S5.7 ABZHANOV, Arhat; Harvard University, Cambridge; *abzhanov@fas.harvard.edu*

Pecking at the Origin of Vertebrate Diversity

The faces of vertebrates are often readily recognizable as they display a number of species-specific characteristics. It is likely that this stunning diversity of cranial morphology in vertebrates was generated by alterations in craniofacial development. We are employing a combination of genetic, genomic, molecular, bioinformatics, 2-D and 3-D imaging and modeling approaches to understand evolution of craniofacial structures, such as highly adaptive beak morphology in such species as Darwins Finches (a classic example of species multiplication and diversification caused by natural selection) and their relatives and African Seedcrackers (textbook example of adaptive polymorphism), and other avian and reptilian species. The major goal of these studies is to use both novel approaches and well-studied evolutionary examples to address some of the long-standing questions in animal development and evolution.

S9.4 ADAMO, Shelley A; Dalhousie University; *sadamo@dal.ca*

The role of physiological constraints in psychoneuroimmunology

Bidirectional connections between the immune system and nervous system exist in both vertebrates and invertebrates. Although progress has been made in understanding how the two systems interact, the adaptive function of these connections is largely unknown. My colleagues and I found that acute stress-induced immunosuppression occurs in insects (*Gryllus texensis*) because of a conflict between lipid transport and immune surveillance. Similarly, illness-induced anorexia in crickets (*G. texensis*) enhances immune function by preventing conflicts between digestive processes such as lipid transport and immune function. These studies suggest that some immune-neural connections exist to facilitate the shift of multifunctional molecules towards or away from immune function depending on the animals immediate requirements.

80.1 ADAMS, Rick A.; Univ. Northern Colorado, Greeley; *rick.adams@unco.edu*

The dark side of climate change: warmer and drier weather patterns significantly curtail reproductive efforts for western bats.

Climate warming is occurring at an accelerated rate in western North America. This is particularly true at higher elevations throughout the Rockies Mountains and Pacific Coastal ranges whereby mean monthly temperatures, precipitation levels, and water availability have already been significantly affected. In this talk I provide data suggesting that bats provide a bellwether for measuring the effects of ecosystem temperature shifts and loss of water resources. In 2006, we measured visitation patterns to an artificial water source of PIT-tagged lactating and nonreproductive female M. thysanodes and found significance differences between the numbers of drinking passes between these two groups (Nlac = 236, Nnonrepro = 18; Wilcoxon rank-sum, p = 0.0001), with lactating individuals visiting 13 times more often. From these data we construct a decay model for assessing the effects of climate-induced declines in natural water resources on reproductive success of bat populations in areas of western North America currently experiencing climate warming. I take this analysis further by incorporating overall climate data for Colorado on mean temperature, mean precipitation, and mean stream discharge rates over the months of June, July, and August as well as winter snowpack averages and compare these data with a 12-year cumulative record of captures (n = 2,123) and the reproduction status of female bats during that time. Significant declines (p = 0.001) are evident in frequency of female reproductive success as correlated with higher monthly mean temperatures, lower precipitation, and lower stream discharges.

30.3 ADELMAN, J. S.*; WIKELSKI, M. C.; HAU, M.; Princeton University, Max Planck Institute for Ornithology; *jsadelma@princeton.edu*

Sickness behavior and fever vary among free-living sparrows along a life history gradient

