@selu.edu*

Cloning and tissue-specific expression of CRH and its binding protein from the hypothalamus of the red-eared slider turtle, Trachemys scripta elegans

Organisms respond to challenging environmental variation by activating a hormonal cascade initiated by the neuropeptide corticotrophin-releasing hormone (CRH) from the hypothalamus. This signal triggers the release of adrenocorticotropic hormone (ACTH) from the pituitary, which in turn stimulates the release of corticosterone from the adrenal gland. Corticosterone then mobilizes energy reserves to stabilize homeostatic systems in vertebrates. Thus, this endocrine stress response mediates the adaptation of the organism to the challenge. This response is modulated by a CRH-binding protein (CRHBP), which binds CRH with high affinity, preventing an over-reaction of the organism to the stressor. In reptiles, the structure of this protein has not been elucidated. The purpose of this project was to compare the expression profiles of CRH and CRHBP in multiple tissues of the red-eared slider turtle, Trachemys scripta elegans, specifically in response to acute immobilization stress. These data may help elucidate the mechanisms by which turtles, and other wildlife, cope with pollutants in their natural environment.

P1.161 ROSS, T.T.*; KINSEY, S.T.; Univ. of North Carolina Wilmington; *kinseys@uncw.edu*

β-GPA treatment leads to elevated basal metabolic rate and enhanced exercise tolerance in mice.

Hypoxia acclimation leads to reduced phosphocreatine (PCr) and elevated AMP in mouse skeletal muscle. While these metabolic changes are associated with improved hypoxic exercise capacity, there is no increase in AMP kinase (AMP-K) phosphorylation or mitochondrial biogenesis during chronic hypoxia. We investigated the effect of experimentally manipulated PCr and AMP on basal metabolic rate (BMR) and normoxic and hypoxic exercise tolerance (NET; HET) in C57BL/6J (B6) mice. Intramuscular concentrations of PCr were decreased by dietary administration of 1% β-guanidinopropionic acid (β-GPA), a creatine analog, for either 2 or 6 weeks. 31P-NMR of gastrocnemius confirmed that PCr /ATP ratios were significantly decreased in both the 2 week (27%) and 6-week (54 %) β-GPA treated mice. BMR was increased by 64% after 2 weeks, but only by 37% after 6 weeks of β-GPA treatment. NET was decreased by 35% after 2 weeks but was not changed after 6 weeks of β-GPA treatment. HET also decreased by 27% after 2 weeks, but in contrast to NET, increased by 23% after 6 weeks of β-GPA treatment. The large increase in BMR and the decrease in NET and HET seen following the 2-week β-GPA treatment probably reflect compromised muscle and cardiovascular function due to extensive AMP-K induced tissue remodeling associated with this acute energetic stress. The more modest elevation in BMR seen in the 6-week β-GPA treatment probably reflects the new steady-state BMR where mitochondrial density in muscle and other tissues is elevated. The fact that the 6-week β-GPA treatment resulted in an enhanced HET, but not NET, suggest an advantage of a reduced energy state on hypoxic exercise.

P1.113 RUPP, Maxwell F.*; HULSEY, C. Darrin; Univ. of Tennessee, Knoxville; *mrupp@utk.edu*

Evolution of Pectoral Fins in Malawi Cichlids

In adaptive radiations such as Malawi cichlids there is a high degree of variation in the way pectoral fins are used in locomotion during feeding and other routine activities. To try and better understand the factors behind the evolution of pectoral fin musculature we wanted to address two questions: 1) Are there differences in the pectoral fin morphology between mbuna (rock-dwelling cichlids) and non-mbuna species? and 2) Do the mbuna show a faster rate of evolution in any aspect of their pectoral fin musculature or external fin structure when contrasted with non-mbuna? To do this, we compared the masses of the eight pectoral fin muscles for 45 species of Lake Malawi cichlid. Using this data and known phylogenetic relationships between the species, we were able to compare rates and patterns of macroevolution between mbuna and non-mbuna cichlids.

P3.135 RYAN, D S*; BERG, O; FEITL, K E; MCHENRY, M J; MULLER, U K; Wageningen University, California State University Fresno, University of California Irvine, University of California Irvine; *david.ryan@wur.nl*

Three-dimensional escape trajectories in larval fish

Fish execute C starts when they escape from a threat. The neural control, body kinematics and hydrodynamics of escape responses have been studied extensively in adult and larval fish. However, due to experimental constraints, biomechanical studies have focused on mapping the body movements and the center-of-mass trajectories from a dorsal view, neglecting the vertical dimension. These 2-dimensional studies suggest that prey randomize their escape trajectories, but bias the response away from the stimulus. This study explored the escape response of larval fish to a horizontal startle stimulus by recording the trajectories in three dimensions. We used a piston to generate a brief suction event simulating a predator attack. Consistent with published findings, our pilot data show that escape responses occurred either away or toward the stimulus in a horizontal plane, there seemed to be also no preference for left or right. However, zebrafish larvae consistently responded to a horizontal stimulus with a downward escape trajectory. We developed several hypotheses: (1) Demersal lifestyle: zebrafish larvae are demersal and might therefore always escape towards the substrate; (2) Insufficient pitch control: fish larvae are more dorso-ventrally asymmetric and have smaller pitch control surfaces than adults and therefore experience a stronger downward pitch; (3) Directional response: fish larvae process the direction of the stimulus and select a trajectory biased away from the stimulus. To test whether larvae use the stimulus direction to bias their escape response or default to a downward trajectory due to behavioral or mechanical constraints, we vary the direction of the stimulus.

P3.195 SALAZAR, J*; CARMACK, CA; THACKER, RW; Ohio State Univ, Univ. of Alabama at Birmingham; *salazar.50@buckeyemail.osu.edu*

Evaluating the phylogenetic utility of alg11, a potential marker for sponge systematics

Studies of molecular systematics using nuclear protein-coding genes are often limited by the need to amplify markers from RNA or cDNA. Recently, *alg11* (which encodes the asparagine-linked glycosylation 11 protein, also known as alpha-1,2-mannosyltransferase in yeast) has been proposed as a novel phylogenetic marker for resolving relationships among sponges, with the advantage of being amplified directly from genomic DNA extractions (Huchon, personal communication). To date, this marker has been examined in 13 specimens of Porifera, including 5 demosponges and 3 calcareous sponges. We sought to evaluate the phylogenetic utility of *alg11* by increasing the diversity of sponges sampled. Proposed *alg11* primers were tested using 35 specimens representing 32 genera of sponges. *alg11* was amplified from 24 of the 35 specimens, with higher success from Demospongiae than from Calcarea. High-quality sequences were obtained for 21 specimens, with an average p-distance of 43.7% for nucleotide sequences and 72.7% for amino acid sequences. In contrast, for these same specimens, a 28S nuclear ribosomal gene fragment displayed an average p-distance of 12.9%. The higher variability of the *alg11* sequences resulted in a phylogeny with longer terminal branches and weaker node support values than obtained from 28S fragments. Although the 28S topology reflected current views of sponge classification, the *alg11* phylogeny placed closely related taxa into disparate clades; concatenating *alg11* with 28S did not improve this lack of phylogenetic signal. Our results suggest that novel phylogenetic markers require evaluation at multiple taxonomic scales, using specimens that reflect the broader diversity of a particular taxonomic group.

P3.5 SALICA, M. J.*; VONESH, J. R.; WARKENTIN, K. M.; Universidad Nacional de TucumÁin, Argentina, Virginia Commonwealth University, Richmond, Boston University, MA; *mjsalica@gmail.com*

Egg clutch dehydration induces early hatching in red-eyed treefrogs

Hydration is essential for embryonic development. Dehydration is a particular risk for terrestrial amphibian embryos in gelatinous eggs. Red-eyed treefrogs, *Agalychnis callidryas*, lay eggs on plants over water. Maternally provided water allows shaded eggs in humid sites to develop to hatching without rainfall, but unshaded eggs and those in less humid sites can die from dehydration. *A. callidryas* is known to hatch early in response to several egg-stage risks, including predators, a pathogen and flooding. We experimentally tested how egg clutch dehydration affects their timing of hatching. We collected clutches from a pond in Gamboa, Panama, and randomly allocated them to wet or dry treatments at age 1 day. Wet clutches were heavily sprayed with aged tap water multiple times daily. Dry clutches were unsprayed, or minimally sprayed in some cases where eggs were dying from dehydration. Egg diameter increased initially in all clutches, as water moved from egg jelly to the perivitelline space. Then treatments diverged, so that dry eggs were smaller than wet eggs by the onset of hatching competence, at 4 days. Overall clutch thickness, including eggs plus jelly, was also less in dry than in wet clutches at 4 days. Embryos hatched earlier from dry clutches than from wet clutches, accelerating hatching by ~11%. Their hatching pattern was similar to that of fungus-infected clutches which, like healthy undisturbed clutches, hatch gradually over a period of days. For many species of amphibians that lay eggs above water, an early transition to the aquatic larval habitat could be an effective defense of embryos against the risk of mortality from egg dehydration.

P3.36 SALYERS, JM*; ALLEN, JD; College of William and Mary; *jmsalyers@email.wm.edu*

Adventures in juvenile sea urchin ecology

During the 1990's, the population of the green sea urchin, *Strongylocentrotus droebachiensis*, decreased dramatically in the Gulf of Maine due to overfishing and has been slow to recover. Predation on juvenile urchins may be one cause of poor reestablishment, resulting in lasting ecological changes to community structure in the Northwestern Atlantic. To determine the effects of predation on juvenile urchin survivorship, we examined (1) the effect of juvenile urchin size on predation by American lobsters (*Homarus americanus*) and hermit crabs (*Pagurus longicarpus*) and (2) the effect of predator density on urchin survival in mesocosm pilot studies. In the first experiment, 10 juveniles of different sizes (0.5 -3.0 mm diameter) were simultaneously presented to three hermit crabs (16-36 mm shell length) or one juvenile lobster (16-32 mm carapace length). Hermit crabs showed size selective predation, feeding preferentially on smaller juveniles. Lobsters showed no size preference for recently settled urchins, frequently consuming all urchins within three hours. However, lobsters showed a strong preference across a wider size range (0.5 - 50 mm diameter) and did not eat urchins larger than 10 mm diameter. In the second experiment, we released 200 juvenile urchins (< 3 mm diameter) in each of two mesocosms, one with background predator densities and one with elevated predator densities. After 15 days, 36% of urchins exposed to background levels of predators were recovered but only 17.5% of urchins exposed to elevated predator levels were recovered. Increased predator density appears to reduce juvenile survivorship, even in the semi-natural environment of mesocosms. Both experiments indicate that predation on juvenile green urchins contributes to poor urchin population reestablishment in the Gulf of Maine.

P3.2 SANDERS, Dana*; MABRY, Karen; New Mexico State University; *dannasan@nmsu.edu*

Habitat Preferences of Peromyscus boylii

The habitat that an animal chooses to live in is crucial for the survival and reproductive success of that animal. The habitat must support dietary needs, and provide living space and the resources necessary for reproduction. We conducted an experiment to assess habitat preferences of brush mice (*Peromyscus boylii*). Observational studies have shown that individual brush mice prefer the habitat they were born in, a result that has not been confirmed experimentally. We gave juveniles and subadults from two different habitats a two-choice test between those habitat types. We filmed test subjects during a one-hour trial period, and are quantifying the number of times the animal entered each habitat, and the total time spent in each habitat. We predict that animals will spend the most time in the habitat from which it originated.

P2.115 SANTIN, A.E.*; POWELL, M.S.; HARDY, R.W.; RODNICK, K.J.; Idaho State University, Pocatello, University of Idaho, Hagerman; *santange@isu.edu*

Dietary carbohydrate and biomarkers of sustained glycemia in rainbow trout

Rainbow trout (*Oncorhynchus mykiss*) are carnivorous fish intolerant of dietary carbohydrate. Our recent work showed low glycated hemoglobin (0.5%) that is not indicative of chronic glycemia. This is probably due to low glucose permeability into erythrocytes. Extracellular biomarkers may reflect variations in glucose concentrations over time. Plasma glucose (PG) changes immediately in the presence of dietary carbohydrate. Fructosamine (SeFa) are plasma proteins with glucose non-enzymatically bound, reflecting glucose levels over two to three weeks in humans. We examined the effects of low (15%) and high (35%) carbohydrate diets on PG and SeFa in female rainbow trout (10 and 100 g) fed to satiety over ten weeks. At two weeks, postprandial PG increased from ~5 mM in small fish on the low carbohydrate diet to 15 mM for fish on the high carbohydrate diet. Conversely, PG was similar (10-15 mM) for larger fish on both diets. After ten weeks, both sizes of fish on both diets had similar PG (5-10 mM), suggesting adaptation to carbohydrate supplementation. At two weeks, SeFa showed little difference between both diets despite significant differences in PG. Surprisingly, after ten weeks, larger fish on the low carbohydrate diet had a 3-fold higher concentration of SeFa over the high carbohydrate diet (~300 vs 100 µmol/L). Possible reasons for lower SeFa in response to the high carbohydrate diet are 1) excess glucose lost via urinary excretion, 2) increased activation of fructosamine 3-kinase promoting protein deglycation, or 3) increased protein turnover. Overall, both small and large rainbow trout can adapt to increased dietary carbohydrate and reduce protein glycation relative to a low carbohydrate diet.

P1.77 SARFATI, A.L.*; SHAFFER, J.F.; KIER, W.M.; COBLE, J.S.; University of North Carolina at Chapel Hill; *sarfati@email.unc.edu*

Using Research Focused Learning Modules for Outreach to High School Science Classrooms

Non-scientists often lack an understanding of the nature of science and scientific research. To bridge the gap between scientific research and high school science classrooms, we created a learning module that explores an ongoing research project on cephalopod muscle diversity. The online learning module depicts the research project using photos, diagrams, interactive learning activities and non-technical language. Similar learning modules on other research topics were created by eight future teachers who participated in a summer research internship at the University of North Carolina at Chapel Hill funded by the Howard Hughes Medical Institute. The learning modules will help high school science teachers incorporate scientific research in their curriculum and communicate university research to non-scientists. These modules also serve as an excellent outreach tool for university laboratories to make complex research accessible to students and community members. The learning modules can be viewed at http://www.unc.edu/depts/our/hhmi/hhmi-ft_learning_modules/.
Supported by NSF IOS-0951067.

P2.155 SAVAGE, E.H.*; ALLEN, L.C.; CHADWELL, B.A.; HRISTOV, N.I.; Winston-Salem State University, NC, Salem College, Winston-Salem, NC, Guilford College, Greensboro, NC, Winston-Salem State University; Center for Design Innovation, NC; *hsavage108@rams.wssu.edu*

No energetic benefit to group flight in the free-tailed bat Tadarida brasiliensis

Striking examples of group behavior abound in nature – insects, fish, birds and mammals come together guided by individual rules to form impressive patterns of movement at the level of the group. Several explanations exist for why organisms group and behave collectively – energetic benefit, information transfer and predator defense among others. Members of the group balance the benefits against the costs of the group – limiting resources, competition for optimal position and increased visibility to predators. Bats are particularly good models for the study of group behavior but little is known about how and why they structure and maintain their aggregations. In this study we examined the group behavior of Brazilian free-tailed bats (*Tadarida brasiliensis*) and tested the hypothesis if free-tailed bats group to gain an energetic benefit. We recorded the emergence of free-tailed bats using an array of thermal cameras and reconstructed the three-dimensional position of individual bats in the group. In addition we measured the wing beat frequency of bats as a function of group size, ambient light conditions and relative position in the group. Our results indicate that there is no energetic benefit to being in the group, in fact it is costly for the bats to aggregate in such dense clusters. Furthermore, there are no relative positions in the flight formation that give an energetic advantage to its members. This suggests that other reasons, such as predator defense or information transfer, drive the group behavior of these fascinating bats.

P2.193 SCHILLING, N.*; CARRIER, D.R.; ANDERS, C.; Small Animal Clinic, University of Veterinary Medicine Hannover, Department of Biology, University of Utah, Clinic for Trauma, Hand and reconstructive Surgery, University Hospital Jena; *nadja.schilling@tiho-hannover.de*

Epaxial muscle function in walking and running humans

During locomotion, human epaxial muscles have been suggested to 1) dynamically stabilize the trunk in the frontal and the sagittal planes during walking, 2) primarily control trunk motions in the sagittal plane during running, and 3) mobilize the trunk in the sagittal and the transverse planes during walking. In this study, we tested an additional hypothesis. Based on observations in quadrupedal mammals, we hypothesized that the human epaxial muscles of humans also function to dynamically stabilize the pelvic girdle against the action of the extrinsic limb muscles and thus provide a firm base for their activity during locomotion. To test this, we manipulated the locomotor forces acting on the trunk and the limbs by having subjects walk and run at three different speeds and inclinations and measured the activity of two epaxial muscles, the m. longissimus thoracis and the m. multifidus lumborum, and six extrinsic limb muscles in seventeen healthy male subjects. Additionally, we recorded the activity of five intrinsic limb muscles to assess whether the epaxial muscles also function in the vertical support of the body. Using correlation analysis, we tested if the changes in the activation patterns of the extrinsic and intrinsic limb muscles associated with changes in gait, speed or inclination were met by corresponding changes in the activation patterns of the ipsilateral and/or the contralateral epaxial muscles. Our results are consistent with the human epaxial muscles providing dynamic stability of the pelvis against the actions of the contralateral retractor and the ipsilateral protractor muscles as well as providing vertical support of the body.

P3.126 SCHMIDT, E.M.*; PFENNIG, K.S.; Univ. of North Carolina, Chapel Hill; *schmide@live.unc.edu*

Context-dependent mate choice in female spadefoot toad hybrids

Two species of spadefoot toads, *Spea multiplicata* and *S. bombifrons*, potentially hybridize where they co-occur in the southwestern USA. Hybrids between the two species are viable; however, hybrid males are potentially sterile and females may be only partially fecund. Nevertheless, hybridization can be beneficial for *S. bombifrons* females in some environments. Indeed, hybrid tadpoles develop more quickly than pure *S. bombifrons* tadpoles, and are therefore more likely to metamorphose and escape shallow ponds before they dry. Consequently, *S. bombifrons* females prefer heterospecifics when in shallow, but not deep, ponds. This facultative preference for heterospecifics is condition-dependent: females in poor condition are more likely to prefer heterospecifics, presumably because females in poor condition produce more slowly developing offspring. How such a behavior evolves depends, in part, on the expression of mating behaviors in hybrids. We therefore examined the mate preferences of hybrid *Spea* females. Females were tested for their preferences for *S. bombifrons* or *S. multiplicata* male calls, and for each of these calls versus a synthesized hybrid call, in conditions mimicking both deep and shallow ponds. Each test was repeated four times to test for individual consistency. Preliminary results show that hybrid females significantly prefer hybrid calls over *S. multiplicata* calls in deep water, but not in shallow water. Moreover, our results suggest that switches in hybrid female preference between deep and shallow water are condition-dependent. These results suggest that hybrid *Spea* adjust their mate preferences based on environmental context and their own body condition in a manner similar to *S. bombifrons*. This has important implications for the study of mate choice variation and the consequences of hybridization.

P3.164 SCHROER, M.L.*; PETERS, M.; HEALY, F.L.; PETERSEN, J.N.; PROPPER, C.R.; Northern Arizona University; *MelanieSchroer@nau.edu*

The effects of shifting population dynamics on behavior and the expression of secondary sex characteristics in Pimephales promelas

Population dynamics and sex ratios can be strong parameters dictating behavioral interactions among individuals. In order to determine how shifting sex ratios impacts behavior of both sexes, we observed the common fish species, the fathead minnow (*Pimephales promelas*), in three male:female sex ratios (one:two, two:two, and five:two). In tanks with more males, we observed a significant increase in time males spent under nest substrates (p=0.005) and displaying nest-tending behaviors (p=0.027). Furthermore, males displayed more aggressive behavior towards other males when there were more males in the tank (p=0.017, 0.004), but behavior towards females did not change in response to population dynamics (p=0.39, 0.49). Finally, in tanks with higher male sex ratios, nest-holding males displayed more pronounced secondary sex characteristics such as the number and size of tubercles (p=0.0002, 0.001 respectively), darker vertical banding (p<0.0001), and darker dorsal and pectoral fin coloration (p<0.0001 and p=0.008 respectively) than non-nest holding males. Our findings increase our understanding of the complex interactions that arise from shifting sex ratios. Furthermore, as fathead minnows are a model species for environmental pollution exposure, our results may be important in the development of behavioral bioassays for environmental disruption including the effects of pollution and climate change on population dynamic- mediated processes.

P2.145 SCHULTZ, E.M.*; KOCH, R.E.; HAHN, T.P.; Univ. of California, Davis; *emschultz@ucdavis.edu*

Assessing life history tradeoffs in an opportunistically breeding songbird

Due to the finite energy budget of an organism, only so much energy can be allocated to somatic physiological processes such as immune function without sacrificing energy to other processes such as reproduction, creating a physiological or life history tradeoff. Life history tradeoffs have been studied extensively in seasonally breeding animals, but little is known about the physiological regulation of these tradeoffs in species with temporally flexible reproductive strategies like the red crossbill *Loxia curvirostra*. Unlike most songbirds, crossbills are able to reproduce 10 months of the year and can offset the high energetic cost of molt by protracting it over a five-month period, often arresting it for summer breeding. In this study we examined individual variation in allocation to two measures of constitutive innate immune function, a hemolysis-hemagglutination assay and differential white blood cell counts, and compared those results between breeding and non-breeding individuals as well to individuals in varying stages of molt. Preliminary data from a single summer, where the abundance of breeding crossbills was low, lacked any significant trends among these variables, but sample size was small. Data from this current summer and late autumn, where abundance of breeding crossbills was high, will be used to augment these prior data to compare individual variation in reproductive condition and molt stage and will be related to the same measures of immune function. Although most previous research has focused on life history tradeoffs in seasonally breeding animals, these results will provide a novel examination of the relationship among tradeoffs in somatic and reproductive processes in an opportunistic breeder under free-living conditions.

P3.159 SECOR, Stephen M.*; CASTOE, Todd A.; POLLOCK, David D.; University of Alabama, University of Colorado School of Medicine; *ssecor@biology.as.ua.edu*

Transcriptome analysis of the regulatory mechanisms of intestinal response for the Burmese python

Snakes that feed relatively infrequently in the wild experience unprecedented magnitudes of regulatory responses with the onset and completion of digestion. For the small intestine, feeding triggers rapid upregulation of intestinal nutrient uptake and hydrolase activities, and cellular hypertrophy that is accompanied by 5-fold lengthening of the microvilli. These responses are reversed once digestion has completed. To examine potential molecular mechanisms underlying intestinal regulation for these snakes, we employed high-throughput Illumina RNA-Seq transcriptome profiling to examine differential expression of genes for fasted and fed Burmese pythons (*Python molurus*). We constructed and sequenced 33 multiplexed cDNA libraries from intestines sampled from pythons fasted and at 6 h, 12 h, 1 d, 4 d, and 10 d postfeeding. Reads were co-assembled *de novo* with other python cDNA data, yielding ~150,000 contigs > 250 bp that were annotated based on similarity to *Anolis*, chicken and human genes. Using these contings as a reference transcriptome, transcript abundances where estimated for each intestinal library. Of the more than 12,000 intestinal transcripts, 2,700 were upregulated by ≥10-fold after feeding. Transcripts showing extreme dynamics (≥300-fold changes) include those for the microvillus protein ezrin, brush border aminopeptidases and amino acid transporters, metabolic pathways, stress response, and calcium binding. This study demonstrates that massive transcriptional responses accompany the extensive physiological remodeling of the python's intestine with feeding. Here we provide preliminary evidence identifying the molecular mechanisms that underlie the phenotypic transitions in intestinal form and function.

P2.196 SELF, J. S.*; MCBRAYER, L.D.; Georgia Southern University; *js06837@georgiasouthern.edu*

Sprint performance and running behavior of obstacle crossing in the lizards Crotaphytus bicinctores, Gambelia wislizenii, Aspidoscelis tigris and Sceloperous occidentalis

Studies of terrestrial locomotion often focus on movement over flat uniform surfaces. In nature, animals frequently transverse many types of terrain, thus they must overcome obstacles or natural barriers such as branches, rocks, and dead wood. The ability for animals to negotiate over or around these obstacles is likely under selective pressure to successfully disperse into new habitats, acquire food, defend territories and avoid predators. Currently, studies have examined changes in locomotor performance as animals approach and cross an obstacle. In this study, four species (Crotaphytus bicinctores, Gambelia wislizenii, Aspidoscelis tigris and Sceloperous occidentalis) were used to examine locomotor performance with and without obstacles. Also, behavioral strategies (e.g. quadrupedal vs. bipedal locomotion) were examined before and after crossing an obstacle. Experimental trials took place in the field in a three-meter runway. A wooden obstacle (approximately 30% of the hindlimb length) was placed across the runway at meter 1.5. We examined the velocity, acceleration, and basic kinematics using high-speed (300 fps) video as individuals accelerated from a standstill and ran down the runway. Each individual was run three times with an obstacle and three times without. Preliminary analyses suggest no significant changes in velocity when running over an obstacle. However, behavioral strategies differ among species when crossing obstacles.

P1.47 SEWALL, K. B.*; NOWICKI, S.; Duke University; *k.sewall@duke.edu*

The relationship between testosterone and aggressive phenotype in male song sparrows (Melospiza melodia)

Male songbirds face a trade-off between providing parental care and seeking mates. Individuals may resolve this trade-off differently, potentially generating equally adaptive paternal and aggressive male behavioral phenotypes in a population. Even in the absence of distinct phenotypes, male songbirds often vary in their behavioral strategy, as seen for example in the persistent individual differences in levels of territorial aggression described in male song sparrows (*Melospiza melodia*). Consistent individual differences in aggression could be explained by individual differences in circulating levels of testosterone, or by brain mechanisms such as arginine vasotocin (AVT) levels or aromatase activity. To determine how plasma testosterone might contribute to persistent differences in aggressiveness, we measured male response to standardized field simulated territory intrusions (STIs). We captured males immediately after STI and took plasma samples within 3 min. and then again after males had been held in the lab for 2 weeks and were habituated to captivity. We quantified plasma testosterone levels using enzyme immunoassay (Assay Designs). We did not find that either base-line or STI-induced testosterone levels correlated reliably with an established measure of aggressive phenotype, the mean approach to the decoy mount and speaker. However, latency to finally approach the decoy and be captured in response to field playback was negatively correlated with STI-induced testosterone. Fully characterizing the endocrine and neuroendocrine architecture of aggressive phenotypes will require future studies examining testosterone levels in response to GnRH challenge and neuropeptide and aromatase expression in the brain.