Studies in ecological immunology suggest that organisms trade-off the limited resources of time, nutrients, and energy between immune function and other life history traits such as reproductive effort. However, we do not understand which of these resources plays the most important role in shaping such trade-offs. We addressed this question using radio telemetry in free-living song sparrows (*Melospiza melodia*) at three sites along a latitudinal gradient in reproductive effort (as measured by clutch size and breeding season length). During the early breeding season, we studied three aspects of the acute phase immune response: 1) sickness behavior, specifically inactivity, which represents a significant investment of time, 2) acute phase protein synthesis, which uses both amino acids and energy to build defensive proteins, and 3) fever, which requires substantial energy. Birds were either injected with lipopolysaccharide, a non-pathogenic bacterial cell wall component, or handled but not injected. In the southern population, where reproductive effort per unit time is lowest, treated birds showed an extended time-course and increased severity of sickness behavior when compared to northern populations. Moreover, treated birds in the southern population displayed the lowest levels of territorial aggression in response to conspecific playback. Fever also differed among sites; treated southern birds displayed increased temperatures whereas treated northern birds showed early and transient hypothermia. Acute phase protein synthesis, however, was similar at all latitudes. These results suggest that trade-offs involving time and energy, but not amino acids, help shape the differences in the acute phase response among these populations.

72.6 ADRIAENS, D.*; CHRISTIAENS, J.; Ghent University, Gent Belgium; *dominique.adriaens@ugent.be*

Candiru catfish ... a fish with many names and many novelties

Evolutionary novelties are considered as crucial step stones during adaptive evolution, triggering novel functions and allowing novel ecological landscapes to be explored. De novo formations and decouplings may arise leading to these novelties. In contrast, highly specialised body plans, as is the case for parasites, arise as the result of extensive reductions. Counter intuitively, one might wonder whether coupling events may also have allowed evolutionary specialisations. Jaw systems in teleostean fishes are one of the most illustrative cases of how different evolutionary events gave rise to a tremendous spectrum of functional systems. According to the assumption of parsimonous evolution, ancestral transformations general reflect a gradual accumulation of novelties (including simple modifications and more complex decouplings). One special case study has proven to be the blood-sucking candiru catfish, legendary for its feeding habit (and especially its mistakes during feeding). In this study, a detailed morphological study is performed on the jaw system of this Neotropical trichomycterid catfish (*Vandellia* spp.). By comparing its morphology with that of a more basal, but closely related trichomycterid (*Trichomycterus* spp.), the level of structural innovations seems to be impressively high (novel ligaments, novel muscle connections, novel dentition, novel mandibular decouplings, etc.). Compiling data on all the coupled and decoupled structural elements, together with muscular components powering the jaw system, a 3D dynamic model of biting in candiru catfish is proposed. So it seems that in this case, an evolutionary trend towards (ecto)parasitic feeding may be the result of a complex pattern of different types of evolutionary novelties.

S8.3 ALBERTSON, R.C.; Syracuse Univ., Syracuse NY; *rcalbert@syr.edu*

Integration and evolution of the cichlid feeding apparatus II: Adaptations for power.

East African cichlid fish exhibit unparalleled rates of diversification among vertebrates. Their evolutionary history is characterized by repeated bursts of trophic specialization, which has led to the evolution of dramatically different head shapes. A major axis of diversity among Lake Malawi cichlids involves anatomical specializations for the generation and stabilization of force during biting. We show that adaptations for a biting mode of feeding involve stereotypical changes in several elements of the head, and that these skeletal elements exhibit a significant degree of genetic and developmental integration. We suggest that the rapid and replicative nature of cichlid trophic evolution may be due, in part, to unique patterns of integration among trophic characters. The addition of cichlids to the growing number of vertebrate species whose genomes have been sequenced will provide an unprecedented opportunity to test this and related hypotheses.

33.3 ALDWORTH, Z. N.*; DANIEL, T. L.; University of Washington, Seattle; *zna@u.washington.edu*

Wing mechanosensors can transmit bending information at high bit rates.