P1.4 SEYMOURE, Brett*; TOOMEY, Matt; CLARK, David; Arizona State University, Alma College; *brett.seymoure@gmail.com*

Reflectance of Snakes of Beaver Island: A Descriptive and Visual Approach

Snakes have limited color vision, yet snakes are known for a variety of colors. Signals of snakes, ranging from aposematism to camouflage, are intended for predators or prey with well-developed color vision. During the summer of 2007 on Beaver Island, MI, we collected snakes of five species: Garter Snakes, Ribbon Snakes, Red Belly Snakes, Green Snakes, and Ringneck Snakes. We measured reflectance at different body locations for each species along with background reflectance and ambient light environment, allowing us to compare contrast between species and background. We describe the conspicuousness for each species of snake relative to their background. Further, we utilize known perception models of natural avian, reptilian, and mammalian predators to suggest the perception of conspicuousness for each snake species. We suggest that the high contrast in ventral coloration of Red Belly snakes and Ring Neck snakes may function as a warning signal, while the low contrast dorsal coloration of most species may enhance crypsis. This study engenders a better understanding of the different ecological coloration tactics of snakes and forms a base for behavioral studies to explore each species' coloration.

P2.165 SHAHBAZI, Mahin*; JIMENEZ, Pedro; CARRUTH, Laura L.; Georgia State University, Atlanta, GA, Autonomous University of Tlaxcala, Tlaxcala, Mexico; *lcarruth@gsu.edu*

The Effects of Corticosterone Treatment on Song Complexity and HVC Size in the Male Zebra Finch

Early developmental stress experienced by male zebra finches (*Taeniopygia guttata*) leads to a reduction of song complexity and decreased HVC (a song control nucleus) size in adulthood. HVC is required for learning and production of song, and song complexity is an important factor in mate choice. The stress-induced reduction in song complexity and HVC size indicates a connection between the hypothalamic-pituitary-adrenal axis, song control brain regions and singing behavior, however the mechanisms underlying these effects are unknown. We are investigating the role of glucocorticoid receptors (GRs) and stress on the development of the avian song system. Our previous work demonstrated that glucocorticoid receptor-like immunoreactive-neurons (GR-like ir-neurons) were localized in the brains of male zebra finches collected from P10 (post-hatch day 10, song nuclei formed), and adult birds (post-hatch day 90 or older, sexually mature and singing crystallized songs). We have quantified the number of cytoplasmic and nuclear GR in each brain region in P10 and adult males. In addition, adult males that received chronic corticosterone (Cort) implants on P5 had altered HVC volume when measured. Songs of chronic Cort implanted vs. control birds were recorded and had a significant reduction in song complexity. The mechanism of how Cort treatment influences HVC size, and ultimately song complexity, has yet to be determined. Supported by GSU Neuroscience Institute and the Brains & Behavior program.

P1.28 SHAPIRO, NS; CHOATE, BA; HUYNH, MH; MURRAY, JA*; Cal. State U. East Bay; *james.murray@csueastbay.edu*

The characterization of antifeedant/defensive properties of a Pacific coast opisthobranch Tritonia tetraquetra (Bergh) and its octocoral prey Ptilosarcus gurneyi (Gray)

Nudibranchs as a clade possess chemical defense mechanisms to deter predation. However, no study to date has assessed the chemical defensive potential of *Tritonia tetraquetra* or the potential chemical ecology shared between the nudibranch and its octocoral prey species, the sea pen *Ptilosarcus gurneyi*. A series of antifeedant experiments using *Hemigrapsus oregonensis* were set up to measure the feeding rate of these crabs when offered tissue from *Tritonia tetraquetra* and *Ptilosarcus gurneyi* as well as by gelatin infused with aqueous extracts of either species. The results of feeding assays indicated 36X fewer feeding attempts upon *Tritonia tetraquetra* tissue ($p<0.001$) compared to palatable control tissue (chicken). We observed 22X fewer feeding attempts upon *Ptilosarcus gurneyi* tissue ($p<0.001$) compared to palatable controls. Furthermore, crabs offered nudibranch or sea pen tissue spent on average <1% of the time feeding, compared to those offered chicken tissue, which spent 45% of the time feeding (~500X difference). Results were similar when the tissue was replaced by gelatin flavored with aqueous extracts of *Tritonia* or *Ptilosarcus* (to control for the possible effects of texture and other non-chemical antifeedant properties). A comparison of feeding probability between crabs offered *Tritonia*-flavored gelatin and *Ptilosarcus*-flavored gelatin indicated that *Ptilosarcus* flavor is ~7X less attractive than that of *Tritonia* ($p=0.04$). These results indicate some chemical defense which makes both of these species unpalatable to potential predators. This is the first study to positively confirm antifeedant properties in either of these species.

P3.84 SHARMA, P.P.*; SCHWAGER, E.E.; EXTAVOUR, C.G.; GIRIBET, G.; Harvard University; *psharma@fas.harvard.edu*

Phalangium opilio (Opiliones, Eupnoi): A new model for study of arachnid development?

Establishment of new model systems is imperative for investigating the developmental basis of organismal diversity. Presently, such models are available for only two orders of Arachnida—*Cupiennius salei* and *Parasteatoda tepidariorum* (Araneae), and *Archegozetes longisetosus* and *Tetranychus urticae* (Acari). The putative clade “Dromopoda” uniting Scorpiones, Pseudoscorpiones, Solifugae and Opiliones is unrepresented. In order to enrich comparative developmental data for Arachnida, as well as revive embryological study of Opiliones, we investigated the eupnoid harvestman *Phalangium opilio* as a candidate model organism. In the present study, we sequenced a developmental transcriptome of *Phalangium opilio* and simultaneously developed protocols for embryo cultivation, fixation, and *in situ* hybridization. We present data from whole mount *in situ* hybridization experiments, highlighting the unique morphology of Opiliones using probes for Hox genes (e.g, *Ultrabithorax*) and leg gap genes (e.g., *Distal-less*). The expression of *Distal-less* in the gnathobases of the first walking leg is consistent with the recruitment of these coxal endites in the formation of the stomotheca, a mouthpart that constitutes the putative synapomorphy of Opiliones + Scorpiones.

P3.197 SHI, Jeff J.*; CHAN, Lauren M.; RAKOTOMALALA, Zafimahery; GOODMAN, Steven M.; YODER, Anne D.; Duke University, UniversitÃ© d'Antananarivo, Field Museum of Natural History; *jeff.shi@duke.edu*

Emerging patterns of microendemism in the rodent Eliurus myoxinus within Madagascar's western forests

Madagascar is considered one of the world's irreplaceable biodiversity hotspots, characterized by its incredible levels of species diversity and endemism. This, coupled with its long isolation from other landmasses, makes Madagascar ideal for the study of speciation and differentiation without the confounding influences of migration and colonization. Using DNA sequence data from one mitochondrial and two nuclear loci, we examined patterns of phylogeographic differentiation in *Eliurus myoxinus*, an endemic rodent widespread along the western coast and its dry forests. Our aims were twofold: to assess whether extant patterns of genetic diversity were concordant with two previously established biogeographic models, and to examine possible evolutionary mechanisms that have shaped this diversity. The genetic diversity of *E. myoxinus* best fits an established model based on current climate gradients, but cannot be fully explained by either of the proposed biogeographic models. The phylogenetic relationships suggest that *E. myoxinus* originated in the southwest and expanded along the west coast into its current distribution. At least three diverging centers of microendemism were identified along the western coast, though with some gene flow between them. Importantly, this study highlights evolutionary processes resulting in latitudinal divergence within this species. This adds to recent evidence for differentiation between north and south as opposed to the more traditional dichotomy between eastern and western Madagascar.

P3.106 SHISHIDO, C.M.*; COLLIN, R.; LESOWAY, M.P.; Smithsonian Tropical Research Institute, McGill University; *csmariko@uw.edu*

The Development of Particle Capture and Ingestion Abilities in Calyptraeid Gastropods with Different Modes of Development

In marine invertebrate larvae, it is generally understood that evolutionary changes between modes of development (planktoptrophy, lecithotrophy, direct development w/large eggs, or direct development w/nurse eggs) occur predominantly from feeding planktotrophic larvae to non-feeding direct developers. It is thought that once complex structures such as the velum, the gastropod larval feeding and swimming organ, are lost they are almost impossible to regain. Molecular phylogenies of calyptraeid gastropods indicate that changes in the mode of development occur rapidly and frequently and also support instances of the re-evolution of planktotrophic larvae from lineages of direct developers. Observations suggest that the velum is retained in several species with complete intracapsular development. We examined 13 species of calyptraeids to determine if the form and function of the velum is retained in species without feeding larvae. We measured the size of the velum and length of the cilia, and compared the ability of each species to capture and ingest particles from suspension. Several developmental stages of each species were exposed to solutions of plastic microspheres ranging from 2 – 90 µm to determine the range of sizes that can be captured by each species and to understand how this relates to velum morphology. Veligers from six planktotrophs, three direct developers with large eggs, and three direct developers with nurse eggs all ingested beads from 2um to 90um. *Crepidula ustulatulina*, the sole species with lecithotrophic larvae only consumed beads up to 25um in diameter. While velum size increased in the early development of all species, the velum of the direct developers and lecithotrophs were absorbed as they neared hatching.

P2.41 SHIVER, N. B.*; GROVE, T. J.; Valdosta State University, Valdosta; *nshiver@valdosta.edu*

Quantification of the oxygen binding proteins myoglobin and hemoglobin in the mangrove killifish, Kryptolebias marmoratus, during emersion

The mangrove killifish, *Kryptolebias marmoratus*, is a tropical fish that can undergo emersion for > 1 month when it leaves the aquatic habitat of mangrove swamps and finds refuge in moist terrestrial habitats such under detritus or within decaying logs above the water line. Our lab is interested in examining expression patterns of the oxygen binding proteins myoglobin and hemoglobin in *K. marmoratus* as individuals switch from an aquatic to a terrestrial environment during emersion. To this end, we adapted protocols to determine hemoglobin and hematocrit in small blood samples obtained from individual fish. Hematocrit was 27.67 ± 1.22%, hemoglobin concentration was 7.41 ± 0.52 g/dL, and mean cell hemoglobin concentration (MCHC) was 26.47 ± 0.94 g/dL in control (immersed) individuals. We are currently measuring hematocrit and hemoglobin protein in blood and myoglobin protein in heart ventricles of emersed individuals. This work was supported by National Science Foundation grant IOS-0817805 to T.J.G.

P1.134 SHORTER, K.R.*; CROSSLAND, J.; WEBB, D.; TALLEY, L.; SZALAI, G.; FELDER, M.R.; VRANA, P.B.; Univ. of South Carolina, Columbia; *shortekr@email.sc.edu*

Epigenetic effects of diet on a natural mammalian variant.

Deer mice (*Peromyscus maniculatus*, or BW) are among the most common native North American mammals and exhibit a great amount of natural genetic variation. The wide-band agouti allele (Anb) is a naturally occurring variant which overexpresses the agouti gene. This results in a more yellow coat-color than the standard stock animals (BW). Crosses were established for BW females and Anb (wide band agouti) males. The parents in these crosses were fed a diet high in methyl donors to assess possible effects on agouti gene expression. In previous experiments with lab mice, the maternal methyl diet had effects on methylation of loci where a retroelement insertion 5' of the Agouti promoter. This experiment is among one of the first to demonstrate the effects of a diet high in methyl donors on a natural variant of the agouti gene. Behavioral data for offspring of these parents were obtained for open field tests and responses to a novel individual. First, a single offspring was filmed alone for 5 minutes. After 5 minutes alone, a control animal was placed in the cage and filmed for 5 minutes with the methyl diet (or control) offspring. Pelts were taken and organs (brain, liver, and testes or ovaries and uterus) were harvested for DNA methylation analysis. Pictures were taken of pelts side by side to quantitate the wide variation in coat colors among the offspring. A tuft of hair was taken from each pelt and bands of color were measured under the microscope. This was done to further quantify the change in banding due to the methyl diet. We are currently assessing the global levels of DNA methylation.

P2.158 SICILIANO, AM*; BEDORE, CN; LONG, JH; PORTER, ME; Vassar College, Florida Atlantic University; *avsiciliano@vassar.edu*

Does School Size matter? Swimming Kinematics of Cownose Rays (Rhinoptera bonasus)

Some groups of animals coordinate their behavior, moving together in swarms or schools. To understand the mechanisms by which schools of fish operate, we investigated cownose rays (*Rhinoptera bonasus*), one of the few species of elasmobranch fishes known to school. Some models of group behavior predict that the size of the school, as measured by number of individuals, will alter the behavior of the school. Our goal was to test this hypothesis. Specifically, we hypothesized that as the size of the school increases, the school's mean swimming velocity will decrease while, at the same time, individuals will decrease the distance to their nearest neighbors. We tested schools of 1, 2, 5, and 10 rays in a tank of 5 m diameter. From overhead video, we measured the kinematics of individuals and the group during schooling behaviors that we categorized as swimming, feeding, and escaping. During the swimming trials, the school was left unperturbed for 20 minutes. During feeding, food was placed in the tank at the beginning of the trial and the school was filmed for 20 minutes. For the escape behavior trials, which lasted for 30 minutes, every 5 minutes a single ray at the leading edge of the school was startled. Response variables over the length of the trial included velocity of each individual, the mean velocity of the school, and the mean distance from the nearest neighbor for each individual. The data suggest an increase in velocity during escape and feeding treatments. Preliminary analyses show support for the importance of school size on behavior. In addition, at the largest sizes the school's behavior is impacted by the physical limits of the tank. This work was funded by the National Science Foundation (IOS-0922605).

P2.60 SIKES, JM*; DILLON, RL; NEWMARK, PA; Univ. of Illinois, Champaign-Urbana, Howard Hughes Medical Institute; *jsikes@illinois.edu*

Germline development in the basal bilaterian Convolutriloba macropyga

The germline is crucial to the biology of all sexually reproducing animals wherein totipotent cells give rise to subsequent generations. To understand how germline specification and development may have evolved within the Bilateria, we have characterized genes with conserved germline function in the Acoela, a lineage basal to other bilaterians. While a single marker has been shown to localize to the acoel germline, little is known about the molecular nature of germ cell development in acoels. We have cloned homologs of *argonaute*, *nanos*, *piwi*, *pumilio*, and *vasa* and have characterized their spatiotemporal expression during germline development in the acoel *Convolutriloba macropyga*. While *piwi* and *vasa* are expressed during all stages of germline development, *pumilio*, *nanos*, and *argonaute* are restricted to early or late stages of germ cell maturation respectively. Expression of *piwi* and *vasa* was also observed in the primordial germ cells of recent hatchlings, corroborating previous reports of embryonic germline segregation in another acoel species. We are currently examining the possible colocalization of these genes at specific stages of germ cell maturation and attempting to knock down gene function via RNA interference to assess the role these genes play during different stages of germ cell development.

P2.15 SILER, CD*; BROWN, RM; University of Kansas; *camsiler@ku.edu*

Philippine Biodiversity Research and Education Outreach (PhilBREO)

Biodiversity Research and Education Outreach - Philippines (PhilBREO) is an international education outreach program to bring biodiversity information and educational tools to the public using a multi-language and multi-disciplinary approach. The project will develop and implement the PhilBREO website to integrate studies of biodiversity, biogeography, education, and conservation. In addition to biodiversity information focused on species of amphibians and reptiles, the site will provide conservation-based education outreach tools. These tools will range from color photographs taken during biodiversity assessments, simple guides to the amphibian species of each forest site, keys for the identification of each species in the wild, and faunal inventories. These lists will allow for a better public understanding of the distribution of vertebrate diversity in the Philippines. In addition to English, all printed information in the guides will be translated into Tagalog, the national language of the Philippines, in an effort to engage a greater percentage of communities and organizations in the Philippines. This effort is currently supported by an Encyclopedia of Life Rubenstein Fellowship to CDS aimed at developing species accounts for all amphibians and reptiles in the Philippines. The project has a number of international collaborators, and we welcome anyone interested in getting involved in the effort. The results of this project will become a large component of the PhilBREO website, and will be added to the databases of our collaborating organizations: Encyclopedia of Life, AmphibiaWeb, The Reptile Database. We encourage you to follow our progress on EOL, the PhilBREO website, or our PhilBREO LifeDesk.

P3.194 SIMISON, Brian W; ARBISSER, Ilana M*; California Academy of Sciences; *iarbisser@gmail.com*

Evolutionary history of the seagrass limpets Lottia depicta and Lottia paleacea

Malacologists have long struggled to understand the phylogenetic relationships of the marine snails, Patellogastropoda, the “true limpets.” Difficulties arise in part because there are few morphological characters available for analysis. Many of these characters are convergent, making distantly related species appear the same. Additionally, the few characters available are phenotypically variable so that members of the same species often differ from one other. Recent advances in molecular systematics have vastly improved our understanding of phylogenetic relationships. Our objective was to better understand the phylogenetic origins of northeast Pacific seagrass limpets, *L. depicta* and *L. paleacea*. These limpets are particularly interesting because the seagrasses that host these limpets range from Baja to Alaska, but the two limpet species do not extend that far north. To better understand the evolutionary relationships of *L. paleacea* and *L. depicta* relative to the other New World limpets, we used 16S, a mitochondrial gene often used in molecular studies of other limpets. We collected limpets from Half Moon Bay, California and sequenced 16S for the collected specimens. We combined our sequences with those available from Genbank and some sequences provided by David Lindberg at the University of California at Berkeley. We aligned the sequences and inferred trees using MrBayes for Bayesian analyses, RaxML for maximum likelihood analyses and PAUP for parsimony bootstrap analyses. We found evidence supporting the hypothesis that *L. depicta* and *L. paleacea* are more closely related to tropical New World limpets than they are to other limpets that share their range. These findings have implications for our interpretations of the origins and biogeography of New World limpets. In addition, the narrow range of habitat preferences shown by seagrass limpets makes them useful as indicator species for climate change.

P3.17 SLAY, CE*; ENOK, S; WANG, T; HICKS, JW; Univ. of California, Irvine, Aarhus University; *cslay@uci.edu*

Experimental reduction of arterial oxygen content increases magnitude of postprandial cardiac hypertrophy in Burmese pythons (Python molurus)

The postprandial period in Burmese pythons (*Python molurus*) is marked by a large increase in oxygen consumption (up to 40-fold in animals fed 25% of their body mass) and significant hypertrophy of gastrointestinal organs. Previous experiments have described a rapid (within 48 hours) and pronounced (40%) postprandial ventricular enlargement, but recent work noted the absence of cardiac hypertrophy under a similar experimental protocol, and suggests postprandial cardiac hypertrophy be considered “facultative” rather than “obligatory.” We hypothesize that postprandial cardiac hypertrophy serves to augment cardiac output and oxygen delivery during a period of peak oxygen demand, and experimental reduction of arterial oxygen content should therefore stimulate more pronounced ventricular enlargement. In this study, we delivered meals equivalent to 25% of body mass to Burmese pythons and allowed them to digest under environmental normoxia, environmental hypoxia, or experimentally-induced anemia. While pythons digesting in normoxia exhibited no postprandial cardiac hypertrophy after 48 hours, animals digesting with reduced blood oxygen content exhibited a 14% increase in mass-specific ventricular mass. This work suggests that reduced blood oxygen content is a stimulant of postprandial cardiac hypertrophy. Under normoxic conditions, depletion of blood oxygen levels during digestion may be the “trigger” for cardiac hypertrophy; if this threshold is not reached, cardiac hypertrophy may not occur. CES would like to acknowledge support from the NSF GK-12 Fellowship (DGE-0638751 to UCI) and an NSF Graduate Research Fellowship. Additional funding was provided by NSF grant IOS 0922756 to JWH and by the Danish Research Council to TW.

P1.176 SMEETS, J.*; KROHMER, R. W.; Saint Xavier University, Chicago; *smeets.j37@mymail.sxu.edu*

Neurogenesis in the Injured Red-Sided Garter Snake Brain

Injury to the homeotherm brain results in the upregulation of the estrogen-synthesizing enzyme aromatase. While peripheral estrogens have been shown to be neurogenic in birds and mammals, the effect of local estrogen provision in the reptilian brain has not been examined. To determine whether or not injury-induced aromatization and or, local estrogen provision can affect neurogenesis following mechanical brain damage, adult male red-sided garter snakes were castrated, implanted with either an empty silastic tube or tubes containing either testosterone or estradiol. A second set of intact animals received a silastic implant containing the anti-aromatase 1, 4, 6-androstatriene-3, 17-dione (ATD). Fourteen days after implantation, animals were given a unilateral penetrating brain injury. All animals were then injected with the thymidine analog 5-Bromo-2’-deoxyuridine (BrdU) on the following schedule: immediately following surgery, 24 hours after surgery and 24 hours prior to perfusion. Animals were perfused at 10, 14 and 21 days post surgery. Two equivalent sets of coronal sections were collected on gelatin coated slides. One set was labeled using an antibody against BrdU while the second set was visualized for the aromatase enzyme. Sections containing the injury site and surrounding areas (III ventricle and preoptic area (POA) were examined for neurogenesis and aromatase immunoreactivity. The total number of BrdU positive and aromatase immunoreactive cells were counted and their locations were recorded.

P1.86 SMELKER, KS*; VALVERDE, RA; Southeastern Louisiana University; *kimberly.smelker@selu.edu*

Vitellogenin induction by PCBs in the turtle Trachemys scripta

Vitellogenin (Vtg) detection is used as an indicator of the presence of endocrine disrupting chemicals, specifically estrogen-mimicking compounds, which are known to cause physiological and behavioral changes in otherwise healthy animals. Vtg is a precursor protein for yolk production in nonmammalian vertebrates. Liver production of Vtg is induced by estrogen stimulation and is normally found only in reproductively active females; however both males and females carry the gene necessary for Vtg production. Previous research shows that polychlorinated biphenyls (PCBs) are environmentally persistant estrogenic contaminants. The purpose of this study was to demonstrate that PCBs are capable of inducing Vtg production in red-eared slider turtles (*Trachemys scripta*). Fifteen turtles of varying size and sex and having no initial detectable Vtg, received 3 intraperitoneal injections of varying concentrations of PCBs. Blood samples were then analyzed using a western blot. Positive control turtles injected with Estradiol-17β and turtles that received 100µg PCBs/g body weight all showed Vtg induction. Two of three turtles that received 10µg PCBs/g body weight showed Vtg induction, and turtles injected with 1µg PCBs/g body weight did not show Vtg induction. These results indicate that turtles exposed to varying levels of PCBs demonstrate Vtg induction in a dose-response manner.

P2.92 SMITH, K E*; THATJE, S; University of Southampton; *Kathryn.Smith@noc.soton.ac.uk*

Combined effects of temperature and hydrostatic pressure on the early ontogeny of the common whelk Buccinum undatum (Linnaeus, 1758)

The dispersal and migration of marine fauna are affected by many factors; two of which to be considered significant are temperature and hydrostatic pressure. To understand the necessary evolutionary adaptations for colonisation of different thermal and hyperbaric environments it is important to understand how these factors affect not only adults, but also early life stages. Here we examine how these variables impact veligers and juveniles of the neogastropod *Buccinum undatum*. Development in this species is intracapsular. Successful development was observed at temperatures from 6 to 18°C. In veligers, temperature negatively affected respiration rates but no effect of pressure up to 400 atm was seen. In juveniles, respiration rates were affected by temperature, pressure and the interaction of the two. The greatest tolerance to high pressure was seen at the lowest experimental temperature (6°C). Behavioural studies indicated both veligers and juveniles could survive pressures equivalent to 3000m water depth (300 atm). The temperature and pressure tolerances observed are outside the bathymetric and latitudinal range of *B. undatum's* current distribution, which may suggest this species is capable of further expanding its distribution range. The increased pressure tolerance seen with decreased temperature in juveniles may be linked to the deep-sea origin of neogastropods. This study highlights the importance of understanding the full effects of temperature and pressure across all ontogenetic stages. Without this knowledge it is impossible to understand better how changes in climate envelopes affect the distribution and radiation of species.

P2.88 SMITH, Matthew E.*; SECOR, Stephen M.; University of Alabama; *mesmith10@crimson.ua.edu*

Gastrointestinal responses to aestivation for the aquatic salamander Amphiuma tridactylum

Aestivation is a natural-history strategy whereby organisms enter a state of dormancy to survive periodic or seasonal episodes of drought, high temperatures, and low food availability. Although the physiological responses to aestivation have been documented for lungfish, desert-dwelling anurans, and the aquatic salamander the siren, very little is known regarding the aestivation behavior and physiology of the amphiuma. Therefore, we examined the physiology and morphology of the three-toed amphiuma, *Amphiuma tridactylum*, in response to laboratory induced aestivation. We hypothesized that as an adaptive response to aestivation, amphiumas experience atrophy of their gastrointestinal tract and associated organs together with the downregulation of gastrointestinal function. These all serve to reduce their metabolic rate, thereby allowing them to survive long periods of dormancy while metabolizing endogenous energy stores. Here we present the rationale, methods, and findings of our study on examining the aestivation response of the amphiuma. To date, we have observed following three months of aestivation for the amphiuma: a 12% decrease in body mass, the shutdown of gastric acid production, no change in intestinal mass, no change in the cellular morphology of the epidermis or intestinal villi, and a 25% decrease in intestinal uptake of the amino acid proline. Given these relatively modest responses observed following three months of aestivation, it appears that for short bouts of aestivation that amphiuma do not need to dramatically alter tissue structure and function.

P1.141 SMITH, J.P.; RUTTER, M.T.; BRIDGES, M.C.; EASTERLING, M.R. ; JACKSON, L.A.; BYRUM, C.A.*; College of Charleston; *byrumc@cofc.edu*

A Genome-wide Survey of Evolutionarily Conserved Nuclear Transport Genes in the Sea Urchin

Due to its ecological significance as well as its commercial and biomedical interest, the genome of the California purple sea urchin, *Strongylocentrotus purpuratus*, was sequenced in 2006. This genome revealed greater than 23,000 genes and members of the Sea Urchin Consortium annotated much of the genome at that time. Two *S. purpuratus* gene families were not annotated in the initial effort: the exportins and the importins. These nuclear transport genes are vital to the movement of biological molecules into and out of the nucleus and currently only one, exportin-5, has been identified in *S. purpuratus*. By backblasting and performing phylogenetic analyses, we have identified *S. purpuratus* genes homologous to human exportins and importins. Within the exportin gene family, we found strong homology between each of the *S. purpuratus* genes and those from the human genome. Similarly strong homology was illustrated within the importin family as well. Our results suggest several gene duplication events may have occurred in the evolution of the importin gene family, leading to the accumulation of additional importin family members within the human genome. Studies illustrating the specific expression of the putative sequences identified will lead to even greater support for the annotations reported.