All insects are equipped with mechanosensory structures in their wings (campaniform sensilla), many of which encode wing bending or strain. In large insects, such as *Manduca sexta*, wings deform significantly during flight. Moreover such deformation can be an important determinant of the aerodynamic forces generated by such wings. Additionally, the bending waves seen in *Manduca* wings may travel at high speeds, well in excess of the time associated with a single wing flap. The extent to which the nervous system can encode such information, however, remains unknown. To address this issue we measured the information transfer rates (bit rates) of wing mechanosensors. We used a band limited Gaussian white noise mechanical stimulus applied to wings with simultaneous intracellular recording from primary sensory neurons. From the statistics of the signal and the emergent spike train we were able to compute the information carried by each spike, and the information transfer rate (bits/s) as a function of stimulus frequency. We found that the jitter (standard deviation of spike occurrence time) is extremely low (200 microseconds) and that the bit rate of information transfer exceeds 100 bit/s and is maximal at a frequency of at least 200 Hz. These results suggest that mechanosensory neurons can transmit strain information at rates that are sufficiently fast to detect bending waves of flapping wings.

64.4 ALFARO, ME*; HARMON, LJ; CARNEVALE, G; SANTINI, F; Univ. of California, Los Angeles, Univ. of Idaho, Univ. of Pisa; *michaelalfaro@ucla.edu*

Did the Fish-Specific Genome Duplication (FSGD) event spawn the teleost radiation? Evidence from the analysis of actinopterygian diversification rates.

The genome duplication hypothesis posits that the duplication of the genome in ancestral teleosts is responsible for the startling disparity in species richness between extant teleosts and nonteleosts (~29000 species vs ~50). Although several studies have corroborated the genome duplication event, there have been no quantitative tests of whether and how diversification rates differ within and among major fish lineages. Here we use a novel stepwise AIC approach in conjunction with a time-calibrated diversity tree of actinopterygians to test whether birth and death rates have shifted in crown teleosts. We find that the teleosts experienced a significant shift in diversification rates that might coincide with the FSGD. In addition, we find evidence for rate increases in the ancestors of the two largest teleost clades: ostariophysans, and percomorphs. We explore the implications of this model for understanding species richness patterns in fishes.

101.7 ALLEN, JD; Randolph-Macon College; *jonathanallen@rmc.edu*
Predator-induced changes in maternal investment in an intertidal snail
Marine invertebrate animals frequently exhibit inducible morphological defenses in the presence of predators. However, few studies have investigated how adults modify reproductive behavior in the presence of predators in order to reduce mortality rates on their offspring. In this study I tested how an intertidal snail, *Ilyanassa obsoleta*, adjusts its investment in eggs and egg capsules in response to a common predatory crab, *Carcinus maenas*. This is a useful system for testing the effects of predators on reproduction because of the readiness with which *Ilyanassa* will lay in the lab, their abundance on mud flats on both coasts of North America and their short time to hatching (~ 2 weeks). Adult *Ilyanassa* have been shown to respond behaviorally to chemical cues from *Carcinus* but the effects of this response on their reproduction has not been assessed. *Carcinus* preys on both adult and embryonic *Ilyanassa* and I therefore predicted that adults would respond to this common predator by adjusting investment in their embryos to reduce intracapsular development time. The mixed development (intracapsular development followed by a feeding larval stage) of *Ilyanassa* was predicted to allow a reduction in one phase of the developmental period (intracapsular development) in favor of an extension of a second phase (a feeding veliger larva) when predation rates are high on the benthos (i.e. when crabs are present). In the presence of chemical cues from predatory crabs, adult *Ilyanassa* laid similar numbers of egg capsules but significantly more eggs per capsule and slightly larger eggs per capsule. Egg capsule size, time to laying and time to hatching were also measured in these experiments and the effects of predatory crabs on these metrics will also be discussed.

98.7 ALMEDIA, Suellen*; IRSCHICK, Duncan; University of Massachusetts at Amherst; *salmeida@student.umass.edu*
The kinetics and kinematics of human performance: Trade-offs between force and accuracy
The production of maximum force during difficult motor tasks is presumed to trade-off with accuracy, but we know relatively little about the nature of this trade-off. We measured the kinetics of a key performance trait (hammering) using a robust Kistler force platform that can effectively measure the force output of hammering strikes. We also filmed strikes with a high-speed video camera to measure key hammering kinematic measures, such as velocity and acceleration. We tested whether there was a trade-off between force (as measured by the force platform) and accuracy (which varied because we varied target size on the force platform). This integration of forces and kinematics allowed us to test whether different individuals employed different hammering strategies, and also whether sex (male versus female) had a significant impact on hammering performance and behavior.