P3.104 SMOOT, SC*; PLANTE, CJ; PODOLSKY, RD; College of Charleston, Charleston; *scsmoot@gmail.com*

Plasticity of Anti-microbial Activity in Egg Masses of Melanochlamys diomedea in Response to Habitat Variation in Sediment Size and Microbial Load

Several marine invertebrates reproduce by encapsulating embryos until hatching inside gelatinous egg masses. The absence of a hard outer covering makes these egg masses particularly susceptible to microbial infection, biofouling, and predation. The mucus and gel matrix surrounding the egg capsules are therefore predicted to contain compounds that reduce these risks. Previous investigations have demonstrated antimicrobial activity with variation between species and lifestages that raise the possibility of plasticity within a species. Furthermore, if adults can adjust the level of protection in response to risk, then the amount of antimicrobial activity found within an egg mass should reflect the bacterial load of the local environment. We are comparing antimicrobial activity in egg masses of the opisthobranch mollusc *Melanochlamys diomedea* with the likely bacterial loads of their collection sites, involving measures of bacterial density and sediment grain size. Egg masses were collected from the field, lyophilized, and extracted with non-polar ethyl acetate (EtOAc) and polar methanol (MeOH). The extracts were then tested and quantified for antimicrobial activity against marine type cultures (*Bacillus subtilis* and *Vibrio harveyi*) and several environmental bacterial strains isolated from egg masses using a 96-well plate assay. Bacterial density was determined using a general bacterial DNA strain and sediment grain size with a RoTap sediment sorter. We will present the results of comparisons among six sites located on different parts of San Juan Island, WA that vary in sediment size and microbial loads.

P3.154 SOARES, Daphne*; STREETS, Amy; Univ of Maryland College Park; *daphne.soares@gmail.com*

Structure of the dome pressure receptors in the skin of the alligator.

Crocodilians have specialized sensory organs on their faces that can detect small disruptions in the surface of the surrounding water, and which are linked to a dedicated, hypertrophied nerve system. DPRs are round, dome-like structures which lack pores or protruding hairs. The epidermis is 40% thinner immediately above the DPRs, whereas the keratin layer is 60% thinner and more compact. A dermal fold below each organ contains a highly branched nerve bundle. Tract-tracing reveals secondary and tertiary branching directly under the epidermis and trigeminal innervation. Here we describe the ultrastructure of these organs and their organization.

P1.132 SOARES, Daphne; Univ of Maryland College Park; *daphne.soares@gmail.com*

Jumping in the Trinidadian guppy

Many fishes are able to jump out of the water and launch themselves into flight. Often such behavior is associated with prey capture, migration or predator avoidance. Here I study the Trinidadian guppy (Poecilia reticulata) which has rapidly evolved in response to environmental pressures and is a well established animal model for the study of ecology and evolutionary biology. This live bearing fish are common in the northern range mountains of Trinidad and are endemic to various streams that vary in ecological characteristics. Crispo et al (2006) argue that geography had substantial effects on guppy genetic structure and that waterfalls substantially reduced gene flow. Fishes from the lower parts of the streams have more allelic diversity than upstream and are believed to be the original population. Downstream guppies have repeatedly and independently colonized and adapted to upstream environments resulting in parallel, rapid changes in life history traits, behaviour and morphology. Dispersal in guppies is partially constrained by geological features but is under strong drive due to high predation in the lowlands. Here I describe the jumping kinematics in the guppy. I take advantage of the well described ecology and evolutionary history of guppies, and suggest possible roles of the jumping behavior in dispersal.

P2.156 SOLOMON-LANE, TK*; PRADHAN, DS; WILLIS, MC; GROBER, MS; Georgia State Univ., Atlanta; *tsolomonlane1@student.gsu.edu*

The relative contributions of allometry, individual behavior, and group dynamics to reproductive success in the bluebanded goby (Lythrypnus dalli)

Although the fitness benefits of sociality are undisputed, it remains unclear how individual social behavior contributes to emergent group dynamics and subsequent individual / group fitness optimization. To test whether certain classes of social behavior and/or group dynamics maximize reproductive success, we quantified egg production and recorded agonistic, affiliative, and reproductive behavior in stable social groups of bluebanded gobies *(Lythrypnus dalli)*, a highly social, marine fish that forms harems of a dominant male and multiple subordinate females. The male fertilizes and cares for eggs contributed by each female in the group. As males increase their fitness by increasing the reproductive success of their females, two factors, in combination, determine reproductive output: 1) the number of eggs laid and 2) the percentage of those eggs that males fertilize, keep healthy, and protect from predation (e.g., females). Single behaviors or traits, such as female size, male courtship, or male approach or displacement rates, do not explain the variation in fitness, eggs laid, or male egg retention. In contrast, males with high agonistic efficiency, the percent of approaches that result in displacement, have higher egg retention. Agonistic efficiency, however, is neither necessary nor sufficient for high fitness. Rather, it is an example of a broader class of socially apt behaviors that are associated with certain emergent properties of social group interactions. This work explores the fitness consequences of these behavioral phenotypes.

P1.197 SORENSON, Graham H*; HUNTINGTON, Chuck E; MAUCK, Robert A; Kenyon College, Bowdoin College; *sorensong@kenyon.edu*

Which way to turn? Within-colony movement patterns in a long-lived seabird

Colonial seabirds often demonstrate high levels of breeding philopatry at multiple spatial scales. We used a 50-year demographic study of a long-lived pelagic seabird, Leach's storm petrel (*Oceanodroma leucorhoa*), to investigate within-colony, between-year movement patterns. Combining nest-site occupancy, reproductive success, and geographic information systems, we investigated questions relating to the effect of reproductive success on the decision to change nesting burrows, as well as the direction and distance to move. We found that the choice to change burrows between years was driven by low reproductive success at both the individual and local level. When changing burrows, individuals moved toward areas within the colony where mean reproductive success had been high the previous year. Our results suggest that storm-petrels respond to colony-wide information when making decisions to improve reproductive success in subsequent years.

P3.82 SPINDLE, ST*; TURBEVILLE, JM; Virginia Commonwealth University; *spindlest@gmail.com*

Confocal microscopy study of embryonic development in the viviparous hoplonemertean Prosorhochmus americanus.

Recent studies of hoplonenemertean planktonic and encapsulated planuliform larvae have greatly clarified their development and provided insight into larval evolution within the phylum. However, an assessment of viviparous development using modern techniques is lacking. To help facilitate a comprehensive comparative evaluation of developmental diversity within hoplonemerteans, we have initiated a confocal laser scanning microscopy investigation of the development in *Prosorhochmus americanus*, one of the few nemertean species that is both hermaphroditic and viviparous. Phalloidin staining reveals that the foregut, midgut, proboscis and body wall musculature form early in development. These results are consistent with those for planktonic hoplonemertean larvae. The cerebral organs form from paired invaginations situated near the anterior end of the embryo as described for some hoplonemertean planuliform larvae. Acetylated tubulin antibody labeling shows that late stage embryos are uniformly ciliated, and in some specimens a caudal ciliary cirrus is present, which is characteristic of species with planktonic larvae. The caudal cirrus may be interpreted as a vestigial structure in the non-swimming *P. americanus* embryos. Our preliminary observations provide no evidence for a transitory larval epidermis during the development of this species, but analysis of additional stages will be necessary to verify its absence. Analysis of the development of the nervous system in this species is ongoing, and both phalloidin staining and acetylated tubulin antibody labeling indicate that the cerebral ganglia and lateral nerve cords are present in early-stage embryos.

P2.52 SPRINGTHORPE, D.*; HEDRICK, T.L.; Univ. of California, Berkeley, Univ. of North Carolina, Chapel Hill; *dspringthorpe@berkeley.edu*

A Miniaturized Animal-Computer Interface for Use with Untethered Subjects

Neuromuscular and neurosensory recordings can offer substantial insight into animal behavior by permitting quantification of motor and sensory activation. However, traditional acquisition equipment often constrains the subject to a limited area or a specific posture. Though these constraints do not typically affect experiments negatively, they can frustrate investigations into neuro-activation in freely-behaving animals, particularly so in studies that involve obstacle navigation or flying subjects. To better enable these studies, we present and test a miniaturized animal-computer interface which permits simultaneous amplification, digitization, and real-time wireless transmission of two independent neuro-activation signals. Although this device was specifically developed for and tested with freely-flying *Manduca sexta* hawkmoths, the device's programmable features, which include variable gains, electrical stimulation capabilities and on-board data processing, make it suitable for a variety of subjects. Application of this device, especially in conjunction with videography to obtain biomechanical and behavioral data, may facilitate new experiments and permit further validation of current models of animal locomotion and sensing by enabling comparisons between model predictions and whole-animal observations across a wider range of behaviors than previously considered.

P1.108 STAAB, KL*; BETANCUR-R, R; HERNANDEZ, LP; George Washington Univ; *kstaab@gwu.edu*

Evolutionary origin and diversification of adductor mandibula structure in cypriniform fishes

Cypriniform fishes comprise over 25% of the world's freshwater fishes and their success is likely due to adaptations associated with feeding. This diverse clade is united by several feeding novelties, including a protrusible jaw. Cypriniform jaw protrusion is used differently by species feeding in diverse trophic niches including insectivory, planktivory, and benthic feeding. Modifications to the pleisiomorphic architecture of the adductor mandibula muscle likely allowed for fine-tuning of jaw protrusion associated with these distinct trophic niches. Here we reconstruct the evolutionary history of adductor mandibula structure and trophic diversity within Cypriniformes. Measurements of mouth angle were combined with available diet data to characterize extant species as benthic, mid-water, and surface feeders and to test for correlations between trophic niche and architecture of the A1 division of the adductor mandibula. We coded characters associated with diet, adductor mandibula structure, and jaw shape in 50 cypriniform and 10 outgroup species, including representatives from each major clade in the order. We test hypotheses regarding both the origin of jaw protrusion and subsequent diversification of jaw morphologies among the clade. Specifically, we hypothesize that benthivory has evolved multiple times and that it is correlated with multiple branches of A1. Using phylogenetic comparative methods, we also test the recently proposed hypothesis that the most recent common ancestor to cypriniforms was a benthic fish. We find that benthic species have independently evolved multiple branches of A1, underscoring this muscle's importance in protruding the upper jaws toward the benthos.

P1.192 STAHLSCHMIDT, Z/R*; SHINE, R; DENARDO, D/F; Arizona State University - Tempe, University of Sydney; *zrs@dal.ca*

The benefits and costs of parental care in free-ranging pythons (Liasis fuscus) in tropical Australia

Parental care has evolved convergently in many taxa. Life history theory attributes this situation to the benefits of parental care to offspring viability outweighing any costs to parental viability, but such benefits and costs have seldom been measured under field conditions. A population of water pythons (*Liasis fuscus*) in tropical Australia provides an excellent opportunity to do so because some females brood their eggs only briefly (< 10 days) post-oviposition ("short brooders"), whereas others remain with their eggs throughout the long (> 50-day) incubation period ("long brooders"). We used radiotelemetry, temperature and humidity data loggers, ultrasonography, hematological techniques, and habitat analyses to measure the benefits and costs of maternal nesting decisions (nest-site selection and brooding duration) in 14 free-ranging female pythons over the 4-month reproductive season. Nest-site selection and maternal attendance enhanced thermal and hydric regimes within the nest. While reproducing female pythons experienced high costs (loss of 60% of maternal body mass) due to egg production, additional mass loss due to brooding was low (< 5%) and inversely related to relative fecundity but was surprisingly unrelated to brooding duration. Clutch size was associated with increased parasite load over the course of reproduction. Our results suggest a range of hypotheses for the coexistence of long-brooding and short-brooding tactics within this population, such as a tradeoff between offspring number and quality (long brooders may produce fewer clutches but enhance offspring quality through maternal attendance). Our study provides the first detailed measurements of the costs and benefits of parental care in egg-brooding reptiles, and it provides insight into the tradeoffs mediated by widespread maternal decisions.

P2.200 STARK, A.Y.*; SULLIVAN, T.W.; NIEWIAROWSKI, P.H.; The University of Akron, Integrated Bioscience; *ays3@zips.uakron.edu*

The Effect of Surface Water and Wetting on Gecko Adhesion

Despite growing interest in the field, few investigations of the gecko adhesive system focus on ecologically relevant conditions in which the system is expected to function. Many adhesive pad-bearing geckos are native to tropical habitats which can be subject to sudden and extreme rainfall events. A previous report using small patches of the adhesive toe pad found that shear force generated by samples fully immersed in water did not differ from those tested in dry atmosphere. Recognizing the complexity of the adhesive system and native environmental conditions, we used shear force adhesion measurements to examine the effect of surface water and toe pad wetting in a tropical-dwelling gecko (*Gekko gecko*) at the whole animal scale. Using a force sensing apparatus, we tested the shear adhesive force of geckos on three substrate treatments: dry, misted with water droplets and fully immersed in water. We also investigated the effect of wetting on the adhesive toe pad by soaking the toe pads prior to testing. Wetted toe pads significantly decreased adhesion in all treatments, as did full immersion in water. Treatments with droplets of water distributed across the surface did not differ from treatments where the surface was dry, except after the gecko took multiple steps. Results indicate that the gecko adhesive system can be significantly compromised by water conditions characteristic of tropical environments. Adhesion can be maintained, however, if the toe pads remain dry and the surface is covered only with small water droplets. These findings suggest that surface water and the wetting of a gecko's adhesive toe pads may have significant consequences on the ecology and behavior of geckos living in tropical environments.

P3.173 STEELE, Harmen*; HARNER, Andrew; BLACK, Patrick; ADAIR, Beth; KOETHER, Marina; REESE, Scott; Kennesaw State Univ.; *sreese3@kennesaw.edu*

Ontogeny of bone buffers in two species of anoxia-intolerant turtles

Adult aquatic turtles use one of 2 strategies for surviving prolonged submergence depending on whether they are anoxia tolerant or anoxia intolerant. While hatchling aquatic turtles use several strategies for surviving their first winter, all are considered anoxia intolerant, even those whose adult forms are tolerant. The ontological sequence for this transition is poorly understood, so we raised two species, *Trachemys scripta* and *Grapemys geographica*, both considered anoxia-intolerant as adults, under controlled conditions measuring bone characteristics known to provide acid buffering in adults over a span of 240+ d. Shell and skeleton water, organic and ash content along with [Ca^{2+}], [Mg^{2+}], [K^+], [Na^+] and [CO_2] were measured. While the animals were able to thermoregulate at summer temperatures, they did not start to feed until 157 d and the percent that was shell and skeleton did not change. The water, organic and ash composition of these elements did change slightly, but never reached the composition seen in the adult animal. The [Na^+] and [Ca^{2+}] of the *T. scripta* shell and the [Mg^{2+}] of the *G. geographica* shell increased over the first four months and then remained unchanged through the remaining months. The shell [CO_2] increased from 1.5-3 fold over 260 d. We suggest that hatchling turtles are unable to attain adult levels of anoxia tolerance in their first year even if their environment is favorable for such accumulation and this may restrict yearling overwintering strategies.

P2.194 STEVENS, CS*; JERRY, C; MARTIN, P; CINCO, T; AHN, AN; Harvey Mudd College; *cstevens@hmc.edu*

Effect of Variable Neural Recruitment on Biomechanics of Walking

Almost all humans walk, but there are two distinct patterns of neural control in the calf muscles amongst individuals. Half of the subjects measured recruit their medial gastrocnemius (MG) more than their lateral gastrocnemius (LG) muscle at most walking speeds ("MG-biased"). The remaining subjects recruited both the MG and LG relatively equally ("unbiased"). Additionally, subjects with greater LG activity have higher peak pressures under the medial side of the foot (Morag & Cavanaugh, 1999). Therefore, we hypothesized an MG-biased recruitment pattern would correlate with greater pressure under the medial side of the foot during walking. First, we measured muscle thickness using ultrasonography. As subjects walked, we simultaneously measured plantar pressure distribution with 4 force transducers under the 1st, 4th, 5th metatarsal heads and the heel, 3D gait kinematics with Qualysis, and muscle activity patterns of the MG and LG muscles with electromyography. Six of 12 subjects walked with an MG-biased recruitment pattern and 6 with an unbiased pattern. In agreement with our previous study, MG-biased subjects had larger MG muscles and shorter heels than unbiased subjects. Subjects also continued to show no difference in joint kinematics correlating with muscle bias. In rejection of our hypothesis, MG-biased recruitment patterns were independent of pressure measured on the medial side of the foot. However, MG-bias recruitment increased with variation of both the pressure-time integrals and the peak pressures under the medial side of the foot. Although MG-biased subjects do not tend to have higher medial pressures, when subjects recruit the MG more than the LG, pressures under the medial side of their foot become more variable. The biomechanics of walking may be affected by differing neural control patterns in the calf.

P1.222 STEVENSON, T.J.*; BUCK, C.L.; QUINLAN, B.A.; DUDDLESTON, K.N.; University of Alaska Anchorage; *Tim.stevenson83@gmail.com*

Post-weaning dynamics of the cecal microbial communities of arctic ground squirrels

The arctic ground squirrel (*Urocitellus parry*) has evolved the most extreme phenotype of any hibernator. The short arctic summer allows only 2-3 months to acquire sufficient energy stores (primarily fat) to survive the hibernation season (7-9 months). Most fat gain (5 to 45% increase) occurs during the 3 weeklong pre-hibernation fattening period. Research in mice and humans shows the gut microflora of obese individuals is more efficient in extracting energy from carbohydrates than that of leaner individuals, and sends signals that predispose the host to storage of triglycerides into adipose tissue. The gut microbiota may play a key role in assisting the arctic ground squirrel to acquire sufficient fat mass to survive hibernation. In order to study the development of the gut microbial community, captive-born juvenile arctic ground squirrels and their ceca were sampled at 4 time points (n=10; weaning and 4,6 and 8 weeks post-weaning) across the active season. Average squirrel mass increased linearly throughout the active season (R^2= 0.9652), while average abdominal white fat mass increased exponentially (n= 10; R^2 = 0.9982). Cecal content peaked at 6 weeks post-weaning (15g ± 4.75). The percent live cells increased linearly from 63.31% ± 3.84 to 80.04% ± 5.00 throughout the active season (n=8, R^2= 0.9989), while percent dead and injured cells decreased linearly, 28.77% ± 3.93 to 17.14% ± 5.67 and 7.87% ± 1.64 to 2.76% ± 0.84, respectively (n= 8; R^2= 0.9804 and 0.9899, respectively). These results suggest that microbial cell viability increases throughout development and pre-hibernation fattening. Additional analyses of the microbial community conducted includes terminal restriction fragment length polymorphism and 16s rDNA clone libraries to investigate microbial community diversity, and short chain fatty acid analysis to investigate microbial metabolic activity.

P1.115 STEWART, TA*; HALE, ME; Univ. of Chicago; *tomstewart@uchicago.edu*

Adipose fin function in Horabagrus brachysoma: first identification of a muscular control mechanism for the adipose fin

The adipose fin lies between the dorsal and caudal fins of some actinopterygian fishes. Among fish fins it is unique in its lack of intrinsic musculature, and is further distinguished by the frequent absence of endoskeletal support. Unlike other actinopterygian fins, it has been presumed to be a passive structure, with no muscular control of its movement. Adipose fins have not been studied in depth and represent perhaps the least well understood of vertebrate appendages. To understand the function of adipose fins in Siluriformes (catfishes), we surveyed the gross anatomy of the Asian sun catfish, *Horabagrus brachysoma*. We identify a muscular linkage associated with the adipose fin, the first putative active control mechanism for this fin system. Tendons extending anteriorly from the postero-lateral sides of the adipose fin connect with paired muscles at the dorsal midline. We propose that this linkage may help control adipose fin position, and call these muscles 'extrinsic adipose fin muscles' (AFCMs). Biomechanical modeling of AFCMs and associated tendons and adipose fin skeletal elements is used to predict fin movement ability and to generate hypotheses that may be tested functionally with muscle stimulation approaches. Currently, hypotheses of adipose fin function are limited to the passive influence of flow around the caudal fin or its serving as a pre-caudal flow sensor. The linkage identified here allows for new hypotheses for adipose fin function. For example, some adipose fins may actively modulate pre-caudal flow or control fin position for sensory functions. This work suggests unrecognized diversity in the adipose fin system, further studies of which may improve our understanding of the evolution and development of novel appendages in vertebrates.

P3.79 STOPPER, Geffrey F.*; GRZYB, Amanda; PERLEE, Brooke; SWIFT, Shannon; ENGEL, Ashley; HARTMAN, Brittany; Sacred Heart University; *stopperg@sacredheart.edu*

Sonic Hedgehog's negative autoregulatory properties in salamander limb development

Sonic hedgehog (Shh) is a diffusible morphogen that is expressed in the posterior of tetrapod limbs and patterns the anterior-posterior axis of the limb. Shh is thought to interact in a positive feedback loop with signaling molecules at the distal tip of the limb that direct proximal-distal outgrowth. Recent experiments support that Shh has negative autoregulatory properties, causing its expression to increase when its signaling is blocked. Previous studies in the salamander *Ambystoma mexicanum* have shown that a 10-day exposure to cyclopamine, which allows Shh expression but blocks its signaling, results in a loss of nearly all Shh patterning function from the onset of exposure, yielding limbs with reduced numbers of digits. Here we investigate the effects of a shorter 2-day exposure to cyclopamine. A simple positive feedback loop predicts a collapse of the loop in the absence of function of one of the loop elements; a limb with Shh signaling blocked for 2 days should result in a morphology similar to a limb with Shh signaling blocked for 10 days. In contrast, a negative autoregulatory loop predicts an increase in expression in response to blocked signaling; a limb with Shh signaling blocked for 2 days should look much more similar to a normal limb. Many of our experimental limbs with 2-day cyclopamine exposures show the same morphologies as normal limbs, with a few showing slight abnormalities consistent with reduced Shh function. This supports that Shh has strong negative autoregulatory properties that allow its signaling to recover from, and possibly even compensate for, short periods of interruption, with little to no morphological effect.

P3.189 STREHLOW, B*; MCCAULEY, M; RICHARDSON, C; PETERSON, K; COTMAN, C; HILL, A; HILL, M; Univ. Richmond, Univ. Mississippi, Univ. Viriginia; *mhill2@richmond.edu*

Examination of genetic regulation of Symbiodinium uptake and the morphological development of the zooxanthella-dense pinadocerm in the sponge Cliona varians.

Several species of sponge harbor intracellular populations of zooxanthellae. The dinoflagellates are primarily located in pinacoderm exposed to light. The processes that produce this spatial distribution are unknown. We used *Cliona varians* forma *varians* to examine the establishment and spatial development of zooxanthella populations under natural field conditions. To create aposymbiotic tissue, pinacoderm was removed from *C. varians*, and the choanosome was placed in a light-tight container for 2 months. Explants of the aposymbiotic sponges were attached to $CaCO_3$ blocks, allowed to heal in the dark for another week, and were then placed in 1 m of water in the flats on the ocean side of Summerland Key. Tissue was sampled every other day for approximately 120 days to examine natural reinfection dynamics. Cryosectioned replicates indicated that sponges remained nearly devoid of zooxanthellae for nearly two weeks, but at some point after 12 days, the zooxanthella populations began to increase rapidly within the sponge. We examined parameters including symbiont density, symbiont position within the sponge, cladal identity of zooxanthellae, and chlorophyll concentration. We also experimentally reinfected aposymbiotic tissue to elucidate patterns in gene expression during the initiation and maintenance of the symbiosis. We used suppressive subtractive hybridization techniques to identify genes involved in zooxanthalla uptake by aposymbiotic *C. varians*. Our work shows that genes involved in phagocytosis, the immune system, and various cell-signaling pathways are regulated during reinfection of sponge tissue. This system provides opportunities to identify commonalities in the pathways that zooxanthellae utilize to gain entry into host cells.

P2.47 STRYKOWSKI, J.L.; ORLANDO, E.F.*; University of Maryland; *eorlando@umd.edu*

Effects of Temperature on Gene Expression and Sex Determination during Embryogenesis in the Mangrove Rivulus, Kryptolebias mamoratus

Rivulus is an androdioecious teleost fish, in which wild populations are comprised of mostly self-fertilizing hermaphrodites having a functional ovotestis and some males. Rivulus was the first fish found to have environmental sex determination, but no studies have investigated the effect of temperature on genes known to be part of the ovarian or testicular differentiation pathways. In the laboratory, embryonic incubation of rivulus at 25°C results in the development of the hermaphrodite phenotype containing ovarian and testicular tissue. Embryos exposed to a lower temperature of 20°C during a critical phase of embryogenesis develop as males. In this study, rivulus embryos were maintained at control (25°C), low (20°C), or high (31°C) temperatures during seven stages of embryogenesis. The expression of seven evolutionary conserved genes with known relevance to gonadal differentiation including *figα*, *foxl2*, *cyp19a1b*, *cyp19a1a*, *dmrt1*, *sox9a*, and *sox9b* was measured using real-time, quantitative PCR. The expression of *cyp19a1a* was downregulated at 20°C and the expression of ovarian-specific genes increased throughout embryogenesis. The downregulation of *cyp19a1a*, one of the aromatase genes, could cause a decrease in circulating estrogens, thus supporting testicular differentiation. These results provide the first data documenting how temperature affects the expression of genes relevant to sex determination during embryogenesis in rivulus.

P2.69 SUCAR, S.*; MOORE, G.; ARD, M.; NEWSOME, J.M; BERNHARDT, L.; RING, B.C; Valdosta State University; *ssucar@valdosta.edu*

A FORWARD GENETIC SCREEN FOR ZYGOTIC AND STERILE MUTANTS IN THE MANGROVE KILLIFISH (KRYPTOLEBIAS MARMORATUS)

The mangrove killifish is unique among vertebrates due to its self-fertilizing mode of reproduction analogous to the invertebrate nematode model system, *Caenorhabditis elegans* . This fish develops externally, is easy to maintain, reaches sexual maturity in about 100 days, making it a desirable, but underutilized developmental genetic model organism. The genetic factors that control the formation of the ovotestis in this species are unknown. We performed a 3 generation genetic screen in order to identify mutants that disrupt normal ovotestis development. The P generation was exposed to different concentration of N-ethyl-N-nitrosourea and 284 F1 fish were screened. 73 F1 fish displayed zygotic defects in their F2 offspring (25%). In order to confirm the zygotic mutant phenotypes into the next generation, 8-10 F2 fish are reared to maturity to form a F1 family. The progeny of each F2 fish are screened to confirm zygotic phenotypes into the next generation. Thus far, we have screened 24 F1 families (33%). Of those screened, 53% of the F2 fish confirmed the zygotic phenotypes as expected in proper Mendelian ratios. In a simultaneous screen of these F1 families, we are able to identify adult F2 fish that are sterile. Sterile fish fall into three phenotypic classes: non-egg layers and non-viable embryos (maternal effect) and non-fertilized embryos (paternal effect). Thus far, we have identified 7 sterile families (29%). We are currently screening another 125 F2 to further confirm zygotic mutations and to identify more sterile families. This screen provides proof of principle that the mangrove killifish is a powerful model for developmental genetics.

P3.157 SUCRÉ, E.; VIDUSSI, F.; MOSTAJIR, B.; CHARMANTIER, G.*; GROUSSET, E.; GROS, R.; LORIN-NEBEL, C.; Univ. Montpellier 2, France, Univ. Montpellier 2, CNRS, France, Univ. Montpellier 2, Medimeer, CNRS, France; *guy.charmantier@univ-montp2.fr*

Impact of UV-B radiation on the osmoregulatory function of ichthyoplankton larvae of the sea bass Dicentrarchus labrax

Coastal marine ecosystems are submitted to variations of several parameters, some affected by global change. Among them, ultraviolet-B radiation (UVBR, 280-320 nm) may strongly impact planktonic fish larvae, in which osmoregulation depends on tegumentary ionocytes, mainly located in the trunk and yolk sac skin. As early *D. labrax* larvae passively drift in the top water column, their ionocytes are exposed to solar radiation. The effects of increased UVBR were investigated on the osmoregulatory function of sea bass larvae in seawater, through nanoosmometric measurements of blood osmolality and through cellular investigations, after exposure to different artificial UVBR treatments. A loss of hypo-osmoregulatory capability occurred in larvae after 2 days of exposure to low (50µW/cm^2: 4h L/20h D) and medium (80µW/cm^2: 4h L/20h D) UVBR. Compared to control larvae kept in darkness, an increased blood osmolality, an abnormal behavior and high mortalities were detected in larvae exposed to UVBR. At the cellular level, an important decrease in abundance of tegumentary ionocytes and of skin mucous cells was observed after 2 days of exposure to UVBR. In the ionocytes, Na/K-ATPase and the Na/K/2Cl cotransporter were immunolocalized. Compared to controls, fluorescent staining was lower in UVBR-exposed larvae. We hypothesize that the impaired osmoregulation in UVBR-exposed larvae originates from the lower number of ionocytes and mucous cells in their skin.

P2.24 SUSS, J.S.; PATEL, S.; NEEMAN, N.; PANAGOPOULOU, A.; RIGGALL, T.; MARGARITOULIS, D.; O'CONNOR, M.P.*; SPOTILA, J.R.; Drexel Univ., ARCHELON; *mike.oconnor@drexel.edu*

Gas exchange and hatching success in loggerhead turtle nests in Greece

Metabolism is important to embryonic development in oviparous reptiles and is influenced by gas exchange, hydric, thermal, and maternal conditions, and nest density. Many reptiles deposit their eggs underground where gas exchange is limited by the diffusive properties of the substrate. Since these clutches cannot move, the air and water in the sand immediately surrounding the nest influences metabolism. Loggerhead turtles bury their clutches 40 cm deep in the beaches along Laganas Bay, Zakynthos and southern Kyparissia Bay, Western Peleponnese, Greece. These beaches differ markedly in sand particle size and nest density, both of which can influence respiratory gas exchangess. During the summers of 2009 and 2010, we measured the physical characteristics of the sand on these beaches, temperatures, oxygen and carbon dioxide levels in nests and hatching success of loggerhead nests. In both years, hatching success was lower at one of the sectors in Kyparissia than all other beaches due to a higher rate of death at a late developmental stage. During incubation on all beaches, oxygen concentration decreased down to 16% and carbon dioxide increased up to 5% in the nests shortly before hatching. Water content at nest depth did not differ between the beaches and was 3.5 +/- 0.34(SE)% moisture and the dry surface sand reached down to an average depth of 19.3 +/- 1.2 cm. Nest temperatures differed among the beaches, affecting sex ratios and incubation duration, but not mortality. Egg mass, hatchling size and clutch size did not differ between beaches, including the beach with the lower hatching success. These results do not explain the lower hatching success on Kyparissia, suggesting that an anthropogenic disturbance had been occurring there.

P2.18 SUSS, J.S.*; HONARVAR, S.; SPOTILA, J.R.; O'CONNOR, M.P.; Drexel Univ.; *jss27@drexel.edu*

Beach characteristics affect the gas exchange environment for sea turtle nests

Sea turtles bury their eggs deeply on a variety of beaches worldwide. During incubation, the developing embryos exchange gases (oxygen and carbon dioxide) with the surrounding sand and atmosphere at a rate dependent on the properties of the sand. Movement of individual gases via diffusion through the sand is described by Fick's Law and movement of bulk air via convection is described by Darcy's Law. We tested the diffusivity and convective permeability of the sands from sea turtle nesting beaches in Greece, Equatorial Guinea, and both coasts of Costa Rica. Median sand grain size ranged from very fine (0.125mm) to coarse (1mm) sands. Permeability to bulk flow in coarser sands was an order of magnitude greater than that in finer sands. In all sand types, dry sands had a lower permeability than sands that were lightly wetted to 2-5% moisture by volume, similar to the field moisture at nest depth. This is due in part to an increase in porosity from the film adhesion of the wet sand particles creating incompressible aggregates and in part to a decrease in tortuosity from the film allowing for greater laminar flow than the rough, dry edges of particles. In monitored nests, oxygen decreased to 16% and carbon dioxide increased to 5% during incubation. Sand moisture on sea turtle nesting beaches can affect respiratory gas exchange of the developing eggs. Selective forces on sea turtle nests include protection from predators and development under optimal hydric, thermal, and respiratory conditions. Climate change models predict hotter, drier climates for many sea turtle nesting beaches that would increase the dry sand layer. It is imperative for conservation and hatchery practices to consider optimal gas exchange in the sand to improve future beach-monitoring efforts.

P3.175 SUSS, AB; PORTER, ME; BOXBERGER, J; KOOB, TJ; LONG, JH*; Vassar College, Doctors Research Group, Inc., MiMedx Group, Inc.; *adsuss@gmail.com*

Building Biomimetic Collagen Fibers: Viscoelastic Properties under Physiological Hydration, Temperature, and Loading

Collagen fibers undergird most load-bearing elements: tendons, ligaments, skin and bone. Using purified Type I bovine molecular collagen, we constructed collagen fibers cross-linked with carbodiimide (CD) or complexed with nordihydroguaretic acid (NDGA). Because quasi-static tension tests indicated that CD-collagen fibers were less stiff and strong than NDGA fibers, we hypothesized that their viscoelastic properties would also differ. Viscoelastic properties are extremely important to characterize, since connective tissues function under dynamic, time- and strain-dependent situations in life. Both types of fibers were mounted in either thermoplastic glue or Kryptonite ™, a calcium-based bone cement. Fibers were then placed in a heated bath of physiological saline, stress-relaxed, sinusoidally-strained at a range of strains and strain rates, and then pulled to failure. We found differences between fiber types in their breakage rates, stiffness, strength, and rate of stress relaxation. These biomimetic collagen fibers have the potential to be used in biomedical applications, biomimetic systems, and biorobotics. This work was funded, in part, by the National Science Foundation (IOS-0922605).

P1.87 SWEENEY, K.M.*; GARREHY, C.A.; FISHER, K.A.; BENOWITZ-FREDERICKS, Z.M.; Bucknell University; *kms060@bucknell.edu*

Effects of yolk testosterone levels and post-hatch food availability on wound healing in male domestic chickens (Gallus gallus)

Avian phenotypes are affected by both physiological maternal effects and post-hatch environmental conditions. We investigated the interactions between yolk testosterone levels, a maternal effect, and post-hatch food availability in young male domestic chickens (Gallus gallus). We hypothesize that maternal testosterone is more likely to promote fitness when environmental conditions, specifically food availability, are favorable. However when post-hatch environmental conditions are suboptimal, chicks exposed to elevated yolk testosterone may suffer reduced fitness compared to those from low yolk testosterone eggs. We investigated immune function as a phenotypic measure important to fitness. To assess the effects of both yolk testosterone levels and post-hatch food availability on immune function, we used a wound healing assay, which was previously validated in non-avian systems. We injected unincubated chicken eggs with 5 ng of testosterone dissolved in 50 µL of sesame oil ("T") or with 5 µL of sesame oil ("C"). On day 7 post-hatch, 30 T males and 20 C males were evenly distributed into diet cohorts. "Ad libitum" chicks had unlimited access to undiluted Poultry Starter Mix while "restricted" chicks had unlimited access to the same food diluted with 30% oat hull filler. Wound healing measures the effectiveness of an integrated innate immune response to a cutaneous wound by measuring the healing rate of a small biopsy. A 5 mm diameter biopsy punch was taken from the wing web of each animal. Standardized photographs of the biopsy areas were taken at days 20, 23, and 26, and the area of the biopsy site that remained open was measured digitally. Preliminary data suggest that wound healing is slower in chicks exposed to elevated yolk testosterone.

P2.132 SWORE, J.J*; KOHN, A.B.; CITARELLA, M.R.; BOBKOVA, Y.V.; MOROZ, L.L.; Whitney Lab for Marine Bioscience, University of Florida, Whitney Laboratory for Marine Bioscience, Dept of Neuroscience, University of Florida, Florida ; *abkohn@msn.com*

Molecular Mapping of Ctenophore Neurons and Glutamate Signaling

Ctenophores are the most basal animal lineage with 'true' neurons and muscles. Here, we performed a genome-wide survey of neurotransmitters in the ctenophore, *Pleurobrachia bachei* focusing on the characterization of glutamate mediated signaling. Specifically, we characterized the molecular organization and expression of more than 20 receptors and associated molecules in *Pleurobrachia*. We developed and characterize their expression using a novel multicolor *in situ* hybridization protocol. All cloned receptors showed remarkable cell-type specific expression but only a small subset of receptors is associated to neuronal type elements. Our data and comparative analysis suggest the presence of well-developed glutamate signaling intercellular signaling. However, this type of signaling is substantially different from other animals and can be explained in terms of extensive parallel evolution. Thus, ctenophore might preserve one of the earliest designs of neural organization among animals.

P1.98 TAFT, Natalia*; LEMBERG, Justin; DAESCHLER, Edward; SHUBIN, Neil; University of Chicago, Academy of Natural Sciences; *taft.nk@gmail.com*

Comparative analysis of the functional relationship between the endochondral and dermal elements of the pectoral fin among fossil and living sarcopterygian fishes

In this study we incorporate data from the relationship of the endochondral and dermal pectoral fin skeletons among key fossil taxa, *Eusthenopteron*, *Sauripterus* and *Tiktaalik* with data on the musculature from the extant lungfish *Neoceratodus* to generate a more complete picture of pectoral fin function in the water to land transition in tetrapods. Several morphological changes in the dermal skeleton (fin rays) of *Tiktaalik* support the hypothesis that *Tiktaalik* used its pectoral fin for routine substrate contact more than other tetrapodomorph fishes. First, the pectoral fin rays were much shorter than those of the other fossil taxa, particularly on the anterior fin surface. Second, for all taxa the anterior fin rays are more robust than the posterior fin rays. Both of these characters are associated with the use of the pectoral fins for substrate contact in living benthic fishes. Third, evidence from multiple specimens suggests that the fin rays of *Tiktaalik* exhibit a uniquely asymmetrical distribution on the dorsal and ventral fin surfaces. Dorsally, the lepidotrichia extend proximally to the distal edge of the ulnare in all three fossil taxa examined. In *Tiktaalik*, the lepidotrichia are restricted to the distal edges of the fin ventrally. We hypothesize that this reduction of lepidotrichia resulted in a fleshy, flexible ventral lobe that could conform to a complex substrate. In addition, data on the pectoral fin musculature from the extant *Neoceratodus* provides new data on how the overlapping dermal and endochondral skeletons are integrated as a functional unit in sarcopterygian fishes.

P2.119 TAMONE, SL*; KELLER, E; LINDEROTH, T; University of Alaska Southeast; *sltamone@uas.alaska.edu*

The effect of eyestalk neurohormones on circulating glucose and trehalose in two species of oregonid crabs

Crustaceans rely on carbohydrates for both aerobic and anaerobic metabolism; the primary carbohydrate of importance circulating in the hemolymph is glucose. Glucose is regulated by crustacean hyperglycemic hormone (CHH); a neuropeptide synthesized and secreted from the X-organ sinus gland within the eyestalk. Glucose is stored in arthropod hepatopancreas in the form of glycogen and CHH acts through receptors to stimulate glycogenolysis. In prior studies we determined that glucose circulated at extremely low concentrations when compared to concentrations in vertebrates and other crab species. Another carbohydrate found in arthropods (most notably insects) that serves a metabolic role as well as a cryoprotective role is the disaccharide, trehalose. We measured circulating glucose and trehalose in two species of intact or eyestalk ablated oregonid crabs; Pacific lyre crab (*Hyas lyratus*) and Tanner crab (*Chionoecetes bairdi*). Trehalose circulated at significantly higher concentrations in both crab species (186.2 ± 22 and 139 ± 42 µg/ml) in *C. bairdi* and *H. lyratus* respectively when compared to glucose (49.7±22 and 15±10 µg/ml) in *C. bairdi* and *H. lyratus* respectively. Eyestalk ablation resulted in significantly lower concentrations of both glucose and trehalose after seven days in *C. bairdi* and this inhibitory effect was eliminated with post ablation injections of CHH containing eyestalk extracts. In *H. lyratus*, eyestalk ablation resulted in significantly reduced concentrations of trehalose but had no effect on circulating glucose. Injection of eyestalk extracts significantly increased both glucose and trehalose in *H. lyratus*. This study is aimed at investigating alternative carbohydrates of importance in cold water crustaceans and their potential regulation by eyestalk neuropeptides.

P1.12 TARASKA, NG*; BOETTGER, SA; West Chester University of Pennsylvania; *nt648886@wcupa.edu*

Initiation of hemic neoplasia in the soft-shell clam Mya arenaria – Evidence of Viral Disease Etiology?

Hemic neoplasia, a diffuse tumor of the hemolymph system, is one of the six most destructive diseases among bivalve mollusks populations, characterized by the development of abnormal, rounded blood cells that actively proliferate and become immortalized. Though the specific etiology of hemic neoplasia in *Mya arenaria* remains undetermined, the involvement of viral pathogens and/or environmental pollutants has been suggested and considered. In this study we are using 5-bromodeoxyuridine (BrDU) known to induce a murine leukemia virus and injection of filtered neoplastic hemolymph in order to initiate hemic neoplasia. *Mya arenaria* from three locations of different neoplasia occurrences were divided into control and experimental treatments injected with 200µl of sterile filtered seawater, 50µg/ml, 100µg/ml or 200µg/ml BrDU respectively. Animals from different size classes were also injected with 2.5% total blood volume of 0.2micron filtered blood from a fully neoplastic animal. Animals were biopsied weekly and development of neoplastic cells counted and recorded on a scale of 1-4 (4 = terminal stage of the disease). These experiments further indicate that neoplasia development in controlled environments is due to viral disease induction in controlled environments, though no viruses have been identified in this study.

P1.3 TAYLOR, Z. J.*; MILLIKEN, G. W.; College of Charleston; *zjtaylor@g.cofc.edu*

Comparison of Startle Response in Two Ambystomid Species

The ability of sensory systems to detect disturbances in the surrounding environment and select an appropriate startle response determines an animal's ability to avoid predation. During the aquatic stage, salamander larvae are particularly vulnerable due to their small size. We tracked developmental changes associated with the startle response in *A. tigrinum* and *A. maculatum*, across the larval lifespan from the early to the late aquatic stage. To evaluate the startle response, larvae were placed into cups on a tray and were subjected to a brief vibrotactile stimulus. Responses were recorded and responsiveness was evaluated using z-scores and described in terms of locomotion. We found that despite being partly sympatric and of a similar ecological niche, the two species have different predator avoidance strategies. In the legless early aquatic stage (10 days post hatching), *A. tigrinum* exhibited the startle response while *A. maculatum* remained immobile. Animals that exhibited a statistically significant response also showed significant locomotion of at least one full body length in distance. In the quadrupedal late aquatic stage (23 days post hatching), *A. tigrinum* continued to exhibit strong startle responses with locomotion while more A. maculatum showed responsiveness to the stimulus. The observed differences in respective escape responses are examples of species typical behaviors present early in development and remain throughout the later part of the aquatic stage although *A. maculatum* begin to show a startle response in the later aquatic stage. Species differences in startle response could be attributed to morphological, ecological and ontogenic differences. *A. tigrinum* is a larger, predatory animal while *A. maculatum* is a smaller prey animal that exhibits comparatively rapid development to the terrestrial stage. Supported by HHMI.

P1.203 TAYLOR, Gordon*; WILSON, Alichia; HAUKENES, Alf; Univ. of Arkansas at Pine Bluff; *gtaylor@uaex.edu*

Evaluation of Thermally Induced Cross-Protection in Channel Catfish

Heat stress initiates a suite of cellular responses across a wide range of plant and animal phyla. These responses can lead to increased resistance to subsequent stressors (e.g. heat, salinity); this latter phenomenon is often referred to as cross-protection. We applied a heat stress treatment to groups of channel catfish fingerlings (32, 34, or 36°C for 1, 5, or 10 min). Upper critical temperatures (UCT) were determined for these animals 24, 48, and 96h after heat treatments. Fish exposed to 34 or 36°C had significantly greater UCT than non-treated controls and the increased UCT was observed for 96 h following heat hardening for animals receiving the 36°C treatments. To evaluate cross protection we exposed animals to 36°C for one minute and 24, 48, or 96 h later groups of animals were immersed in a 35 ppt NaCl solution. Mean time to death for heat treated and control animals were compared. Fish pre-treated with a thermal stressor had significantly higher mean time to death than controls at both 48 and 96h after heat treatment. In a similar experiment, fish were hardened and exposed to high pH (10.9) 24, 48 or 96h after heat treatment. At 96h post hardening, mean time to death during the pH challenge was significantly greater in heat treated animals than control fish. These results provide evidence of heat hardening and cross protection in channel catfish. The utility and mechanisms of this response continue to be investigated in order to determine if inducing the heat shock response before events like transport and stocking can ameliorate some of the negative manifestations of stress that are attributed to these events.

P3.69 TENLEN, J.R.*; GOLDSTEIN, B.; Univ. of North Carolina, Chapel Hill; *tenlen@live.unc.edu*
Disrupting gene function in tardigrades by RNA interference
How morphological diversity arises is a key question in evolutionary developmental biology. As a long-term approach to address this question, we are developing a close relative of both *Drosophila* (Phylum Arthropoda) and *C. elegans* (Phylum Nematoda), the water bear *Hypsibius dujardini* (Phylum Tardigrada), as a model system. We expect that using a close relative of two well-studied model systems will facilitate identifying genes relevant to understanding the evolution of development. Methods for disrupting gene activity are essential to this effort. No such method yet exists in Phylum Tardigrada. Here, we report that tardigrade gene function can be disrupted by RNA interference (RNAi). From *H. dujardini* ESTs present in GenBank, we identified and amplified putative homologs of several genes encoding proteins known to affect development in other organisms. We adapted protocols used in C. elegans for RNAi by microinjection of dsRNA, using a chamber we developed to hold anaesthetized animals during injection. Significant embryonic lethality was observed in progeny of *H. dujardini* adult females injected with dsRNA targeting genes encoding actin, Mago nashi, myosin or a 14-3-3 protein. Each experiment resulted in distinct terminal embryonic phenotypes that were consistent with predicted functions, suggesting that RNAi was gene-specific. Conversely, progeny of females injected with water or with dsRNA targeting green fluorescent protein developed normally. Experiments are in progress to determine the degree to which RNAi depletes target mRNAs. These studies present the first evidence that gene function can be disrupted by RNAi in Phylum Tardigrada, providing a method to dissect developmental gene functions in an organism that may sit at a key position in animal evolution for evo-devo studies.

P1.76 TESSMER, D*; TAYLOR, KR; NISHIKAWA, KC; Coconino Institute of Technology, Northern Arizona University; *dtessmer@fusd1.org*
The Experience of Research From a High School Teacher's Perspective
To create a bridge between high school education and the world of research, it is critical to provide opportunities for high school teachers to experience authentic university research. Through these rewarding experiences, teachers, such as myself, become less intimidated, more informed, and eager to expose their students to this important career. Having the opportunity to join Dr. Nishikawa and her research laboratory for the summer through a generous NSF grant, I will share my insights, failures, frustrations and successes as a chemistry and physics teacher within a biological laboratory. Based on this exposure, I challenged my students to begin their own authentic research using an inquiry approach and simple technological tools such as the Arduino platform. I will present my students' experiences with their initial attempts and results at collecting data and how this influenced their ideas about research.

P2.110A THAPA, Gita*; VERWORN, Natalie; GREENLEE, Kendra; North Dakota State University; *gita.thapa@ndsu.edu*
Developmental attenuation of high-fat diet-induced mortality in the tobacco hornworm caterpillar, Manduca sexta
Availability of dietary protein may limit insect growth, and they respond to variable protein by altering behavior and physiology. Insects fed high carbohydrate diets have increased fat storage, and excess fat storage in insects may have a fitness cost. Do high lipid diets also result in adverse consequences in insects? Young Manduca sexta larvae reared on 5.6% fat diet had 80% mortality and 43% lower body mass compared to those reared on 3.4% fat or 0.4% fat diets. Older larvae showed no differences in mortality or body mass. Growth rates and development time differed slightly, as high fat fed caterpillars wandered later than those fed low and medium fat diets. To test the hypothesis that the increased survival of older larvae was due to increased lipid transport, we measured mRNA expression of Apolipoprotein I and II (APO1 and 2), proteins responsible for transporting lipids to the fat body and to various tissues. APO1 and 2 expression did not differ with dietary fat content. Interestingly, caterpillars fed a high fat diet during the first two days of the 5th instar ate less than others, possibly accounting for their slower development. When 5th instar larvae were given a choice between high fat and low fat diets, there was no difference in their preference. Preliminary analyses of fat body and fecal pellet lipid content showed no differences with diet, suggesting that the ability to digest and store the ingested lipid is similar among groups. To test the hypothesis that caterpillars are preferentially metabolizing fat during the 5th instar, we will measure the respiratory quotient of caterpillars on various diets. Although it is clear that 5th instar larvae are better able to tolerate dietary lipid, the mechanism remains unknown.

P3.111 TIMM, L*; GRUNBAUM, D; Texas A&M University, Galveston, University of Washington, Seattle; *ltimm@neo.tamu.edu*
Effects of blastocoel geometry and density on swimming ability in early-stage larvae
Planktonic larval phases are seen across marine taxa. Recent evidence suggests that early development of swimming capabilities may play a crucial role in larval survival. As marine environments vary most rapidly in the vertical direction, vertical swimming is likely to be an important performance criterion for early-stage larvae. However, vertical swimming requires an effective mechanism for larval orientation. The relatively simple external morphology of most early-stage larvae, and their lack of internal sensory structures, suggest that these larvae orient primarily through a passive gravitational mechanism, i.e., by having a center of buoyancy anterior to their center of gravity. This mechanism may depend strongly on a morphological feature seen in many early-stage larvae: an anterior blastocoel. We hypothesize that larvae are able to manipulate their blastocoel density by preferentially transporting ions in or out, and that the blastocoel plays a crucial role in oriented swimming. This hypothesis implies that altered environmental conditions would require compensating changes in blastocoel characteristics to maintain swimming. For example, in fresher water the blastocoel may be enlarged to maintain larval buoyancy. To test the effects of salinity on early-stage larval blastocoels, we reared *Dendraster excentricus* larvae at higher and lower salinities and measured their blastocoels at three pre-pluteus stages. We used observed morphologies to parameterize hydrodynamic models of early swimming across a range of blastocoel densities. Larval blastocoel size differed significantly between treatments, with larger blastocoels developing in lower salinity. Model results suggest that blastocoel geometry and density have important consequences for swimming performance rates, possibly indicating new biomechanical constraints on early-stage larvae across a broad range of marine taxa.

P3.29 TOBIAS, M.S.*; CONNELLY, S.J.; Rochester Institute of Technology; *mst9615@rit.edu*

Interaction of nutrition and UV radiation on Daphnia

In nearly all of Earth's ecosystems, organisms are being forced to develop mechanisms that will increase their fitness (survival and reproduction) in response to global climate change. Studies of the physiological and behavioral responses of freshwater organisms to temperature and solar ultraviolet (UV) radiation are highly variable (species, conditions, extremes of stressors, etc). It is well known that UV can induce significant stress in some organisms, including direct DNA damage, reduced reproduction rates, and death. Organisms in freshwater systems such as lakes and ponds are faced with high levels of UV exposures due to the clear water, thus must develop mechanisms to cope with the stressors. It has been known that food quality and quantity impact the fitness of many organisms, including freshwater species. The fitness response to acute UV-A exposure was studied in model freshwater cladocerans. *Daphnia pulicaria*, *D. lumholtzi*, and *D. dentifera* were raised on different algal food sources (*Selenastrum capricornutum* and *Scenedesmus sp.*) and exposed to acute UV-A (320 – 400nm; 1000 uW cm-2). Some daphniids, including *Ceriodaphnia dubia*, had increased levels of survival and reproduction with increasing UV-A radiation if reared on specific food combinations. While others, including *D. dentifera*, were negatively effected by the variable food sources, compounding their sensitivity to UV-A. Analysis of food sources may provide a better understanding of how organisms can cope with environmental stressors (improved nutrition), despite the rapid changes that can occur in their habitats. These findings can be extended to other populations and should be taken in to consideration for climate change models.