105.3 ALTSHULER, Douglas L.*; PRINCEVAC, Marko; PAN, Hansheng; LOZANO, Jesse; University of California, Riverside; *douga@ucr.edu*
Wake patterns of the wings and tail of hovering hummingbirds
The role of bird tails in generating forces, maintaining stability, and enhancing maneuverability has been considered for birds during forward flight. However, aerodynamic contributions of the tail to hovering flight are completely unknown. Here we demonstrate that hovering Anna's hummingbirds (*Calypte anna*) use complex tail kinematic patterns ranging from in phase to antiphase movement with the wings, covering several phase shifted patterns. We also employed Particle Image Velocimetry (PIV) to attain detailed flow measurements in the horizontal plane under individual hummingbirds at three levels with respect to the tail: in the tail, at the tail tip, and just below the tail. The velocity patterns underneath the wings indicate that flow oscillates between the forward and backward directions in response to the down- and up-strokes, respectively, and that the sideways flows with respect to the bird are consistently from the periphery to directly underneath the body axis. These results are consistent with a ring vortex pattern corresponding to each stroke. The region around the tail is dominated by axial flows along the body axis and away from the bird. We propose that these flows are generated by interaction between the wakes of the two wings at the end of the upstroke, and that the tail acts as a baffle to generate pitching moments that contribute to pitch stability.

5.1 AMARELLO, MELISSA*; NOWAK, E.M.; TAYLOR, E.N.; SCHUETT, G.W.; REPP, R.A.; ROSEN, P.C.; HARDY, D.L.; Southern Illinois University, Carbondale, IL, United States Geological Survey, Northern Arizona University, Flagstaff, AZ, California Polytechnic State University, San Luis Obispo, CA, Georgia State University, Atlanta, GA, National Optical Astronomy Observatory, Tucson, AZ, University of Arizona, Tucson, AZ, 7585 S. Main Ave, Tucson, AZ; *m.amarello@gmail.com*
Body size variation among Arizona populations of the western diamond-backed rattlesnake (Crotalus atrox) is predicted by GIS-based estimates of isothermality and precipitation
In many vertebrates, differences in resource availability and quality are important influences contributing to intraspecific variation in body size, which is coupled with numerous life-history traits. Here, we examined body size variation in relation to resource availability among Arizona populations of the western diamond-backed rattlesnake (*Crotalus atrox*) using GIS-based environmental data. The broad physiographic structure and variable adult snout-vent length (SVL) of *C. atrox* in Arizona provide an ideal model situation to investigate proximate determinants of geographic variation in body size. Our hypothesis asserted that more resources permit continued growth after sexual maturity to an eventual larger body size; thus, adult *C. atrox* will have greater SVL in areas with enhanced or perceived resource abundance. To test this idea, we used precipitation and isothermality to characterize resource availability in a mixed linear model to explain geographic variation in SVL of adult *C. atrox.* In support of our predictions, individuals were larger at sites that were more isothermic and wetter. Our analysis demonstrates the importance of using GIS-based environmental variables and linear mixed effects models to understand geographic variation in body size in lieu of restricting analysis to only a single variable under the framework of a simpler model.