P2.143 TOKAR, DR*; VELETA, K; CANZANO, J; HAHN, DA; HATLE, JD; Univ. of North Florida, Univ. of Florida; *jhatle@unf.edu*

Physiological effects of RNAi for vitellogenin on somatic storage and reproduction in grasshoppers

Trade-offs between reproduction and storage are widespread in animals, but the physiological basis of these trade-offs is known in only a few cases. To understand how organismal storage responds to the investment of protein resources in reproduction, we investigated the physiological responses to direct reduction of vitellogenin. In the grasshopper *Romalea microptera*, vitellogenin is a precursor protein to vitellin. Eggs are ~50% lipid and ~50% protein, of which ~90% is vitellin. We used RNAinterference (RNAi) to reduce vitellogenin transcript abundance. We compared vitellogenin RNAi treatments to two control groups, buffer-injected individuals, and individuals treated with RNAi against a 90 kDa hexameric storage protein from the hemolymph. Individuals were injected with dsRNA 5 days after adult ecdysis. Dissections were performed at ages 12, 19, 26, and 33 days. Ovarian mass and oocyte length were significantly decreased in the vitellogenin knockdown group ($P=0.0152$ and $P<0.0001$, respectively); in contrast, they were not changed in the buffer or 90 kDa hexamerin RNAi groups. Early results suggest that mRNA levels of vitellogenin and 90 kDa hexamerin were reduced substantially by their respective RNAi treatments. Fat body mass was significantly increased ($P<0.0001$) in the vitellogenin knockdown group. This suggests that knockdown of reproductive protein may result in greater storage of somatic lipids. This preliminary conclusion will be further tested by measures of fat body composition and hemolymph protein levels in response to RNAi treatment. Funding provided by NIH 2R15AG028512-02A1 to JDH.

P1.190 TRACY, Chris/T; TODD, Jennifer*; WAKELING, Stephanie; PIRTLE, Elia; TRACY, C/Richard; University of Melbourne, University of Nevada Reno; *dtracy@unr.edu*

Predicting extinction due to global climate change

Recent literature has included multifarious publications estimating the vulnerability of species to extirpation or extinction due to environmental change caused by global warming. Predictions of extinction risk are generally estimated from what is known about life histories, physiology, and trends in climate change. However, there is a dearth of information about how species can avoid extinction in the face of environmental change. How can populations avoid extirpation? (1) Individuals in the population could move to a new location where climate change is mitigated (e.g., higher elevations). (2) Individuals could change their activity to times (daily or seasonally) during which times the effects of climate change are mitigated. (3) Individuals might have seasonally adjustable physiologies allowing individuals to function well in newly extreme environments; thus, the magnitude of climate change might be small relative to the physiological flexibility of individuals. (4) Individuals could evolve to become well suited to new environmental conditions under climate change. Thus, moving, adjusting physiology or behavior, or evolving in the face of climate change could annul the effects of climate change in ways that reduce a population's vulnerability to extinction. It would seem, then, that reliable predictions of extinction risk require scientific testing of the extent to which populations can avoid extinction, and each of the mechanisms listed above should serve as requisite, testable hypotheses before credible predictions of extinction can be made.

P2.180 TREIDEL, L.A.*; WHITLEY, B.N.; BENOWITZ-FREDERICKS, Z.M.; HAUSSMANN, M.F.; Bucknell Univ., Lewisburg; *lat019@bucknell.edu*

Prenatal exposure to testosterone mitigates the stress-induced rise in oxidative stress in domestic chickens (Gallus gallus)

Elevated levels of maternally deposited androgens in avian eggs impact several offspring traits, such as begging behavior, metabolic rate, and growth during early development. Prenatal androgens also influence oxidative stress. Current studies, however, disagree whether their impact is beneficial or costly, with some reporting increased oxidative stress resistance and others reporting increased levels of oxidative damage. Previous work in our lab has shown that during an acute stress response, birds' shift into a state of oxidative stress with increased oxidative damage and decreased antioxidant defense. Here, we tested how prenatal testosterone exposure would impact the stress-induced rise in oxidative stress in female domestic chickens (*Gallus gallus*). Prior to incubation, eggs were either injected with an oil vehicle (n=10) or testosterone (5ng, n=10). At either 18 or 19 days post hatch, all birds were subjected to an acute stress series and blood samples were taken at <3, 20, and 45 min. Baseline oxidative damage to erythrocyte DNA, vulnerability of DNA to a hydrogen-peroxide challenge, and DNA repair capabilities following the challenge were assessed for all blood samples using the single cell gel electrophoresis assay. We found that regardless of yolk treatment, after the first 20 min of the stress response all birds had increased levels of DNA damage, but control birds experienced more DNA damage than testosterone birds. Our work suggests that while yolk androgens can increase metabolic rate, which is known to elevate oxidative stress, prenatal testosterone exposure can also protect against oxidative stress by mitigating stress-induced oxidative damage to DNA.

P3.76 TREVINO, Michael; STEFANIK, Derek; HARMON, Shane; BURTON, Patrick*; Wabash College, Boston University; *burtonp@wabash.edu*

Wnt signaling promotes oral fates during regeneration and embryogenesis in the cnidarian Nematostella vectensis

Although all metazoans display axial polarity during development, the evolutionary origins of the mechanisms underlying this polarity remain poorly understood. Recent work has identified a conserved role for the canonical Wnt signaling pathway in patterning of the primary axis across a wide variety of taxa. Much of the data now available from non-triploblastic animals originates from study of non-embryonic modes of development, yet the relationship among embryonic and adult (e.g. regeneration) developmental modes is unclear. Using beta-catenin as a marker, we investigated the role of the Wnt signaling pathway during both regeneration and embryogenesis in the cnidarian Nematostella vectensis. Induction of Wnt signaling with alsterpaullone results in ectopic oral tissue development during both regeneration and embryogenesis. The specificity of these effects is demonstrated by upregulation of beta-catenin, as measured by qRTPCR. Our data indicate that canonical Wnt signaling is responsible for oral patterning across Nematostella developmental modes. When interpreted in the context of data from other cnidarians, these results suggest that the Wnt/beta-catenin pathway may have been involved in patterning the primary body axis of the anthozoan-medusozoan common ancestor, and that this signaling module has been recruited to pattern the oral-aboral axis in multiple developmental contexts within Cnidaria. Our data also contribute to a growing body of literature indicating a conserved role for patterning mechanisms across the various developmental modes of metazoans.

P2.133 TRIBLEHORN, Jeffrey D*; PAOLINI, Marissa L; YAGER, David D; FREDERICK-HUDSON, Katy H; College of Charleston, University of Maryland, College Park, University of Missouri, Columbia; *triblehornj@cofc.edu*

Comparative study of large axons in the abdominal connectives of mantids (Mantodea) and cockroaches (Blattodea)

Insect nervous systems lack myelinated axons and must increase axon diameter for faster action potential propagation. In abdominal connectives, large diameter axons are typically associated with the wind-sensitive cercal system that mediates escape and flight behaviors. These large axons carry information from the rear of the animal to the thoracic motor centers. Since not all insects fly or exhibit escape responses, large diameter axons likely vary based on these behaviors across species. We compared: 1) the nine largest axons in the abdominal connectives in five cockroach species and twenty mantis species; 2) the four largest axons in the dorsal and ventral intermediate tracts (DIT and VIT) due to their behavioral relevance: the VIT initiates escape responses while the DIT mediates continued escape running and flight maintenance and 3) morphological characters related to the cercal system. Initial results suggest cockroaches that exhibit escape responses possess similar, potentially adaptive, characteristics that are not present in non-escaping cockroach species. In mantids, sexual dimorphism in flight is reflected in the DIT. In *Parasphendale affinis*, DIT neurons occupy more connective space in flying males than in non-flying females, but the DIT dimorphism does not exist in *Hierodula grandis* where both sexes fly. Our data set includes several morphological and neural characteristics that can be mapped onto existing cockroach and mantis phylogenies to trace the evolutionary development of large diameter axons in these groups. Funding: NIH National Center for Research Resources Grant P20 RR-016461 and HHMI.

P3.129 TSUNEKAGE, T*; RICKLEFS, RE; Univ. of Missouri, St. Louis; *ttsunekage@umsl.edu*

A Comparative Study of Oxidative Damage In Avian Embryos

The length of avian embryonic development period varies greatly across species. There is evidence that the rate of embryonic development may be linked to the rate of aging and maximum lifespan. Faster development may lead to increased accumulation of cellular damage and damage early in life may have more profound effects on longevity than damage that occurs later in life. Embryonic samples of five different species with incubation periods ranging from 14 to 42 day were collected. We investigated differences in embryonic oxidative damage to and repair of DNA using single cell gel electrophoresis on red blood. We aim to advance the understanding mechanisms that may underlie the relationship of embryonic development period and longevity.

P3.120 TUBERVILLE, T.D.; University of Georgia's Savannah River Ecology Lab; *tracey.tuberville@gmail.com*

Maternal and paternal contributions to growth in hatchling turtles

Hatching size and subsequent growth rates can have important implications for offspring fitness, including survival to reproductive maturity and size and age at maturity. In turtles, maternal effects on both hatching size and growth rates have been documented. However, significant variation in these traits is frequently observed among individuals from a single clutch, suggesting that paternal identity can also influence fitness-related traits in offspring. This study examined the maternal and paternal effects on size and growth rates of hatchling gopher tortoises *Gopherus polyphemus*, a species in which females can store sperm between breeding events and produce multiply-sired clutches. We collected a total of 15 clutches from two translocated populations in which all potential breeders had been catalogued and genotyped at five highly polymorphic microsatellite markers. The resulting 64 offspring were reared under standardized captive conditions for 8 months, genotyped, and measured at hatching and just prior to release. After assigning parentage to each offspring, we tested for maternal, paternal and family effects on offspring size at hatching, first year growth rates, and size at release. We will place our findings in the context of similar work with other taxonomic groups.

P3.80 TULIN, S*; SMITH, J ; Marine Biological Laboratory; *stulin@mbl.edu*

Transcriptome Analysis of Embryogenesis in Nematostella vectensis

Gene Regulatory Networks are a powerful tool to elucidate the important regulatory events of embryogenesis. We are studying the embryonic Gene Regulatory Network for the cnidarian, *Nematostella vectensis*, because its pivotal position in the tree of life as the outgroup to Bilaterians will allow us, by comparing regulatory network architecture, to address key outstanding questions about the evolution of body axis specification. In order to build a complete embryonic network it is necessary to begin with a full transcriptome analysis with multiple time points during the first 24 hours of development. We have used Next-Generation sequencing on the Illumina HiSeq 1000 with strand-specific RNA-seq library construction in order to reach saturation coverage of all embryonic transcripts. The transcriptomes will be used to bolster the *Nematostella* reference genome in cooperation with other *Nematostella* labs, and taken further into the network construction pipeline. Parallel efforts are focused on developing advanced, high-throughput network prediction techniques such as High Density RNA-Seq and Perturbation-Seq.

P3.123 TUN, K.M. *; PEIRIS, F.C; CARLTON, E.D.; MATSON, K.D.; MAUCK, R.A.; Department of Biology, Kenyon College, Gambier, Ohio 43022, Department of Physics, Kenyon College, Gambier, Ohio 43022, Indiana University, Bloomington, Animal Ecology Group, Center for Ecological and Evolutionary Studies, University of Groningen, P.O. Box 14 9750 AA Haren, The Netherlands; *tunk@kenyon.edu*

Finding the blue in bluebirds: what does full-spectrum data tell you about individual quality that a camera cannot?

Energetically costly traits are thought to display honest signals of individual quality because only high quality individuals can afford and maintain these traits. Plumage color in birds has often been interpreted in this way. While many studies have measured plumage color in the visible spectrum using relatively inexpensive photographic techniques, fewer have measured plumage color in the full spectrum due to the cost of such measurements. Previously, we have shown that visible-light plumage coloration is an honest signal of individual quality in the in Eastern Bluebird (*Sialia sialis*). In this study, we measured full spectrum reflectance of rectrices from bluebirds included in the previous study and compared these full spectrum data with the previously collected visible-light-only data. Here we report on 1) the correlation between visible and full spectrum data for these feathers and 2) the utility of both visible and full spectrum data for analysis of individual quality in this species.

P2.79 TWEETEN, Kay A*; ABITZ, Allison; St. Catherine University; *katweeten@stkate.edu*

Patterns of Cleavage and Gastrulation in Embryos of Freshwater Oligochaetes from the Lumbriculus Complex

Reports of sexually reproducing forms of *Lumbriculus variegatus* and other oligochaetes from the *Lumbriculus* complex have been so limited that architomy is thought to be the major reproductive process in these annelids. As we have collected *Lumbriculus* from sloughs and lakes in Minnesota, Iowa, Wisconsin, and Montana, we have found an abundance of specimens that were sexually reproducing. Morphology of sperm from worms collected at Gull Point State Park in Iowa and from Crystal Lake in Minnesota was studied. Sperm were filiform with total lengths of 99 and 95 microns for the MN and Iowa specimens, respectively. DAPI and MitoTracker Green FM staining showed that sperm mitochondria were localized posterior to an elongated nucleus that occupied most of the 35 micron long head region. Patterns of cleavage and gastrulation were determined by microscopy of fixed embryos that were stained with DAPI and nile red. Similar patterns of development were observed in embryos from cocoons produced by MN and Iowa specimens of *Lumbriculus*. Cleavage was holoblastic and resulted initially in two cells of unequal size. The second cleavage gave rise to one large cell and three smaller cells of similar size. During the third cleavage, micromeres were generated asynchronously in a spiral pattern. In subsequent cleavages, extensive and rapid division of the micromeres occurred, while cleavage of the macromeres was slower and limited to a few divisions. The mechanism of gastrulation was primarily epiboly with an expanding sheet of micromeres eventually encompassing the macromeres. Expression of beta-catenin in developing embryos was determined by immunofluorescent staining. Our observations suggested that specification of cell fate occurs very early in embryonic development in *Lumbriculus* species.

P1.91 UNDERWOOD, E.B.*; KOHNO, S.; RAINWATER, T.R.; BOGGS, A.S.P; DOHENY, B.; MCCOY, J.; GUILLETTE, L.J.; College of Charleston, Charleston, Hollings Marine Laboratory, Charleston; MUSC, Charleston, Hollings Marine Laboratory, Charleston, MUSC, Charleston, MUSC, Charleston; Hollings Marine Laboratory, Charleston; *elunderwood@davidson.edu*

Using sexually dimorphic gene expression in scutes as a marker of sex in the American alligator

The increasing levels of environmental contaminants are cause for concern as they have deleterious,irreversible impacts on ecosystems around the globe. One group of contaminants, endocrine disrupting chemicals(EDCs),are important as they can affect an organism's reproduction and development. In species that undergo temperature dependent sex determination,such as the American alligator,EDCs can cause sex reversal during development. This change in sex determination could potentially skew sex ratios within a population,consequently impacting the entire ecosystem. Thus,it is important to be able to monitor sex ratios in American alligator populations in a non invasive or minimally invasive way. Currently,no way exists to determine the sex of hatchlings. This study explores cadidate genes expressed in a sexually dimorphic pattern in scute samples taken from adult alligators from the Yawkey Wildlife Preserve,Georgetown,SC. RNA was isolated from 24 different scute samples (12 males and 12 females). Quantitative RT-PCR was conducted using 5 candidate genes (ESR1,ESR2,AR,CYP19,and StAR) to quantify mRNA expression. We detected all 5 mRNAs in the alligator scutes,however no single gene was expressed in a sexually dimorphic pattern. These results indicate that the scute could have a steroidogenic function and receive sex steroid signals. Moreover,our data suggest this tissue could also be disrupted by EDCs.

P3.61 UYENO, T.A.*; GILLES, B.; LEE, D.V.; BARBANO, D.L.; WILKINSON, K.C.; PAI, D.K.; GISZTER, S.F.; NISHIKAWA, K.C.; Valdosta State Univ., INRIA, Montpellier, FR, Univ. of Nevada - Las Vegas, N. Arizona Univ., Univ. of British Columbia, Drexel Univ.; *tauyeno@valdosta.edu*

Towards the automatic animation of a virtual 3D Bullfrog skeleton

We are building an accurate computer model of the bullfrog musculoskeletal system in order to develop a quantitative understanding of motor control during feeding lunges, a voluntary movement that is controlled by relatively few spinal motor primitives. We have developed individual-specific, virtual skeleton models using high-resolution micro-CT imaging data (1024x1024x2222 slices, 45x45x45 µm resolution). The bones were automatically segmented by comparing them to a low-resolution, articulated, template model. Prior to euthanizing, fixing, and scanning the bones of each frog, we recorded X-ray video of six feeding lunges. To make these recordings, six frogs had up to 16 capsule-shaped, silver markers (2-5 mm x 0.81 mm diameter) implanted between the periosteum and the surface of cranial, limb, and axial bones. The frogs were allowed to recover from this surgery for at least two weeks so that the markers would be encapsulated within the fibrous sheath and immobile relative to the underlying bone. Markered frogs were trained to perform a feeding lunge within a biplanar, high speed X-ray system. We recovered kinematic data using XROMM software (XROMM.org, Brown University) and used both the bone shadows and the single markers on select bones to dynamically register the movements to our virtual skeleton. This was done using an adaptive algorithm that located each bone model via surface registration for each frame taken during the feeding lunge. These visualizations will be used to test the hypothesis that voluntary feeding movements are controlled by the same set of spinal motor primitives that have been identified during wiping and other movements in decerebrated frogs. Supported by IIS-0827688.

P2.57 VALLEY, J. R.; MARTIN, V.J.*; Appalachian State University; *martinvj@appstate.edu*

Eye Development in Box Jellyfish

The complex eyes of the cubozoan jellyfish *Carybdea marsupialis* exhibit many similarities to the camera-type eyes of higher metazoans including the presence of a cornea, lens and retina of ciliated photoreceptors. During the transformation of the polyp to the eye-bearing medusa, the development and arrangement of several components were followed including the neuropeptide FMRFamide, UV opsin-like protein (indicates photoreceptor formation), J1-crystallin (indicates lens formation) and shielding pigment formation. In following the 14-day transformative process, 8 morphological stages were identified. Starting with a steady-state polyp, the main features of transformation include recession of polyp tentacles, change of symmetry from radial to tetraradial, eye development, emergence of medusa tentacles, and detachment. The first ocelli to appear are the complex eyes followed by the simple ocelli; the small complex eye is the first to exhibit pigment formation (melanin) as well as photoreceptor formation. J1-crystallin was located in the developing lenses/lens-like material in the complex eyes and slit ocelli and also exhibited extracellular extraocular staining. Crystallin staining was present in all six ocelli in adult rhopalia. Extensive neurological rearrangement and development takes place during the transformation. Developmental mechanisms in eye formation similar to both vertebrates and invertebrates were seen including the formation of an ocular placode, formation of an invaginated optic cup, synthesis of a crystallin lens in the optic cup, differentiation of the retina (resulting in multiple photoreceptor populations exhibiting opsin and melanin synthesis) and formation of neuropeptide-producing rhopalial nerves in close vicinity with the eyes/ocelli.

P1.214 VARGAS, F; CARRILLO, A; HULSE, K; HOCKERSMITH, B; DICKSON, K*; California State Univ., Fullerton; *kdickson@fullerton.edu*

Effects of Variable Environmental Temperatures on Hatching Success and Larval Length and Yolk Area in the California grunion, Leuresthes tenuis

California grunion spawn on sandy beaches during spring high tides in March–August. Fertilized eggs incubate in the sand until they are washed out by waves, the trigger for hatching, 10-14 days post-fertilization (dpf). If not washed out, embryos can extend incubation in the sand until a subsequent spring high tide. This study tested the hypotheses that, compared with constant temperature, incubation at the variable temperatures that occur in the sand where grunion eggs are laid results in reduced hatching success and less yolk, but does not affect mean larval length at hatching. Environmental sand temperatures were recorded at Cabrillo Beach, Los Angeles, CA, every 10 min during the 2011 spawning season. Gametes stripped from male and female grunion collected on Cabrillo Beach were mixed in filtered sea water. Three replicate containers of fertilized eggs were placed into each of three environmental chambers, one set at a constant 20&degC, one in which temperature changed hourly to match the mean sand temperatures recorded in April 2011 (range of 11.7-20.0&degC), and one set at 16.3&degC, the average of the variable temperatures. Embryos from 20&degC first hatched at 8 dpf, and at 14 dpf for the 16.3&degC and variable groups. Hatching success was >80% after 10 dpf for 20&degC, but averaged only 32% at 16.3&degC and 35% at variable temperatures. At hatching, larval length did not differ among groups. Larval yolk area and its rate of decrease with dpf did not differ between the 16.3&degC and variable-temperature groups. Thus, fluctuations in temperature had little effect on grunion embryos when compared with the average temperature, but there were expected differences between 16.3 and 20&degC. (funded by NSF-URM)

P1.137 VAUGHN, R.*; GARNHART, N.; THOMAS, W.K.; GAREY, J.R.; LIVINGSTON, B.T.; Univ. of South Florida, Univ. of New Hampshire, California State Univ., Long Beach; *revaughn@mail.usf.edu*

Sequencing and analysis of the gastrula transcriptome of the brittle star Ophiocoma wendtii

The gastrula stage represents the point in development at which the three primary germ layers diverge. At this point the gene regulatory networks that specify the germ layers are established and the genes that define the differentiated states of the tissues have begun to be activated. These networks have been well characterized in sea urchins, but not in other echinoderms. We have sequenced and characterized the gastrula transcriptome of the brittle star *Ophiocoma wendtii*. The transcriptome is composed of 99,285 sequences of which some 12,530 can be identified when compared to existing databases. When compared to the sea urchin *Strongylocentrotus purpuratus* UniGene set there are 6931 genes that are shared with those expressed in the *O. wendtii* gastrula transcriptome. We have characterized the functional classes of genes present in the transcriptome and compared them to those found in sea urchin. We then examined which members of the germ layer specific gene regulatory networks of *S. purpuratus* are expressed in the *O. wendtii* gastrula. The brittle star expresses genes representing all functional classes at the gastrula stage. Brittle stars and sea urchins have comparable numbers of each class of genes, and share many of the genes expressed at gastrula. Examination of the genes that are utilized in sea urchin germ layer specification in the brittle star reveals the conservation of key regulatory components as well as genes that were either lost or co-opted in the two groups.

P1.159 VELTEN, B P*; MCLELLAN, W A; PABST, D A; Univ. of North Carolina, Wilmington; *bpv7747@uncw.edu*
A comparative study of the locomotor muscle of extreme deep-diving cetaceans
Deep-diving marine mammals exhibit adaptations to increase their oxygen storage capabilities and prolong aerobic metabolism during a dive. These adaptations include high levels of myoglobin and low mitochondrial volume densities (MVD) within locomotor muscles. Most studies to date have examined the muscle physiology of deep-diving pinnipeds, with few studies focusing on cetaceans. Recent tagging data demonstrate that short-finned pilot whales (*Globicephala macrorhynchus*) are deep divers that can perform high-speed sprints deep within their dives (Soto et al., 2008). Beaked whales (e.g *Mesoplodon densirostris* and *Ziphius cavirostris*) are currently thought to perform, on average, the longest and deepest dives of any air-breathing vertebrate (50-60 min and 800-1000 m) (Tyack et al., 2006). We propose to examine the locomotor muscles of these extreme divers. Assays will be performed on an epaxial locomotor muscle (*m. longissimus*) collected from stranded animals (*G. macrorhynchus*, n=6; Ziphiids, n=6). Myoglobin concentration will be measured to determine the oxygen storage capability of the axial locomotor muscles. Muscle fiber profiles will be determined and used as an indicator of the metabolic pathways used to fuel muscle contraction. Using transmission electron microscopy, MVD will be measured as an indicator of the muscle's rate of oxygen consumption. Muscle buffering capacity will be measured to determine if these animals exhibit enhanced abilities to cope with an increased reliance on anaerobic metabolism during a dive. We hypothesize these species will exhibit adaptations to prolong their aerobic dive duration through high myoglobin concentrations and low MVD. However, the extreme nature of their dives may also require enhanced anaerobic capabilities and result in high muscle buffering capacities.

P2.13 VENDETTI, J. E. ; California State Univ., Los Angeles; *jannvendetti@yahoo.com*
A perspective on natural history collections after the Tōhoku earthquake and tsunami: buccinid gastropods and the EOL
The Museum of Sea and Shells in Rikuzen-Takata, Japan (Iwate Prefecture) housed the R. Tiba collection of Western North Pacific whelk (Gastropoda: Buccinidae) holotype specimens as well as dozens of buccinid paratypes and hundreds of other shelled mollusks and type specimens. In 2008, I visited this museum to photograph its buccinid gastropods as part of my dissertation research. On March 11, 2011 a powerful tsunami resulting from the Tōhoku earthquake off the coast of Honshu, Japan destroyed most of the Museum as well as much of the community of Rikuzen-Takata. Amazingly, some of the Museum's Tiba type collection, which was stored in locked cabinets, survived and was found among the rubble in the aftermath of the tsunami. These specimen cases were transferred to the Iwate Prefectural Museum to be cleaned, repaired, and eventually made available to malacologists. However, many type specimens from the Museum's collections were lost, as one would expect in a disaster of such proportions. Here I present the Encylopedia of Life (EOL: www.eol.org) as a valuable and convenient online resource for hosting holotype images of the Tiba collection as well as other institutional collections, type and non-type. The EOL allows digital images, videos, and text to be posted and quickly integrated into the site, creating species pages that may be updated in near-real time and located rapidly by search engines. EOL curators and contributors may also partner with scientific colleagues and interested amateurs to add vetted information on classification, distribution, references, and species descriptions. Not only does the EOL website offer substantive opportunities for scientific outreach, online type specimen information would remain available when actual collections are re-located, destroyed, or otherwise unavailable.

P2.134 VERDECIA, Mark*; BREHM, Paul; MANDEL, Gail; LOOGER, Loren; LAVIS, Luke; HHMI Janelia Farm Research Campus, Vollum Institute, OHSU; *verdecia@mac.com*
A genetically encoded fluorescent protein in echinoderms marks the history of neuronal activity
Since the original identification of GFP from jellyfish and corals, the genetically encoded fluorescent proteins have become mainstream indicators for imaging. Functionally homologous candidates exist in more highly evolved bioluminescent invertebrates, including echinoderms. For example, in brittlestars, stimulus-evoked bioluminescence is transient, lasting seconds, and emanates from specialized cells (photocytes). Prior to light emission, we observe little or no green fluorescence. However, concurrent with light emission, an intense green, calcium-dependent fluorescence develops that persists indefinitely.

P2.3 VICKERY, R.E.; HOLLOWELL, K; HUGHES, M*; College of Charleston, SC; *revicker@g.cofc.edu*
Why have long antennae? Exploring the function of antennal contact in snapping shrimp
Many organisms use antennae to gather information from the environment. Crustaceans uniquely have 2 sets of antennular organs, allowing for segregation of function: short antennules, used to perceive soluble chemical signals, and often much longer second antennae, primarily used for perception of contact chemical and/or tactile signals. While the roles of soluble chemical signals are known in many species, the role of direct antennal contact is poorly understood. Our objective was to determine the degree to which antennal contact behavior differs between social contexts, and between species with different antennal morphology. We staged competitive and pairing interactions in two species of socially monogamous, burrow-dwelling snapping shrimp, *Alpheus angulosus* and *A. heterochaelis*. *A. heterochaelis* performed more antennal contact overall than *A. angulosus*, and *A. heterochaelis* did not reduce antennal contact behavior in highly aggressive competitive interactions. These results suggest that antennal contact provides information not readily assessed by other means in *A. heterochaelis*, given the proportionally longer antennae in this species and the high risk of injury associated with antennal contact. Only *A. angulosus* females modified their antennal contact behavior according to context, performing more antennal contact in pairing than in competitions. In both species, pairing involves more antenna-to-antenna contact when the female has prior burrow residency, suggesting that antennal contact may play a role in female assessment of potential mates. Overall, we found differences in antennal behavior according to sex, species and context; this hitherto undocumented diversity in antennal behavior underscores the importance of considering direct antennal contact in studies of crustacean behavior and ecology.

P2.163 WACK, Corina L*; RATAY, Mary K.; WOODLEY, Sarah K.; Chowan University, Murfreesboro, NC, Duquesne University, Pittsburgh, PA; *wackc@chowan.edu*

Stress-induced behavioral changes are not mediated by corticosterone in red-legged salamanders

In most vertebrates, exposure to stressors can cause changes in physiology (i.e. immune function) and behavior (i.e. reproduction). These changes may be mediated by plasma glucocorticoids (GCs), which also increase when animals are exposed to stressors. To further understand stress effects on behavior, we tested the hypothesis that stress-induced changes in locomotor activity in the red-legged salamander (*Plethodon shermani*) are mediated by increase in plasma corticosterone (CORT), the primary GC of most vertebrates. We conducted three experiments. In the first experiment, salamanders were handled. Handling was designed to mimic capture by a predator and is a standard protocol for eliciting increased GCs. Forty-five minutes after the onset of handling, locomotor activity was recorded. In the second experiment, a non-invasive dermal patch containing CORT (2.5 ug) was administered and locomotor activity was assessed approximately two and 24 hours later. In the third experiment, two doses of CORT (0.63 and 2.5 ug) were administered via dermal patches to subjects, and locomotor activity was assessed 0.5 and 12 hours after patch removal. Although handling decreased locomotor activity, neither high nor low doses of corticosterone altered locomotor activity compared to controls at any time point. These data suggest that stress-induced changes in locomotor activity are not mediated by CORT.

P2.179 WALDRON-FRANCIS, Kaiden*; LATTIN, Christine R.; BREUNER, Creagh W.; ROMERO, L. Michael; Tufts University, University of Montana-Missoula; *kwaldronfrancis@gmail.com*

Characterization of intracellular glucocorticoid and mineralocorticoid receptors in skin of House Sparrows

Corsticosterone (CORT) is responsible for a range of biological functions, including helping to mediate the stress response. Effects of CORT are controlled by hormone receptors, and by studying these receptors, we can further understand CORT's role as a biological mediator. However, most investigations of receptors have focused on mammalian vertebrates and especially in neural tissue. Our knowledge of CORT receptors is lacking in other tissues from other taxa, especially avian peripheral tissues. Our study aimed to characterize levels of intracellular glucocorticoid (GR) and mineralocorticoid (MR) receptors in skin of wild House Sparrows (*Passer domesticus*) using radioligand binding assays. Competition assays were used to determine the displacement of [^{3}H]CORT by unlabelled CORT, mifepristone (RU-486), and aldosterone (ALDO). Both CORT and ALDO were able to fully displace [^{3}H]CORT, whereas RU-486 was not. We estimated dissociation constants (K_d) of MR and GR by saturation binding analysis. Skin cytosol exhibited a single-binding site with a K_d (~3.9 nM) similar to that previously reported for GR in House Sparrows. There appear to be minimal MR-like receptors in House Sparrow skin. The next steps following this preliminary characterization will include comparisons of receptor concentrations between individuals, as well as across different skin regions.

P1.165 WALKER, R.A.*; DORNHOFFER, T.M.; DEAROLF, J.L.; Hendrix College, Conway, AR ; *walkerra@hendrix.edu*

Do multiple doses of betamethasone increase the oxidative capacity of the fetal guinea pig scalenus muscle?

One dose of prenatal steroids has been shown to aide in the respiratory development of premature babies, without any significant detrimental side effects to either the infant or the mother. However, it is unclear whether multiple doses of prenatal steroids have a more profound positive effect, or whether they are accompanied by harsh side effects. Previous research in our lab indicated that a multi-course exposure to betamethasone actually increased the oxidative capacity of the fetal guinea pig scalenus, an accessory inspiratory muscle. However, additional research and a more standardized method of data collection are necessary to support our hypothesis that multiple doses of prenatal betamethasone actually increase the oxidative capacity of this muscle. Scalenus samples were collected from fetal guinea pigs that were exposed to multiple doses of betamethasone, or sterile water, (2 injections per week, 24-hours apart at 65%, 75%, and 85% gestation) prior to collection of muscle samples. Each sample was cut in a cryostat, and the sections were stained for their NADH-tetrazolium reductase (NADH-TR) or myosin ATPase activity. The density of NADH-TR staining was measured in the slow and fast twitch fibers in each fetal muscle using Scion Image. Z-scores were then calculated and used to identify the proportions of slow and fast twitch fibers staining darkly and lightly for NADH-TR. If our hypothesis is supported, the NADH-TR activity of both slow and fast twitch scalenus muscle fibers will increase with multiple doses of betamethasone. Thus, the breathing muscles of steroid treated fetuses will have an increased oxidative capacity compared to the muscles of non-treated fetuses, which is indicative of a higher fatigue resistance and overall stronger ventilatory capacity.

P2.12 WALLACE, R.L.*; SCHROEDER, T.; RIOS ARANA, J.V.; WALSH, E.J.; Ripon College, Ripon, University of Texas at El Paso, El Paso, Universidad Autonoma de Ciudad Juarez; *wallacer@ripon.edu*

Determinants of rotifer species diversity in aridland aquatic habitats

Compared to tropical and temperate environments, life for zooplankton in aridlands is precarious: vast tracts of dry land separate habitats and risk of drought is continual. However, many aquatic habitats in the Chihuahuan Desert (CD) harbor high levels of species diversity and endemism. Here we investigate the role of habitat permanence and physiochemical environment in determining rotifer community composition in CD waters. We sampled 163 habitats (76 permanent natural, 20 permanent artificial, 14 temporary, and 53 ephemeral) over a 6-yr period recording a suite of environmental parameters, as well as species composition. We identified over 250 rotifer species (ca. 12% of all monogononts); these belong to 51 and 77% of known genera and families, respectively. An RDA analysis of the entire data set shows that ca. 8% of species diversity is attributable to habitat characteristics. However, an analysis of taxonomic distinctness shows that the most diverse arrays of species are found in permanent habitats and nestedness analyses shows significant spatial structuring of communities: permanent to ephemeral (p=0.001; 4 null models). Species composition varied dramatically among the 4 habitat categories: Range, Mean (SD) – permanent natural 1-48, 10.1 (10.0); permanent artificial 1-33, 15.1 (12.1); temporary 1-33, 12.8 (8.6); ephemeral 1-14, 4.4 (2.9). To further investigate these patterns, we compared their species composition using several metrics of similarity that confirmed the high variability in community structure.

P3.27 WALSH, E.J.*; WOODS, M.A.; SCHROEDER, T.; Univ. of Texas, El Paso; *ewalsh@utep.edu*

Microcosm tests of interspecific competitive abilities and habitat monopolization

The Monopolization Hypothesis states that if a species establishes itself in an environment then other species will not be able to colonize the same habitat. This occurs due to resource monopolization and competitive numerical advantages of early colonists. Here we conduct a series of microcosm experiments to investigate competition between two rotifers (*Epiphanes chihuahuaensis* and *Cephalodella sterea*) commonly found in rock pools in the Chihuahuan Desert. In the first experiment, *Epiphanes* and *Cephalodella* were placed together in microcosms at a high and low food concentrations. At low food concentration, *Cephalodella* were nearly driven to extinction, but at high concentrations both species coexisted. Next, *Epiphanes* were limited to a population size of 3. Under these conditions, *Cephalodella* populations gradually increased to an average of 67 females per replicate. In the final experiment, *Cephalodella* was allowed to establish a population size of ~125 individuals before *Epiphanes* were introduced. *Cephalodella* grew exponentially until introduction of *Epiphanes*, then population growth rate slowed dramatically and eventually they became extinct in all but one replicate. Finally, observations were made to see how the two species interact. Surprisingly, observations indicated that *Epiphanes*, ingested *Cephalodella*, in more than 50% of trials at two ratios: 1 *Epiphanes*: 20 *Cephalodella* and 1 *Epiphanes*: 30 *Cephalodella*. These results indicate that competitive interactions between these two species is partially interference and not solely exploitative. Further, results did not support either the Monopolization Hypothesis. *Epiphanes* were superior competitors in every experiment.

P3.155 WALTERS, IJ*; CAIN, SD; Eastern Oregon University; *renerooser@comcast.net*

Comparative Anatomy of Ciliated Tissues in Armina californica

Ciliated cells and surfaces, coupled with mucus secreting cells and organs, are nearly ubiquitous in the animal kingdom. For example, humans regulate their cerebral-spinal fluid, reproduction, as well as maintain healthy lungs using ciliated tissues. In addition, other animals such as sea slugs use cilia as their primary mode of locomotion. Our knowledge of ciliated cells, however, is minimal when compared to our understanding of muscle cells, which are involved in several other types of cellular movements. Recently, the sea slugs have become a model for understanding the nervous control of cilia. Here we describe the morphology and physiology of cilia from the nudibranch *Armina californica*, as a first step in investigating the nervous control of ciliated surfaces in this slug. We used standard histological procedures to section and stain *A.californica* tissues. In this study we investigated the four types of ciliated tissues. Furthermore, we looked for mucus-secreting ducts and cells associated with the ciliated tissues. Preliminary data indicate that cilia vary in size and length and have varying amounts and types of mucus.

P3.56 WALTERS, L*; TURNER, T; PAUL, V; KUFFNER, I; Univ. of Central Florida, Univ. of the Virgin Islands, Smithsonian, Ft. Pierce, USGS; *linda.walters@ucf.edu*

Sea Urchin Foraging: Impacts in Coral Recruits

The die-off of the long-spined black sea urchin *Diadema antillarum* in Caribbean waters in the 1980s coincided with a dramatic increase in macroalgal biomass on coral reefs. Scientists hypothesize that the return of this keystone herbivore will drastically reduce current algal biomass and enable corals to once again dominate. On reefs in St. Thomas, US Virgin Islands, *Diadema* abundance in shallow waters has greatly increased in recent years, making this a perfect location for studying juvenile coral-algal-*Diadema* interactions. We have previously run in situ, recruitment assays with larvae of the hard coral *Porites astreoides* and dominant macroalgal species (*Dictyota menstrualis, Lobophora variegata, Acanthophora spicifera, Halimeda opuntia*) and found that sometimes *Dictyota* significantly reduced coral recruitment. Here we show the results of complementary trials in which we examined the survival of coral spat on tiles when placed in contact with these macroalgae with and without *Diadema*. Survival of corals on tiles, algal consumption and algal fragmentation were checked after 14 hr (overnight). Additionally, we ensured *Diadema* was actually contacting the tile surfaces by counting *Diadema* encounter incidences (scrapes, shallow and deep punctures) with each algal species on tiles covered with plasticene after 14 hr. Only *Dictyota menstrualis* had an impact and coral spat mortality was greatest when in contact with both *Dictyota* and foraging *Diadema*. Hence, even the positive impacts associated with the return of *Diadema* may be reduced in the presence of certain species of algae.

P2.25 WANG, Congwen; SEARS, Michael W*; Bryn Mawr College; *msears@brynmawr.edu*

Challenges of modeling the environments of animals: Features of geospatial datasets bias predictions of thermal heterogeneity

A pressing challenge for ecologists is to predict the potential ranges of species in light of changing climates. One approach has been to model the niches of organisms using georeferenced climate, topography, and land cover as drivers. A potential problem for this approach is that the spatial resolution of input data is often much more coarse than the spatial resolution of habitats used by organisms. Further, this approach also assumes that all habitats are homogeneous within each spatial unit used as model input. Despite these issues, such models are becoming common tools for ecologists. We have begun to construct more realistic models that explicitly incorporate landscape features into classical biophysical models of organisms. Using simulated landscapes, we examined the effects of the spatial resolution of input data, fractal dimension of elevational features, and topographic relief on the thermal heterogeneity of surface temperatures of organisms. We found that thermal heterogeneity decreased as spatial data become more coarse, increased with the fractal dimension of the landscape, and decreased with reduced topographic relief. The implication of these simulations is that estimates of the thermal heterogeneity of habitats used to predict the ranges of species are often underestimated, likely producing underestimates of potential ranges.

P3.83 WANG, Lingyu*; OOKA, Shioh; POUSTKA, Albert ; WIKRAMANAYAKE, Athula; University of Miami, Max-Planck Institut fÃ¼r Molekulare Genetik, Germany; *cellcreator@bio.miami.edu*

Investigating the molecular determinants for polarity in the sea urchin egg

The Dishevelled (Dsh) protein in the Wnt signaling pathway is required for endomesoderm specification in sea urchin embryos. Dsh is highly enriched in a vegetal cortical domain of the unfertilized egg, and during early cleavage stages this protein is selectively activated in vegetal pole blastomeres where it initiates Wnt/beta-catenin signaling. The mechanisms that tether Dsh to the vegetal cortex, and activate this protein in the Wnt pathway during early development are unknown, but this information is critical for understanding early pattern formation in the sea urchin embryo. To identify candidate molecules with potential roles in regulating Dsh function in the early embryo, we carried out two separate molecular screens. To identify all RNAs enriched in the egg cortex, we did a large-scale RNA-seq screen. The mRNAs of most Wnt signaling pathway core components were enriched in the egg cortex. We are currently using in situ hybridization to identify those RNAs that are asymmetrically distributed along the animal vegetal axis. To begin to characterize the Dsh-binding scaffold in the vegetal pole and to identify Dsh-interacting proteins in 16-cell stage micromeres, we carried out co-immunoprecipitation (Co-IP) experiments. These Co-IP studies have identified several proteins that potentially interact with Dsh in the cortex and in 16-cell stage embryos. We will describe the functional roles of these proteins in tethering Dsh to the vegetal cortex, and in "activating" Dsh in the Wnt/beta-catenin pathway.

P2.138 WANG, Z.-J.; SUN, L.; PENG, W.; MA, S.; ZHU, C.; FU, F.; HEINBOCKEL, T.*; Howard Univ. Coll. of Medicine, Washington, DC, Luye Pharma Group Ltd., Yantai, Shandong, China, Luye Pharma Group Ltd., Yantai, Shandong, China, Yantai Univ., Pharmacy, Yantai, Shandong, China; *theinbockel@howard.edu*

Ginseng Derivative Ocotillol Enhances Neuronal Activity through Increased Glutamate Release: A Possible Mechanism Underlying Increased Spontaneous Locomotor Activity of Mice

Ginsenosides are the main active ingredients in ginseng. Ocotillol is a derivate of pseudoginsenoside-F11, which is an ocotillol-type ginsenoside found in American ginseng. We examined the effects of ocotillol on neuronal activity of mitral cells (MC) in mouse olfactory bulb slices using whole-cell patch-clamp recording, and on animal behavior by measuring locomotor activity of mice. Ocotillol evoked action potential firing and membrane depolarization of MCs. In blockers of AMPA/kainate (CNQX), NMDA (D-AP5) and GABA-A (gabazine) receptors, the excitatory effect of ocotillol was abolished. The ocotillol effect persisted in gabazine but was eliminated by applying CNQX and D-AP5, suggesting that ionotropic glutamate receptors were involved in the effects of ocotillol. In voltage-clamp, ocotillol evoked an inward current and an increased frequency of spontaneous glutamatergic EPSCs. Both the inward current and sEPSCs were blocked by CNQX and D-AP5. Our results indicate that the excitatory action of ocotillol on MCs was mediated by enhanced glutamate release. Behavioral experiments demonstrated that ocotillol increased locomotor activity of mice. Our results suggest that ocotillol-evoked excitability was mediated by increased glutamate release, which may be responsible for the increased spontaneous locomotor activity. Support: Whitehall Foundation, U.S. PHS grants S06GM08016 (MBRS-SCORE, NIGMS/NIH), U54NS039407 (SNRP, NINDS/NIH), 2G12RR003048 (RCMI, NIH-NCRR).

P3.115 WARGELIN, L.W.*; BOUCHARD, S.S.; WARKENTIN, K.M.; Otterbein University, Boston University; *lindsay.wargelin@otterbein.edu*

Metabolic carryover effects in postmetamorphic red-eyed treefrogs

Resource availability has a strong effect on growth and development. Low food levels reduce larval growth rates and, in anurans, can delay metamorphosis dramatically. There may also be important metabolic implications, as some animals respond to low resource availability with reduced metabolic rates. Such effects could have long term impacts if larval metabolic adjustments persist post-metamorphosis. We assessed the effect of different competitive environments on metabolic rates of postmetamorphic red-eyed treefrogs. We reared larvae at high, medium, and low densities (5, 25 and 45 per 400 L), providing each tank with equal food levels so per capita resources were lower in high density mesocosms. We assessed larval growth rate by photographing larvae at two time points and measuring length with image analysis software. We later collected and measured metamorphosing individuals as they emerged from the water. Once metamorphosis was complete, we assessed metabolic rates by measuring oxygen consumption in a closed-system respirometer. Low-density larvae grew four times faster and began emerging over two weeks earlier than high-density larvae. Froglets generated from low-density environments were also three times heavier than those from high-density environments. We measured oxygen consumption of individuals ranging in size from 0.33 – 0.99 g. Overall, metabolic rate scaled with body mass with an allometric slope of 0.97. This slope is greater than that reported for other anurans, and suggests that metabolic rates of smaller high-density froglets could be depressed relative to larger low-density froglets. Such an effect could arise due to changes in organ size occurring during the larval period and carrying over post-metamorphosis.

P2.166 WARNE, Robin*; REEVES, Brooke; CRESPI, Erica; BRUNNER, Jesse; Southern Illinois University, State University of New York, Washington State University, Washington State University; *rwarne@siu.edu*

Integrating physiological and behavioral responses to stressors into an epidemiological framework

Environmental stressors as agents in disease emergence and epidemics have garnered much attention during the past decade. However, stressors are not all alike. Glucocorticoid (GC) stress hormone activation can vary in magnitude, while some stressors such as predation actually suppress GC activity. Furthermore, GC are also important regulatory hormones, with roles that vary across taxa and life stages. For GC profiles to serve as general biomarkers of stress, concerted research endeavors are clearly needed to provide greater resolution. Such endeavors could also shed light on how stressors influence disease outbreaks through understanding of how altered GC activity influence not only immune function but also animal behavior. For example, while food shortage induction of GC translates into increased foraging activity, exposure to predators suppresses GC expression and behavioral activity. Both interactions must influence pathogen transmission rates through GC immunomodulatory effects on host susceptibility, and behavioral effects on contact rates with infective agents. Here we argue that integration of these interactions into the susceptible-infectious-recovered (SIR) epidemiological framework is crucial to understanding disease transmission and persistence. Neuroendocrine and behavioral focused research could increase understanding of: (i) How differing environmental stressors alter host immunity and thus susceptibility and infectivity? (ii) What traits determine if recovered animals are susceptible or resistant to future pathogens? (iii) What are the conditions, costs and traits that underlie patterns of host tolerance to sublethal infections; and does tolerance contribute to disease persistence and epidemic outbreaks?

P2.70 WATSON, B. L.*; PODOLSKY, R. D.; College of Charleston; *blwatson1@g.cofc.edu*

How Will Ocean Acidification Affect Reproduction? A Study of Sperm Respiration In The Purple Sea Urchin, Arbacia Punctulata.

As atmospheric CO_2 levels continue to rise, the increase in CO_2 concentration in ocean surface waters is leading to historically rapid declines in pH, a process called Ocean Acidification. Studies of the effects of ocean acidification have focused mainly on animals that rely on calcification, which is compromised by declines in pH, to produce skeletons or protective structures. Less studied are other biological processes that are also pH sensitive, such as the activity of spawned sperm that are normally held in a suppressed metabolic state at low pH in the gonad. We studied the effects of CO_2-induced pH decline on reproduction in the sea urchin *Arbacia punctulata* by monitoring respiration rates of sperm incubated in sea water with CO_2 concentrations predicted several hundred years into the future. Our results show a negative effect of pH on sperm respiration that is most dramatic in the next 100 years. In addition, we found a previously described negative relationship between sperm concentration and respiration, known as the Respiratory Dilution Effect (RDE). We are combining these measurements with studies of changes in sperm motility and fertilization rate to understand processes responsible for changes in fertilization success. It is not yet clear, for example, whether declines in respiration and activity may be offset by increases in sperm longevity as a consequence of the RDE.

P2.45 WELLS, M.W.*; TURKO, A.J.; WRIGHT, P.A.; University of Guelph, ON; *wellsm@uoguelph.ca*

Terrestrial development in embryonic mangrove rivulus (Kryptolebias marmoratus)

The mangrove rivulus, *Kryptolebias marmoratus*, inhabits small pools of water in highly variable mangrove swamps. Adult rivulus will leave the water when aquatic conditions become unfavorable (e.g. hypoxia, H_2S) and can remain in the moist leaf litter for days to weeks. In the laboratory, adults are known to voluntarily deposit embryos terrestrially without obvious consequences for development and hatching, however wild rivulus embryos have never been observed. We hypothesized that wild mangrove rivulus emerse and release their embryos terrestrially as a strategy for avoiding the challenging aquatic conditions of the mangrove swamps. As such, the biology of amphibious reproduction was investigated in adults and embryos. We tested the effects of air exposure on adult reproductive output and embryonic development, along with the various environmental hatching triggers commonly associated with terrestrial development. Adult rivulus, which were air exposed for 96 hours, were found to have a higher reproductive output compared to aquatic controls. The metabolic rate of embryos reared in air was 2-fold higher relative to aquatic controls. These findings suggest potential fitness advantages to terrestrial development and can also act as a strategy for avoiding the harsh environmental conditions of mangrove swamps. In terms of hatching triggers, freshwater elicited no hatching response, while hypoxia (aquatic and terrestrial) triggered hatching in >90% of embryos. This suggests that rivulus are able to detect oxygen levels in both water and on land, which could provide an effective way of avoiding mortality from oxygen depravation and ensuring safe return to the water. Overall, the results support the hypothesis that rivulus may exploit terrestrial niches in the wild.

P1.188 WELLS, S.L.*; MCCONAUGHA, J.R.; Old Dominion University, OEAS; *swells@odu.edu*

The Effects of Changing Abundance on Reproduction in an Exploited Decapod Crustacean

Intense predation can alter the behavior and physiological responses of prey populations including their reproductive output. Commercial exploitation is now recognized as a strong perturbation and can have a strong influence on physiology including reproductive potential of the exploited species. The population structure and density of the blue crab, *Callinectes sapidus*, in Chesapeake Bay was adversely affected by overexploitation. Reproductive impacts included decreased egg production, decreased female reproductive effort, and reduced sperm transfer. Female polyandry recently detected by microsatellite DNA analysis, is a reproductive behavior that may be a result of decreased male size and density. In the last few years, conservation measures have been implemented which have significantly increased the abundance of this population. In response to these changes, female reproductive investment and output have rebounded with increased crab abundance. There have been observed increases in the number of eggs per brood, egg diameter, and energy allocation to each egg. Each of these parameters has shown positive intra- and inter-annual changes. Observation of reproductive parameters over the last 10 years shows that both positive and negative changes in abundance can affect reproductive outcomes in this exploited crustacean population.

P3.16 WELSH, C.*; HOQUE, R.; IKOTUN, I.; JEAN LOUIS, A; CATAPANE, E.J.; CARROLL, M.A.; Medgar Evers College, Brooklyn, NY; *catapane@mec.cuny.edu*

Study of Octopamine in Bivalves

Octopamine (OA), a biogenic amine first identified in octopus, is well studied in arthropods and gastropods. Its presence and actions have rarely been reported in bivalves. Previously, we identified OA in ganglia, gill, palps and hemolymph of the oyster *Crassostrea virginica* (order Osteoida) and found it a cardio-acceleratory agent. Here we examined the presence and effects of OA in *Mercenaria mercenaria* and *Mytilus edulis*. Amines were measured by HPLC and spectrofluorometry with an isocratic, ion-pairing Gemini 5µ C18 column. Clam and mussel heart preparations were prepared *in situ* by connecting ventricles to isotonic transducers with a small stainless steel hooks. Heart rate was monitored with a Narco Systems Physiograph. The results show OA present in ng amounts, along with serotonin, dopamine and norepinephrine, in the cerebral, visceral and pedal ganglia, as well as the gill, palps, heart and foot. Mussel and clam basal heart rates averaged 12 and 8 beats/min, respectively. Superfusion of OA (10^{-6}-10^{-3} M) raised mussel heart rate by 80%, but reduced clam heart rate by 50%. The actions of OA were prevented by the OA antagonist phentolamine. The study identifies OA in the nervous system and innervated organs of two additional bivalve orders, Mytilorida and Veneroida, and demonstrates OA has cardio-acceleratory properties similar to *C. virginica* in *M. edulis*,but cardio-inhibitory properties in *M. mercenaria*. The different result in clam appears at first to be confusing, but Veneroida hearts are well know to respond differently to drugs and stimulations compared to other bivalve orders. This work was supported by grants 2R25GM0600309 of the Bridge Program of NIGMS, 0516041071 of NYSDOE and 0622197 of the DUE Program of NSF.

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Do Betta splendens females eavesdrop on female-female aggressive interactions?

Research on animal communication is often concerned with dyadic interactions. When these dyadic signaling interactions occur in more complex social environments, eavesdropping is often favored. Eavesdropping occurs when an individual gains information from a signaling interaction in which she is not directly involved. Several studies have found evidence of eavesdropping in the fish species *Betta splendens*; both males and females have been shown to eavesdrop on male-male aggressive interactions. Females of this species are also fairly aggressive, so we investigated whether females also eavesdrop on female-female aggressive interactions. To explore this question we conducted dominance trials, in which a pair of females competed over food in front of an unseen observer. We then conducted choice trials, in which the observer was allowed to feed by either competitor. We found no evidence that *Betta splendens* females eavesdrop on female-female aggressive interactions. There are several potential reasons for this outcome. One possibility is that females do eavesdrop on female-female interactions, but could not gain useful information from observing dominance trials in this experiment. Similarly, it is possible that the female observers gained useful information from eavesdropping, but it was overridden by information available through interacting with the competitors in the choice trials. Another possibility is that females do not eavesdrop in this context. This last possibility would be interesting because females of this species have been shown to eavesdrop in other contexts. Further research is needed to elucidate the extent of eavesdropping behavior in *Betta splendens* females.

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Phylogenetics, Morphometrics and Biomechanics of Reef Fishes

Fishes use a sensational diversity of jaw mechanisms to capture and process their food. One of the hallmarks of this diversity is the complexity of the kinetic fish skull, which can have more than 20 mobile skeletal elements driven by numerous muscles. This complexity has often led to compelling examples of both divergence in form and function, as well as convergence in design and behavior. The integration of biomechanical modeling, geometric morphometrics and phylogenetic analysis is critical to addressing questions of functional evolution, biomechanical convergence, and radiation in diverse clades. Here we present detailed morphometric analysis of the skull in two diverse reef fish families; the Labridae (the wrasses) and the Balistidae (the triggerfishes). Procrustes geometric and standard morphometric analysis were performed on a set of 20-32 landmark coordinates summarizing the shape and key functional elements of the skull. Morphospace plots of phylogenetically independent contrasts reveal cranial shape-based clustering patterns that largely mirror higher-level phylogenetic groupings. However, frequent convergences in cranial shape across phylogenetic groupings are also identified. New software for analysis of cranial levers and linkages allows for simulation of structure-function relationships in a wide range of taxa, using the same coordinate data sets employed for morphometric tests. Linkage modeling leads to several conclusions regarding the evolution of function in reef fishes: (1) Coordinate based shape analyses can yield functional insight using mechanically relevant landmarks; (2) Novel biting mechanisms in triggerfishes and wrasses are associated with novel morphospace occupation; (3) Multiple mechanical variables and levels of design should be considered when defining convergent biomechanical systems. Funded by NSF DEB-0844745, NSF DGE-0903637 and an NSF EAPSI Fellowship 2011.

P1.7 WHEAT, S. K.*; CAYRON, E.; VONESH, J. R. ; WARKENTIN, K. M. ; Whitman College, Walla Walla, WA, Arizona State Univ., Phoenix, Virginia Commonwealth Univ., Richmond, Boston Univ., MA; *wheatsk@whitman.edu*

How do tadpoles use chemical cues to assess risk? Cue concentration versus pulse frequency.

Prey often alter their phenotype in response to predator cues to reduce vulnerability at the cost of reduced growth. Thus, prey are predicted to respond proportionally to the degree of risk, but this requires they accurately assess risk in different environments. In aquatic systems, many taxa use chemical cues from predation events in risk assessment. However, questions remain regarding what aspects of these cues provide the best information about risk. Cue concentration provides information about either the number or size of prey consumed, while cue pulse frequency provides information on predation events irrespective of prey size. If pulse frequency provides less ambiguous information about risk, we might expect prey to respond more strongly to this aspect of chemical cues. We conducted two laboratory experiments with hatchlings of the red-eyed treefrog (*Agalychnis callidryas*) to address this question. The first experiment quantified the effects of increasing cue concentration of two predators (dragonflies and water bugs) at a common cue pulse frequency. Responses were weakly dose dependent for both predators. The second experiment quantified the effects of pulse frequency at a common total amount of cue. Increasing pulse frequency strongly reduced growth, even though individual pulses in high frequency treatments contained little cue. These results highlight the importance of cue pulse frequency in risk assessment and help us to interpret results from field experiments in which tadpoles responded more strongly to caged predators that consumed many small compared to few large prey.

P3.28 WHIPPO, R*; LOWE, AT; BRITTON-SIMMONS, KH; University of British Columbia, Friday Harbor Laboratories; *rosspitality@gmail.com*

Benthic community structure mediated by the red sea urchin Strongylocentrotus franciscanus in the San Juan Archipelago

The red urchin *Strongylocentrotus franciscanus* is a ubiquitous member of the San Juan Archipelago marine community ranging from the shallow subtidal to depths greater than 100m. Despite the absence of attached algae on which to feed in the deep subtidal, red urchins are quite common in these habitats, subsisting primarily on detrital seaweeds produced in the shallow photic zone. By capturing these fluxes of organic material from the water column using their spines, they are able to remain attached to the substrate and do not actively seek food. Red urchins are also known to be strong interactors in shallow algal habitats, but very little is known about interactions between urchins and the surrounding community in the deep subtidal. These urchins are up to 20cm in diameter, and extensive field observations suggest that the presence of urchins dramatically alters localized benthic invertebrate abundance patterns. This study tested the hypothesis that red sea urchins alter benthic invertebrate community structure and abundance patterns in the deep subtidal zone. This was accomplished through the use of underwater photography pairing invertebrate communities underneath and adjacent to randomly selected urchins across three sites in the San Juan Channel. Analysis revealed that sea urchins are significantly altering abundance patterns of sessile and mobile fauna they are associated with. The influence of urchins on mobile community abundance varied widely between sampling depths, while sessile organismal abundance did not. Future work will be aimed at understanding the mechanism by which urchins alter these communities. This study increases our ecological understanding of deep subtidal environments in the Pacific Northwest and highlights the important role dominant grazers play in biological communities.

P2.184 WHITENACK, Lisa B.*; HESSEL, Anthony L.; RYERSON, William; Allegheny College, University of Connecticut; *lwhitena@allegheny.edu*

Jumping kinematics in the Plethodontidae I: performance, morphology, and scaling

Plethondontid salamanders are capable of a variety of defenses, including apoesomatic coloring, autotomizing limbs and tails, toxin secretion, and escape. To date, jumping as an escape mechanism has only been studied in *Desmognathus ocoee*. For this study, we examined five additional plethodontid species (*D. fuscus, D. ochrophaeus, Eurycea bislineata, Plethodon glutinosus, and P. cinereus*) to determine if other plethodontids are capable of this behavior and to explore the link between jump performance and morphology. Salamanders were filmed at 500 fps jumping over a 5 cm gap, with five trials per individual. Variables measured include bending angles, durations, and velocities, as well as jump height. Preliminary results indicate that all species studied exhibit the stereotypical C-start escape-type jump, as seen in *D. ocoee*. When all species are considered together, loading time and maximum jump height are correlated with size and mass. When considered individually, few correlations occur. For example, mass and size are only correlated with maximum height and unloading velocity for *P. glutinosus*, but tail length is correlated with loading time for *D. fuscus* and total length with unloading time for *D. ochrophaeus*. The ratio of tail length to SVL is not correlated with any kinematic variable, and *E. bislineata* and *P. cinerus* exhibited no correlations. It is possible that the larger overall size and mass of *P. glutinosus* is beyond a threshold where size matters that the other smaller species do not cross.

P2.178 WHITLEY, B.N.*; TREIDEL, L.A.; BOWDEN, R.M.; HAUSSMANN, M.F.; Bucknell Univ., Il. St. Univ.; *bnw002@bucknell.edu*

Chronic stress alters stress-induced oxidative damage in domestic chickens (Gallus gallus)

Glucocorticoid release in response to an acute stressor facilitates rapid energy expenditure by redirecting limited resources to essential functions, promoting short-term survival. However, repeated exposure to stress (i.e., chronic stress), can cause dysregulation of glucocorticoid secretion and abnormal glucocorticoid levels that can suppress growth, immune function, and reduce survival. We have previously shown that elevated glucocorticoids during an acute stress response accompany an increase in oxidative stress. Whether a similar oxidative stress response to an acute stressor occurs when an animal is simultaneously experiencing chronic stress is unknown. To test this, we exposed domestic chickens (*Gallus gallus*) to either control (C; n = 10) or chronic stress (S; n = 10) conditions. At twelve days post-hatch, all birds experienced an acute stress series (blood samples collected at <3, 20, and 45 min). Chronic stress birds were then exposed to 30 minute stressors five times a day for ten days. All birds underwent a second acute stress series after the chronic stress period. Oxidative damage and total antioxidant capacity were measured in all plasma samples. While there was no difference between C and S birds in oxidative stress levels before the initiation of the chronic stress period, after ten days of chronic stress, S birds had a decreased oxidative stress response compared to the C birds. Chronically stressed birds may have lower corticosterone levels during an acute stress response resulting in decreased oxidative stress. Alternatively, if chronically stressed birds have elevated baseline corticosterone there may be a concomitant protective increase in antioxidant defenses, mitigating the rise in oxidative stress in response to an acute stressor.

P3.185 WILLIAMS, Jason*; DAVID, Andrew; Hofstra University; *biojdw@hofstra.edu*

Morphology, ecology, and reproduction of the cryptogenic sponge associate Polydora colonia (Polychaeta: Spionidae)

The spionid polychaete *Polydora colonia* (Moore 1907) is a widely distributed polydorid worm, typically found associated with sponges. The species was first described from Massachusetts and has been reported in other regions of the western Atlantic, the Mediterranean Sea and South Africa. In spite of many reports of the species, the natural history of *P. colonia* is virtually unknown and studies are needed to determine its status as an introduced species. The current work focused on collections of *P. colonia* from Long Island, New York made between 2007-2010. *Polydora colonia* was associated with two host sponges (*Microciona prolifera* and *Halichondria bowerbankii*) attached to docks; the worms reached densities as high as 7.8 worms/mm3 during July to August. Morphological research based on light and scanning electron microscopy showed the specimens agree with prior studies and no features were found that distinguish it from previous descriptions and museum specimens from around the world. *Polydora colonia* exhibited adelphophagy (nurse eggs consumed by developing larva) and the earliest free-swimming stage was a 7 chaetiger larva. Asexual reproduction (via architomy) was recorded for the first time in this species; overall prevalence of architomy was 24% (n= 780). Anterior regeneration was completed in 8 days and followed a similar morphogenic pattern to other spionids. Sponge material (including spicules) was found in the gut of 53% of worms examined (n=100), the first evidence of sponge feeding in polydorids. *Polydora colonia* appears to have been introduced to marinas in many localities around the world and further studies should be completed to examine its impacts, including effects of feeding on host sponges.

P1.23 WILLIAMS, L.E.*; DEFUR, P.L.; Virginia Commonwealth University; *williamsle@vcu.edu*

The Effects of River Sediment Contaminants and Moderate Hypoxia on the Blue Crab (Callinectes sapidus)

The blue crab is an ecologically and economically important invertebrate to the Chesapeake Bay. The juvenile male blue crab moves into low salinity areas during warmer months to feed and grow by undergoing molting. The tributaries afford important habitat during this vulnerable life stage. In crustaceans, growth, molting and reproduction are all hormonally controlled and the juvenile molting crab may be the life stage that is most sensitive to low doses of chemicals that are found in the James River. Multiple anthropogenic stressors found in the James River include hypoxic waters and contaminants found in the sediment and the water column. The combination of stressors may interact and potentially cause adverse effects that, for each individually, show no effect. The physiological effects of a multiple stressor environment were determined by comparing the blue crab's basal oxygen uptake to the oxygen uptake after exposure to river sediment contaminants and moderate hypoxia. The effect of the multiple stressor environment was also measured by enzyme analysis, where N-acetyl-ß-glucosaminidase activity was measured in the epidermal tissue.

P1.184 WILLIAMS, Tony D*; EVANS OGDEN, Lesley J; MARTIN, Kathy; Simon Fraser Univ., Burnaby, Canada, Univ. of British Columbia, Vancouver, Canada; *tdwillia@sfu.ca*

Altitudinal differences in songbird fattening rates during fall migration

It is clear that stopover habitats can be limiting for some migratory songbirds and this can lead to population limitation. Many songbird species have been observed using high altitude 'stopover' habitat throughout North America. Thus, it is important to determine if these 'alternative' habitats represent high quality stopover sites, supporting high fattening rates, such that birds can refuel without deviating far from their 'optimal' migration schedules. In this study we used plasma metabolite analysis to estimate fattening rates of four species of migratory songbirds during fall migration over three years at two low altitude (< 25 m ASL) and two high altitude (1200 m ASL) sites in southwestern British Columbia, Canada. We predicted that fattening rates would be greater at high altitude sites during fall migration, especially in frugivorous species, due to the delayed phenology of food availability at higher altitude. Our analyses supported this prediction for three of four species: fox sparrow, golden-crowned sparrow and hermit thrush all had higher estimated fattening rates at higher altitude sites. These three species have the most frugivorous diets during fall migration. In contrast, the orange-crowned warbler, which is largely insectivorous during fall migration showed the opposite pattern, with higher estimated fattening rates at low altitude sites. There were no differences in estimated fattening rates among the three more frugivorous species at high altitude sites, but all species had higher fattening rates than the orange-crowned warbler. These data support the hypothesis that altitudinal differences in estimated fattening rate are related to species differences in diet and seasonal phenology of food availability.

P1.198 WILLIAMS, J.B.*; LEE, R.E.; Southern Illinois University, Miami University; *jasowil@siue.edu*

Effect of dehydration and freezing on cryoprotectant and ion distribution and hemolymph volume in the goldenrod gall fly, Eurosta solidaginis

Extracellular freezing and dehydration concentrate hemolymph solutes, which can lead to cellular injury due to excessive water loss. To determine whether freeze tolerant larvae employ protective mechanisms against excessive cellular water loss we examined the effect of extracellular freezing and dehydration on hemolymph volume, and cryoprotectant and ion levels in the hemolymph. Dehydrated larvae or ones that had been frozen at -5 or -20°C had a significantly smaller proportion of their body water as hemolymph (26.0 to 27.4%) compared to controls (30.5%). Even with this reduction in water content, hemolymph osmolality was similar or only slightly higher in frozen or dehydrated individuals than controls (908 mOsm•kg^{-1}), indicating these stresses led to a reduction in hemolymph solutes. Hemolymph and intracellular content of ions remained largely unchanged between treatment groups; although levels of Mg^{++} in the hemolymph were lower in larvae subjected to freezing (0.21±0.01 µg•mg^{-1}dry mass) compared to controls (0.29±0.01 µg•mg^{-1}dry mass), while intracellular levels of K^{+} were lower in groups exposed to low temperature (8.31±0.21 µg•mg^{-1}dry mass). Whole body glycerol and sorbitol content was similar among all treatment groups, averaging 432±25 mOsm•kg^{-1} and 549±78 mOsm•kg^{-1} respectively. However, larvae subjected to dehydration and freezing at -20°C had a much lower relative amount of cryoprotectants in their hemolymph (~35%) compared to controls (54%) suggesting these solutes moved into intracellular compartments during these stresses. The correlation between reduced hemolymph volume (i.e. increased cellular water content) and intracellular movement of cryoprotectants may represent a link between tolerance of dehydration and cold in this species.

P3.148 WILLIS, Katie L*; CARR, Catherine E; Univ of Maryland; *kwillis@umd.edu*

Middle Ear Cavity Morphology Across Testudines

We hypothesize that the function of the large middle ear cavity in testudines is to act as a resonator for underwater sound. To determine if middle ear cavity size was affected by environment or phylogeny, we measured the middle ear in different species. Using microMRI and microCT scans of over 20 species, which have a wide range of ecologies and include examples from most of the testudine families, we reconstructed and measured the middle ear cavities using Neurolucida (MBF Bioscience). Because the frequencies in question are low, volume matters more than the shape of the cavity in determining best resonance frequency. In all but one species examined, the middle ear cavity was a curved ellipsoid that scaled with head size. The exception to this pattern was the Chelus fimbriatus, which displayed a more hourglass morphology but scaled in the same manner. Unlike the middle ears of lepidosaurs and archosaurs, testudine ears are uncoupled. Middle ear cavities ranged in volume from 0.03 mL to 2.56 mL; head widths from 19-96 mm. These values scaled approximately linearly. By treating the middle ear cavity as a sphere, we calculated their best resonance frequencies underwater as 385-1737 Hz, corresponding to the largest and smallest heads respectively. After separating species by ecology and phylogeny, we found no significant difference (ANOVA p= 0.987 and p=0.943, respectively) in the variation of middle ear cavity volume with head width, suggesting that there has been little modification from the ancestral condition. Given that the cavity resonates underwater within the testudine hearing range, but resonates in air out of range, the middle ear morphology supports the hypothesis of an aquatic origin for testudines.

P1.196 WILLIS, MC*; PRADHAN, DS; NAUDE, PW; SOLOMON-LANE, TK; GROBER, MS; Georgia State Univ., Atlanta, Univ. of Georgia, Athens, georgia State Univ., Atlanta; *mwillis9@student.gsu.edu*

Egg laying and development in Bluebanded Gobies

Many species of seasonally breeding vertebrates have multiple, overlapping broods during the breeding season. As a result, there may be considerable temporal overlap in territory defense, sexual, and mating behaviors during the nesting phase. The bluebanded goby (*Lythrypnus dalli*) is a hermaphroditic fish that commonly lives in groups consisting of one dominant male and a harem of females. During the breeding season, male *L. dalli* court females and persuade them to enter his nest and lay eggs. After spawning, the male provides all parental care, while simultaneously courting/subordinating his females and defending his territory. Males with eggs in their nest have higher levels of circulating androgens compared to males without eggs. To better understand the cues that induce male parenting, it is critical to understand egg laying and development in this species. During mid-breeding season, social groups (N=41) of wild-caught *L. dalli*, each consisting of one male and three females were established. Each group was provided with an artificial nest, and parenting behavior of each male was observed at three weeks. The quantity and physical appearance of the eggs were recorded twice daily. There was an average of ~6.8 d before the first appearance of eggs and ~2.9 days between the appearance of eggs and the fertilization of the clutch. Further evaluation of these data will reveal patterns that are associated with multiple clutches of eggs. This study provides critical insights into understanding the breeding ecology of *L. dalli*, which will be useful for future projects.

P3.77 WINTERS, Ian*; RUED, Anna; SIYU , Ding; POSFAI, Dora; GENTILE, Lisa; RIVERA, Ajna; HILL, April; University of Richmond, University of the Pacific; *ahill2@richmond.edu*

Knockdown of PaxB and Six1/2 by RNAi leads to developmental defects of the aquiferous system in the freshwater sponge Ephydatia muelleri

Sponges belong to an ancient metazoan lineage, and they represent an extant relic of the first experiment in animalian multicellularity. Thus, members of this phylum hold important clues about fundamental aspects of animal development. The genomes of sponges are remarkable because they possess an extensive set of animal-specific genes despite the lack of major animal traits (e.g., neurons, organ systems). Among these animal-specific genes, the demosponge genome is known to encode one Pax and one Six ortholog. Pax and Six genes are two members of a gene regulatory network, which regulates aspects of organogenesis (e.g., sensory organ, kidney). Here we examine the regulation and function of a Pax and Six gene in the freshwater sponge *Ephydatia muelleri*, an emerging model for behavioral and expression studies. We present data that: 1) Suggests PaxB and Six1/2 are involved in a regulatory network in *Ephydatia muelleri* which means that this network originated early in the Metazoa 2) Targeted knockdown of PaxB and Six1/2 affects endopinacoyte, choanocyte and oscula development in this species leading to defects of the aquiferous system.

P1.204 WISE, Kelsey L*; GRAY, Emilie M; Colorado College; *kelsey.wise@coloradocollege.edu*

Thermal acclimation affects the aerobic scope of hissing cockroaches

The "hotter is better" hypothesis states that the rate-depressing effects of low temperature cannot be compensated by acclimation or adaptation. In the present study we test this hypothesis by using metabolic rate and aerobic scope as performance indicators. Madagascar hissing cockroaches (*Gromphadorhina portentosa*) were acclimated to different temperatures for several weeks. After this acclimation period resting and maximal metabolic rates (RMR and MMR respectively) were measured via flow-through respirometry at temperatures ranging beyond the acclimation temperatures. RMR was obtained from animals kept in a dark chamber, at a given temperature, for at least 40 min. Following 1 min of vigorous shaking, MMR was calculated by using the highest continuous 30-sec running average of metabolic rate. Aerobic scope was determined as the difference between MMR and RMR. Preliminary results indicate that while the thermal reaction norms for RMR of cold acclimated animals are left-shifted compared to those of warm acclimated ones, the reaction norms for MMR displayed a reverse pattern, resulting in the warm acclimated animals having a higher aerobic scope. If confirmed, these results would lend support to the hotter is better hypothesis but also raise questions concerning the perception of metabolic rates as performance traits.

P2.96 WOJCIECHOWSKI, M.S.*; STAWSKI, C.; JEFIMOW, M.; KOTEJA, P.; Nicolaus Copernicus University, ToruÅ', Poland, Jagiellonian University, KrakÃ³w, Poland; *mwojc@umk.pl*

The capacity of non-shivering thermogenesis in bank voles from lines selected for high aerobic metabolism

Comparative data suggest that high non-shivering thermogenesis (NST) capacity in mammals evolved as a compensatory mechanism for low basal metabolic rate (BMR). We report preliminary results of an experiment testing the hypothesis that NST capacity is negatively correlated with BMR in bank voles (*Myodes glareolus*). The experiment was done on 32 voles from lines selected for high O_2 consumption achieved during swimming and on 27 voles from unselected, control lines. Compared to control lines, BMR in the selected lines is ~14.6% higher (7.1% after adjusting for differences in body mass, m_b). Non-anesthetized animals exposed to ambient temperature = 27.5 ± 0.5°C were injected with noradrenalin (NA) at a dose of (mg kg^{-1}) = 2.53 m_b (g) $^{-0.4}$ and their rate of oxygen consumption (VO_2) was measured continuously in an open-flow respirometry system. NST capacity was defined as the highest 4-minute VO_2 after NA-injection. The NST capacity (mean ± SD) did not differ between the selected (3.79 ± 0.78 mlO_2 min^{-1}) and control lines (3.52±0.79 mlO_2 min^{-1}; analysis of covariance with m_b as a covariate: p=0.49). We also found no correlation between m_b-adjusted BMR and NST capacity among individuals within the selection groups. Thus, we found no support for the prediction that selection leading to a higher BMR results in a decreased capacity for NST. However, the results may be affected by unusually high locomotor activity of the voles from selected lines, which we observed after NA-injection. We hope to eliminate this factor by undertaking the same experiment on anesthetized voles. *This study was supported by a grant from the Polish Ministry of Science and Higher Education N N304 168739 to MSW and N303 275233 to PK, and UJ/INoS DS/BW 757 to PK.*

P1.25 WOJDYLO, J.E.; RICE, C.D.*; Clemson University, Clemson SC; *cdrice@clemson.edu*

AHR-1, AHR-2, AND CYP1A EXPRESSION IN TISSUES OF CREOSOTE-ADAPTED ATLANTIC KILLIFISH (FUNDULUS HETEROCLITUS) FROM THE ELIZABETH RIVER, VA USA

The Atlantic Wood (AW) creosote facility on the Elizabeth River, Portsmouth VA, is a declared EPA Superfund site. Compared to a reference population, AW killifish are shown to be resistant to PAH-related embryo toxicity and recalcitrant to CYP1A induction by PAHs, yet a large percentage of fish harbored extensive hepatic lesions. In 2010 we examined AW killifish to determine if CYP1A expression remains low, if the frequency of hepatic lesions remains high, and to describe the expression of AhR in these fish. Using an expression plasmid, we expressed recombinant killifish AhR-1 and AhR-2 to generate mAbs, resulting in mAbs 7B8 and 5B6 respectively. Head kidneys (HK), intestines, and livers were isolated from AW and reference killifish (Kings Creek, Gloucester County VA) and processed for histological evaluation and immunohistochemistry (IHC). We find that the frequency of liver lesions is very high, including a high percentage of neoplasia. We find that CYP1A expression (using mAb C10-7) is very low to absent in hepatic lesions, detectable in normal hepatic tissues, but highly expressed in intestinal epithelia and HK of AW fish. Low CYP1A expression was detected in fish from the reference site. AhR-1 protein is not abundantly detectable in any of the tissues examined. AhR-2 is highly expressed in all tissues of both populations, but much higher in AW fish. Interestingly, while many hepatic lesions in AW fish express very low levels of CYP1A, these same lesions express higher levels of AhR-2 than surrounding normal tissue. Our study shows that AW killifish remain an important model for understanding the relationship between the AhR and acquired resistance to PAHs. (NIH R15-ES016905-1)

P1.85 WOLFF, SE*; COSTON, JM; VELDHOEN, N; HELBING, CC; PROPPER, CR; Northern Arizona University, University of Victoria, University of Victoria; *stephanie.wolff@nau.edu*

Effects of Exposure to 4-tert-Octylphenol on Sexual Differentiation and Gene Expression in African Clawed Frogs

The chemicals released into the environment, known as endocrine disrupting compounds (EDCs), pose threats to wildlife and human health. Contact with EDCs is possible through contaminated water, food, air, and soil. One group of particular concern is the alkylphenols, such as 4-tert-octylphenol (OP), with estrogen-like activity that contributes to numerous detrimental physiological impairments. The purpose of this study was to determine the effects of OP on gene expression of two genes essential in sexual differentiation, forkhead box L2 (Foxl2) and steroidogenic factor 1 (SF-1). African clawed frog (*Xenopus laevis*) tadpoles were exposed for two weeks during critical stages of sexual differentiation to three levels of OP (10^{-7}M, 10^{-8}M, and 10^{-9}M), a positive estradiol (E2 control (10^{-9}M)) and a negative ethanol vehicle control. After two weeks of exposure, gonads were collected for qPCR and animals were sexed genomically. At the stage of development analyzed, there was no sexual dimorphism in expression of either gene. However, animals exposed to E2 and OP had significantly lower levels of Foxl2 mRNA compared to controls, while animals exposed to either compound had significantly higher levels of SF-1. Our results demonstrate that OP sets up a pattern of gene expression disruption similar to E2 during the very earliest stages of gonadal differentiation. Our results suggest that these compounds effect gonadal differentiation and functional outcomes by disrupting expression of genes critical to development.

P3.180 WOOD, B.M.*; ANDERMANN, R.J.; HOMBERGER, D.G.; Louisiana State Univ., Baton Rouge ; *bwood6@tigers.lsu.edu*

The morphology of the myomere-myoseptal intersections in a lamprey (Petromyzon marinus) and a shark (Squalus acanthias)

An accurate anatomical description of the myomere-myoseptal intersections in the axial musculature of piscine vertebrates is a necessary basis for a mechanical explanation of how contractile forces are transmitted from one myomere to the next via myosepta. As a first step, the superficial muscle fiber bundles were analyzed through microdissection at their intersection with myosepta in the trunk region. In the lamprey, the tendons of myomeric muscle fiber bundles join a myoseptum on each side, but in opposite directions, at shallow to right angles (depending on the curvature of the myoseptum). In the shark, the tendons of myomeric muscle fiber bundles traverse a myoseptum to connect mainly to muscle fiber bundles directly across, but separate slips of tendons connect to muscle fiber bundles diagonally across. These observations suggest that, at least in the superficial axial musculature of lampreys and sharks, muscle fiber bundles do not terminally attach to myosepta. Hence, contractile forces of the superficial muscle fiber bundles may be transmitted to one another across the myosepta. These observations show that the structural and mechanical relationships between the myosepta and myomeres deserve to be analyzed in depth. Furthermore, a realistic ("realitätsgetreues") biomechanical model of the myomeric-myoseptal intersections may provide information for a more complete understanding of (1) the interactions between the central nervous system and the axial musculature; (2) the evolutionary changes in the axial musculature of Petromyzontiformes and Chondrichthyes; and (3) the evolutionary history of early fishes.

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Tadpole responses to combined environmental stressors – pesticides and salinity

Habitats are becoming increasingly degraded due to human activities, often experiencing multiple stressors simultaneously. Many freshwater habitats are compromised by pollution from various sources, including pesticides from agricultural, residential and urban runoff. In addition, increasing salinity is an emerging threat to freshwater habitats, due to runoff of road salts, salinization of inland habitats and saltwater intrusion into coastal freshwater sources, particularly as sea levels rise. Although stressors are often studied in isolation, assessing their combined effects is crucial to understanding how populations respond to human-altered habitats. We investigated the effects of pesticides and salinity, alone and in combination, on growth and development of southern toad tadpoles (*Anaxyrus terrestris*). Tadpoles were exposed to eight treatments, consisting of three commonly-used pesticides – carbaryl, glyphosate, and atrazine – and a no-pesticide control, with and without elevated salinity. Tadpoles exposed to increased salinity were smaller and less active and ultimately metamorphosed later and at a smaller size. Among the pesticides investigated, carbaryl was particularly harmful, decreasing survival, reducing growth and activity, and leading to delayed metamorphosis. When experienced together, carbaryl and salinity showed a synergistic effect on tadpole growth, with much more pronounced growth suppression than with either stressor experienced alone. Thus, tadpoles are more vulnerable when the two stressors are experienced together, and in some cases the combined effect is greater than predicted by the sum of their individual effects. Ultimately, both pesticides and increasing salinity put amphibian populations at risk, and populations that experience both impacts simultaneously are at particular risk.

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Measuring Allostatic Load in Wintering Gambel's White-crowned Sparrows, Zonotrichia leucophrys gambelii

Regulation of energetic expenditure, considered here as allostatic load, is central to organism-environment interactions, and the value of responses that modify behavior or physiology is often measured in terms of energetic benefits. In this study, I assessed the total energetic costs incurred by white-crowned sparrows, *zonotrichia leucophrys gambelii*, in real time through the use of heart-rate transmitters. I present data validating the use of heart rate as a proxy for metabolic rate via flow-through respirometry and doubly-labeled water. Experiments measuring heart rate in outdoor aviaries and preliminary field tests on free-ranging birds indicate that these birds depress metabolism on cold winter nights when temperature alone would be predicted to lead to increased energetic expenditure. Implications and future directions for this research will be discussed.

P3.124 WORTHINGTON, Amy/M; BERNS, Chelsea/M; SWALLOW, John/G*; Iowa State University, Ames, University of South Dakota, Vermillion; *john.swallow@usd.edu*

Size matters, but so does shape: Quantifying complex shape changes in a sexually selected trait in stalk-eyed flies

The elaborate morphologies of sexually selected ornaments are predicted to be costly. Ornament size is frequently used as a measure of fitness, yet shape plays an important role and, surprisingly, is often overlooked. Shape often exhibits allometry with size, which can occur due to biomechanical, developmental, or performance constraints. Therefore, shape can provide additional insights into the morphological differences between individuals and the potential limits on sexual trait exaggeration. Here, we used landmark-based geometric methods to quantify head shape in a sexually dimorphic species of stalk-eyed fly (*Teleopsis dalmanni*) to examine patterns of sexual shape dimorphism. Our analyses revealed a significant difference in head shape between the sexes, with males exhibiting smaller eye bulbs, thinner stalks, and smaller heads than females. Additionally, as eyestalk length increased within each sex, a similar pattern of shape change was observed as that between sexes. We discuss how shape variation may be the result of constraints acting against further ornament exaggeration and how changes in shape may significantly impact whole-organism performance in stalk-eyed flies.

P3.167 WRIGHT, ML*; STEVES, I; CALDWELL, RL; UC Berkeley; *wrightml@berkeley.edu*

Did social monogamy evolve as part of a sedentary lifestyle in Lysiosquilloid mantis shrimps?

Although social monogamy, when a male and female live together for at least one breeding season, is characteristic of several ecologically important crustaceans, little is known about the evolution of social monogamy in crustaceans. In Lysiosquilloid mantis shrimps, social monogamy occurs in eight genera. Many mantis shrimps are sit-and-wait predators that seldom leave their burrows. This sit-and-wait feeding strategy may confer fitness benefits by decreasing vulnerability to predators and increasing energy available for reproduction. However, since foraging and mate searching often occur simultaneously, sit-and-wait predation may decrease mating opportunities, leading to the evolution of social monogamy. To investigate whether the evolution of social monogamy is associated with the evolution of sit-and-wait predation and burrow dwelling in the Lysiosquilloidea, we conducted a phylogenetic comparative study using behavioral, ecological, and morphological data. We hypothesized that social monogamy would evolve more often in burrow dwellers living in soft-bottom substrates We also hypothesized that the body shape (thorax and abdomen) would lengthen for better maneuvering inside the burrows. We used geometric morphometrics to characterize the body shapes of 44 mantis shrimp species. We digitized dorsal body shape by placing 21 landmarks on the abdomen and thorax and obtained shape data of landmarks using Procrustes superimposition. A mantis shrimp maximum parsimonly tree of 103 taxa was constructed using a concatenated matrix of genetic (12S, 16S, 18S, CO1) and morphological data (Ahyong 2001). Data on the social mating system, habitat, depth range, and foraging strategy of each species were collected from the literature. Using ancestral reconstruction and PGLS, we analyzed the associations between relative warps of the shape data, social monogamy, predation strategy, and habitat preference.

P3.70 WU, H.R.; ZHANG, Q.J.; CHEN, Y.T.; YU, J.K.*; ICOB, Academia Sinica, Fujian Normal University; *jkyu@gate.sinica.edu.tw*

Expression patterns of germline specific markers indicate a preformation mechanism of germ cell development in cephalochordates

The segregation of germline cells from somatic cells is a critical step in metazoan animal development. In recent years, comparative studies in diverse organisms using conserved germ-cell specific markers, such as *Vasa* and *Nanos* gene products, have provided interesting insights into the evolution of germ cell specification mechanisms. We previously showed that the gene products of *Vasa* and *Nanos* become localized to the vegetal side during oogenesis in the cephalochordate amphioxus *Branchiostoma floridae*. These co-localized *Vasa* and *Nanos* maternal transcripts aggregate into a compact granule after fertilization, suggesting a preformation mechanism of germ cell development. In addition to the localized maternal transcripts, *Vasa* and *Nanos* are also expressed zygotically in the posterior growth zone in amphioxus embryos, suggesting they may also function in highly proliferating somatic stem cells. Here we further characterize expression of *B. floridae* homologs of *Piwi* and *Tudor*, both genes are known for playing important roles in germline development in diverse metazoan animals. We identified multiple Piwi-like genes and Tudor domain containing genes from the amphioxus draft genome. Within the two amphioxus Piwi-like homologs, one displays maternal and zygotic expression patterns identical to those of *Vasa* and *Nanos*, suggesting it may also function in both germline and somatic stem cells. More interestingly, we found one of the *Tudor* genes is only expressed maternally and co-localized with *Vasa/Nanos* maternal transcripts in the putative germline progenitor cell, suggesting that it may function exclusively in germ cell formation in amphioxus. Therefore, our results demonstrate the molecular distinction between the amphioxus germline stem cells and somatic stem cells.

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Rudiment Formation in the Sea Urchin Lytechinus variegatus

Sea urchin metamorphosis is dramatic process. In a matter of minutes, a bilaterally symmetric larva transforms into a radially symmetric juvenile urchin. Prior to this radical change in body plan, a group of cells organize to form the imaginal rudiment on the left side of the larval body. However, the identities of the larval cells that contribute to this rudiment, as well as the molecular mechanisms that establish the rudiment's pentaradial symmetry, are poorly understood. My thesis research focuses on these questions, as well as how the embryonic gene regulatory network of the sea urchin is adapted to specify development of the juvenile body plan. Currently, I am cloning several candidate genes from *Lytechinus variegatus*, including *Distal-less*. DLX protein has been shown to specifically localize to the developing rudiment in sea urchins (Lowe et al. 2002), and it has long been known to affect the formation of imaginal discs in *Drosophila*. I plan to make in situ hybridization probes from *Distal-less* and other candidate genes known to be involved in *Drosophila* imaginal disc patterning in order to examine the role of these genes in rudiment development.

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Mapping developmentally dynamic synaptic inputs on motor neurons in zebrafish

During development, motor neurons must integrate thousands of excitatory and inhibitory interneuron inputs to produce essential rhythmic motor behaviors, therefore, functional motor behaviors require a balance between excitation and inhibition (E/I balance) of motor neurons. Interestingly, althought the set of rhythmic motor behaviors keeps expanding during development, the E/I balance is always well maintained to produce functional motor behaviors. To better understand how such E/I balance is maintained during development, we conducted this study to obtain a developmental map of synaptic inputs onto zebrafish spinal cord motor neurons. To visualize how pre-motor interneurons synapse onto motor neurons during development, we backfilled ventrally projecting motor neurons in the transgenic fish line in which glutamatergic and glycinergic interneurons are labeled with different fluorescent proteins. Also, we stained wild type fish with antibodies against post-synaptic proteins to specifically label excitatory and inhibitory post-synapses, so as to visualize the localization of stabilized excitatory and inhibitory synapses at different developmental stages. The combination of both the pre-synaptic and post-synaptic components will allow us to further understand the developmental territories of different types of synapses onto motor neurons as well as their impact on E/I balance. Such knowledge will also promote our understanding about the formation of a functional spinal cord motor circuit, as well as provide a baseline for further study about the regulation of motor output in mutants or morphants with disrupted motor behaviors.

P3.92 YEOH, Aaron/J; VELA-MENDOZA, Allison/V; GILLEN, Chris/M*; Kenyon College; *gillenc@kenyon.edu*

Scaling of Manduca sexta midgut tissue and amino acid transporter expression

We assessed mass and gene expression in 3rd through 5th instar *Manduca sexta* midgut. Wet mass of gut tissue increased in comparison to total body mass with a scaling exponent of 0.85, while gut content mass scaled at a 1.33 exponent, indicating that surface area may become increasingly limiting in larger larvae. Scaling exponents of anterior and posterior midgut were 0.96 and 0.85, above the 0.67 value predicted for isometric scaling, while the exponent for middle midgut was 0.70. Dry masses showed the same pattern. KAAT1 is a potassium-amino acid transporter expressed on the apical membrane of *Manduca sexta* midgut. We tested the hypothesis that increased expression of membrane proteins helps compensate for the decreased relative surface area of the midgut in later instars. We compared mRNA expression between 4th and 5th instar larvae. Expression of the KAAT1 gene was 2.3 to 3.1 fold higher in 5th compared to 4th instar larvae, supporting the hypothesis of increased membrane protein expression in larger larvae. KAAT1 was expressed 300 to 1500 fold higher in middle and posterior midgut compared to anterior midgut. We are optimizing RNA interference to characterize the consequences of decreased KAAT1 expression. A plasmid construct with a 453bp KAAT1 PCR fragment and flanking T7 promoters was developed for the production of KAAT1 dsRNA. We are testing the effects of different delivery methods, timing and dosage with assessment of phenotype and gene expression with qPCR.

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The ontogeny of quadrupedal walking in squirrel monkeys (Saimiri boliviensis)

For more than 120 years, locomotor researchers have known that adult primates employ a unique footfall sequence during walking. Most quadrupedal mammals use lateral sequence (LS) gaits, in which hind foot touchdowns are followed by an ipsilateral forefoot touchdown. In contrast, most quadrupedal primates use diagonal sequence (DS) gaits, in which hind foot touchdowns are followed by a contralateral forefoot touchdown. However, gait selection in immature primates is more variable, with infants and juveniles frequently using LS gaits either exclusively or in addition to DS gaits. I explored the developmental bases for this phenomenon by examining the ontogeny of gait selection in growing squirrel monkeys walking on flat and simulated arboreal substrates (i.e., a raised pole). Results showed that although DS gaits predominated throughout development, immature squirrel monkeys nonetheless utilized LS gaits in more than one-third of the ground strides and in nearly one-sixth of pole strides. Gait selection was not significantly associated with either age or body mass per se, arguing against the oft-cited argument that general neuromuscular maturation is responsible for ontogenetic changes in preferred footfall sequence. Rather, lower-level biomechanical variables, specifically the position of the whole-body center of mass and the potential for interference between ipsilateral fore- and hind limbs, best explained variation in footfall patterns. Overall, results demonstrate the promise of developmental studies of growth and locomotor development to serve as “natural experiments”, testing how morphology is, or is not, associated with locomotor behavior – perhaps offering new insight into primate locomotor adaptation. Research supported by the Leakey Foundation, Stony Brook University and NEOMED.

P3.138 YOUNG, Bruce A; DUMAIS, Jessica; MCMAHON, Katelyn; BURNELL, Amy L*; Univ. of Massachusetts, Lowell; *amy.reichlen@gmail.com*

A tale of two tails: Swimming mechanics in Varanus salvator

Varanus salvator is a relatively large, semi-aquatic lizard. The tail makes up nearly half of the total body length, supports a low dorsal fin, and, particularly at the proximal base, has robust musculature. Unlike most semi or fully aquatic vertebrates, the tail of the water monitor tapers to a point with no distal expansion for increased surface area. The mass, physiological cross-sectional area of the axial and hypaxial muscle, and lateral projected surface area all decrease along the length of the tail. When swimming these lizards hold their limbs still against the lateral body surface and make limited axial undulations anterior to the pelvis; this is a form of carangiform or sub-carangiform locomotion. Kinematic analysis demonstrated that the undulatory propagation along the tail of *V. salvator* is similar to what has been described in some anguiliform and other subcarangiform swimmers (e.g., increased amplitude, negative angles of attack, etc.). Applying established equations for undulatory propulsion demonstrates that propulsive force, work, and the slip ratio all decrease along the length of the tail. This creates an unusual situation in which the proximal 1/3 of the tail generates roughly 60% of the propulsive force while the distal 1/3 accounts for less than 15%. A series of experiments involving electromyography, high-speed digital videography, and modeling were undertaken to explore the functional differences between the proximal and distal portions of the tail. In particular, we sought to determine if the distal half of the tail was moving under active muscle control (or through passive coupling with the proximal tail base) and the relationship between expanded lateral surface area and tail length.

P3.130 YOUNG, R.C.*; KITAYSKY, A.S.; Univ. of Alaska Fairbanks; *rebecca.young@alumni.iu.edu*

Life history traits and senescence in six auk species

Current aging theories describe the senescence as caused by accumulated cellular damage, especially damage caused by oxidative stress. Telomeres are a new relatively non-invasive technique tha may be used to monitor senescence. In short-lived species telomere shortening is often tightly linked to aging, however in longer-lived species with "slower" life histories this relationship may be almost entirely decoupled. Because oxidative stress is driven in part by metabolism, life history parameters (such as metabolic rate, growth rate, and reproductive output) are expected to drive evolution of senescence rates. We tested this hypothesis for the three sister-species pairs of auks (in the Alcidae family of long-lived seabirds). We analyzed telomere length in red blood cells of captive birds in relation to their chronological age. Auks are pursuit-diving predators, they vary by diet, lifespan, and body size, but each focal species has a maximum reproductive output of 1 chick per year. This phylogenetically controlled comparison of age-dependent telomere attrition among relatively long-lived piscivorous murres (large bodied), piscivorous puffins (medium bodied), and relatively short-lived planktivorous auklets (small bodied) allows for further development of hypotheses regarding senescence rates in birds that differ in their basic life history and ecological traits.

P2.78 ZALISKO, Edward J.*; ERTON, Timothy S.; FORBES, Scott T.; FEARN, Richard L.; Blackburn College; *ezali@blackburn.edu*

Respiratory Rates of BC-Floater Axolotls in Normoxic and Hypoxic Conditions

At the 2009 SICB meetings, our laboratory first reported a new, non-lethal axolotl phenotype based upon three generations of captive-bred axolotls (Ambystoma mexicanum). The new phenotype, named BC-Floater, results in the sustained inflation of the lungs for weeks to many months. Animals expressing this phenotype float inverted or list for two or more consecutive weeks, with trunks breaking the water's surface. BC-Floaters inhale but rarely exhale, apparently exchanging gases primarily through long gills. The present investigation tested inhalation rates of BC-Floaters in normoxic and hypoxic conditions. BC-Floaters (F; N = 22), Recovered BC-Floaters which once expressed the BC-Floater trait but have recovered on their own to normal body postures (RF; N = 11), and Non-Floaters (NF; N = 19) were individually tested for 30 minutes in three aquatic conditions with varying oxygen concentrations: still water (4.0 mg/L), aerated water (6.4 mg/L), and hypoxic water (1.1 mg/L) created by bubbling nitrogen. In still water, inhalation rates for NF and RF were identical (1.6 breaths/30 min) and were 593% more frequent than rates for F (0.27 breaths/30 min). In aerated water, inhalation rates were similar to still water (NF = 1.2, RF = 1.6, F = 0.18). However, compared to the aerated conditions, breathing rates in hypoxic conditions greatly increased in all groups (NF = 500%, 6.0 breaths/30 min; RF = 563%, 9.0 breaths/30 min; F = 889%, 1.6 breaths/30 min). These data indicate that 1) RF appear to have returned to normal respiratory rates similar to NF, 2) F breathe at statistically significant lower rates than NF or RF (alpha = 0.05), and 3) F increase their respiratory rates greatly in hypoxic conditions to rates comparable to F and RF in aerated water (with 582% greater oxygen levels).

P1.11 ZANOTTO, F/P*; ORTEGA, P; CASTRO, J/M; SA, M/G; UNIVERSIDADE PRESBITERIANA MACKENZIE, SAO PAULO, UNIVERSITY OF SAO PAULO, SAO PAULO; *fzanotto@mackenzie.br*

Cadmium and Calcium Transport in Gill Cells of Ucides cordatus, a Mangrove Crab

Cadmium (Cd) is a transition metal, non-essential for animals and can cause many adverse effects such as alteration of other essential ions during cellular transport. Cd transport has not been studied in detail in crustaceans and it seems to interact with calcium (Ca) transport, an essential ion for crustacean molting. Therefore, the present work was undertaken to characterize Cd transport in gill cells of a crab found in contaminated mangrove regions. For that, gill cells were marked with fluo-3 and the change in fluorescence was followed with the addition of Cd alone, Ca alone and Cd + Ca together in the following equimolar concentrations (0.5, 1.0 and 1.5 uM). Results show that Cd enters gill cells and after 5s the fluorescence decreases to baseline values. Cd transport alone causes a change in fluorescence (ΔF x 4s-1) from 600 (0.5 uM) up to 1,600 for Cd at 1.5 uM. The fluorescence change is smaller for anterior compared to posterior gill cells. Addition of Cd+Ca decreases fluorescence change for all concentrations at around 50%, compared to Cd transport without Ca. BAPTA, a selective intracellular Ca chelator was incubated with gill cells at 2 mM and after that Cd transport was measured. Results show that the change in fluorescence for all Cd concentrations varies from 5-10 fluorescence units in the presence of BAPTA. This work shows that Cd enters gill cells, and equilibrates intracellularly within 4-5 seconds. Moreover, intracellular Ca seems to interfere with Cd transport by decreasing Cd influx dramatically through yet unknown mechanisms. Project supported by FAPESP grant 2009/15546-3 and Mackpesquisa.

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Feeding at the Air-water Interface: Biomechanics and Functional Morphology of Feeding in Funnel-mouthed Tadpoles (Megophryidae: Megophrys)

Larval anurans occupy a great variety of ecological niches, and accordingly they have evolved tremendous diversity of feeding mechanisms. The feeding apparatus of the funnel-mouthed tadpoles is among the most intriguing, but the mechanism of feeding with such apparatus is not well understood. Here the feeding biomechanics and relevant morphology are investigated in details through a combination of lab and field experiments using tadpoles of the genus *Megophrys*, a group native to Eastern and Southeastern Asia. The morphologies of oral discs and branchial skeletons were quantitatively studied multiple species, and a series of high-speed filming and fluid experiments were conducted to examine the hydrodynamic function of this apparatus. Funnel-mouthed *Megophrys* tadpoles filter a thin film of water collected from the surrounding water surface. The film flow is primarily driven by shearing effects generated by the branchial skeleton movements. Moreover, the spatial arrangement and wetting properties of papillae on the oral disc play important roles in channeling and filtering the film flow. Results of these studies suggest *Megophrys* tadpoles use an efficient mechanism to collect the surface film. This work illuminates how functional novelties evolve homologous modules, and contributes to our understanding of the ecology and evolution of adaptive radiation in larval anurans.

P2.112 ZHANG, Y.*; SWANSON, D.L.; Univ. of South Dakota; *yufeng.zhang@usd.edu*
Does the energetically expensive lifestyle of swallows affect thermogenic capacity?
Because both summit (M_{sum} = maximum thermoregulatory metabolic rate) and maximum (MMR = maximum exercise metabolic rate) metabolic rates are functions of skeletal muscle metabolism, correlations between these measures of maximal metabolic output could occur, but this has been little studied in birds. Moreover, because energetically expensive lifestyles are often correlated with high metabolic rates, cross-training effects of a high-energy lifestyle (i.e., high exercise) on thermogenesis, and vice versa, may exist. We tested this cross-training hypothesis with swallows, a family with an energetically expensive aerial insectivore lifestyle. Specifically, we measured basal and summit metabolic rates in six species of temperate-zone breeding swallows to address the question of whether a high-exercise lifestylewas reflected by elevated BMR and thermogenic capacity. BMR for temperate-zone swallows was higher than for tropical swallows, similar to results from other bird taxa. In addition, our preliminary data suggest that BMR in swallows shows a tendency to be higher than BMR for other birds. In contrast, M_{sum} values for the species of swallows that we measured were consistent with Msum values for other swallow species, including tropical species, but the M_{sum}-mass regression for swallows was not significantly different from the M_{sum}-mass regression for other birds. These data suggest that swallow M_{sum} is similar to that for other birds so cross-training effects are not apparent.Thus, the energetically expensive lifestyle of swallows apparently elevates maintenance energy expenditure, but not thermogenic capacity.

P2.106 ZIPPERT, K.J.*; FURIMSKY, M.; Westminster College - PA; *zipperkj@wclive.westminster.edu*
The effect of glucosamine and chondroitin sulfate on fin regeneration in zebrafish, Danio rerio
High performance athletes and body builders commonly utilize supplements to enhance their bodies' ability to repair tissue damaged as a result of overuse and physical stress. Supplements, such as glucosamine and chondroitin sulfate, have been shown to increase tissue growth and regeneration, specifically in heavily used muscles and joints, thus decreasing recovery time following injury. In order to test the effectiveness of glucosamine and chondroitin sulfate on tissue regeneration, the adult zebrafish fin regeneration model was employed. Fish were lightly anesthetized with clove oil, prior to amputating the caudal fin. Following recovery from anesthesia, fish were placed in aquaria containing either chondroitin sulfate or glucosamine, or a combination of the two supplements. Caudal fin regeneration was monitored over the course of fourteen days, with fin growth measurements taken every two days. Experimental groups and control groups were compared to assess the effectiveness of the supplements, chondroitin sulfate and glucosamine, on the rate of zebrafish fin regeneration.

P2.139 ZUNGUL-HASTY, LS*; CAIN, SD; Eastern Oregon University; *zungull@eou.edu*
Localization of NOS in the ciliated foot epithelium of the pond snail Lymnaea stagnalis
Several neurotransmitters have been shown to regulate the behavior of cilia in various animals. These include acetylcholine, serotonin, and at least three neuropeptides. Although these transmitters also function as cilio-regulatory neurotransmitters in sea slugs, other neurotransmitters must control aspects of ciliary behavior not regulated by identified transmitters (e.g. ciliary arrest). Nitric oxide (NO) is a highly reactive gaseous molecule that is present in most organisms as a neurotransmitter. NO is produced when nitric oxide synthase (NOS) catalyzes the conversion of L-arginine to L-citruline and nitric oxide. NO is freely diffusible and typically acts through activation of guanylate cyclase. To determine if NO might contribute to the control of cilia, we investigated whether the enzyme NOS was present in the ciliated foot epithelium of the pond snail *Lymnaea stagnalis*. The foot tissue was labeled by both NADPH diaphorase and NOS immunohistochemistry. Initial results suggest the NOS was present in the foot. The role of NO in the control of ciliary behavior will also be investigated.

P3.45 ZUZOW, M/Z*; SERAFINI, L; HITT, L; VALENZUELA, J; TOMANEK, L; California Polytechnic State Univ., San Luis Obispo; *mzuzow@calpoly.edu*
Proteomic responses of Mytilus congeners to hypo-saline stress
The invading Mediterranean blue mussel species *Mytilus galloprovincialis* requires higher salinity levels than the more hypo-saline tolerant and native *M.trossulus*,which it replaced from its southern range in California, possibly due to climate change.It is also the warm-adapted congener.Hypo-salinity,due to an increase in extreme precipitation events,has been hypothesized to limit the expansion of the invader.By comparing the proteomic responses of the congeners to acute hypo-saline stress we were trying to identify the interspecific differences that set limits to hypo-saline stress and assess their contribution to the range shifts.We exposed mussels to acute hypo-saline(100%, 85% and 70% salinity)stress for 4h followed by a 0h and 24h recovery period while the shells were forced to stay open. We used gill tissue to separate proteins with 2D gel electrophoresis and identify protein expression patterns (two-way ANOVA, $p<0.02$).About a third of the proteins(and the same total number) showed a time-dependent response to different salinities (interaction effects) in both species.A similar proportion showed time-and salinity-dependent patterns (main effect)in *M. galloprovincialis*.Differing slightly, *M.trossulus* showed more of a time-independent response to hypo-saline stress.The results suggest that although there are broad similarities in the responses of the two congeners, *M.trossulus* may be responding faster to hypo-saline stress, which in turn may limit the invaders range expansion.Proteins identified with tandem mass spectrometry include proteins involved in cytoskeletal modifications, molecular chaperones, proteasome, oxidative stress proteins and proteins involved in energy metabolism.

Author Index

AUTHOR INDEX

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