91.9 AMIEL, J.J.*; WASSERSUG, R.J.; Dalhousie University, Halifax, Nova Scotia, Canada; *js448419@dal.ca*

Physiological and Behavioral Adaptations of the Ribbonsnake (Thamnophis sauritus) to Cold Climates

Temperate region snakes that encounter climatic extremes may have behavioral and physiological adaptations that allow them to thermoregulate well below their preferred body temperature. To explore this possibility we used infrared cameras to collect thermal data from ribbon snakes (*Thamnophis sauritus*) in Nova Scotia, where the species is at the northern limit of its range. At our field site *T. sauritus* have been found to be active at air temperatures below 10ºC in the early spring, before all the snow has melted, and in the late fall, after the first snow fall of the season. Two experiments were performed. In the first we tested whether snakes at low ambient temperatures can restrict warm blood to their tails in order to conserve heat for vital organs. In the second experiment we examined whether snakes can perfuse warm blood throughout their bodies by exposing only their heads to direct light while keeping their bodies concealed. When the ambient air temperature is well below the snakes' preferred active temperature they display significant temperature differentials between their bodies and tails. They warm their bodies but their tails remain cold. Snakes also appear to be able to create a thermal gradient along their bodies by exposing just their heads to direct light, and distributing warm blood from their heads to their unexposed bodies. We suggest that behaviors, such as this head-basking coupled with anatomical shunts and preferential perfusion of warm blood, allow these snakes to function at low environmental temperatures. These thermoregulatory processes challenge the widely held belief that reptiles, such as snakes, must be thermal conformers at low ambient temperatures.

S2.8 AN, J.; Shanxi Normal Univ.; *anjianmei@hotmail.com*

A review of bopyrid isopods infesting crabs from China

Isopod parasites of the subfamilies Ioninae and Pseudioninae are known to infest the branchial chambers of brachyuran crabs. In total, 20 species of parasitic isopods infest crabs from China, belonging to 6 genera from the Ioninae and 1 genus from the Pseudioninae. Specifically, the following genera are represented: *Allokepon* Markham, 1982 (3 species), *Apocepon* Nierstrasz & Brender Brandis, 1930 (3 species), *Cancricepon* Giard & Bonnier, 1887 (1 species), *Dactylokepon* Stebbing, 1910 (5 species), *Gigantione* Kossmann, 1881 (4 species), *Onkekepon* An et al., 2006 (2 species) and *Tylokepon* Stebbing, 1906 (2 species). A new species of *Tylokepon* from *Menaethius monoceros* (L.) collected in China is distinguished from other members of the genus by two projections on pereomere 6, and entire pleopods and uropods without any tuberculate on their surface. A list of all brachyuran species (34 species in nine families) so far recorded as bopyrid hosts in Chinese waters, with their parasites and localities will be discussed.

17.4 ANDERSON, C.V.*; DEBAN, S.M.; University of South Florida; *cvanders@mail.usf.edu*

Chameleons Maintain High-Performance Tongue Projection at Low Temperature

The impact of environmental factors on the physiology of ectotherms such as lizards, for example, the effect of temperature on muscle contraction velocity, are known to constrain natural activity patterns. Low temperatures are expected to impact performance of muscle-powered movements such as locomotion and tongue protraction and thereby hinder the ability of many lizards to capture prey. Chameleons are unusual among lizards in that they do not pursue prey by chasing and lunging, but instead use ballistic tongue projection to ambush prey. We hypothesize that chameleons are able to maintain tongue projection performance at a high level at low temperatures-despite the strong influence of temperature on muscle dynamics-by virtue of their tongue projection mechanism, which has been shown to use rapid recoil of elastic collagenous sheaths within the tongue to power tongue launch. We further hypothesize that tongue retraction performance, which relies on the retractor muscle doing work directly on the tongue and prey, is affected strongly by temperature. To test our hypotheses, we imaged *Chamaeleo calyptratus* at 3000 Hz feeding on crickets at 15-35C. For each feeding event, we calculated instantaneous velocity, acceleration and power of the tongue and calculated Q_{10} values of these parameters for both projection and retraction. In accord with our hypothesis, *C. calyptratus* is able to maintain tongue projection performance over the examined temperature range and that peak mass specific power of elastically powered projection is far less sensitive to temperature (Q_{10}=1.21) than muscle-powered retraction (Q_{10}=3.67). The relative temperature insensitivity of tongue projection, combined with the ambush hunting strategy of chameleons, may ease temperature limitations on their activity patterns and may explain observations of chameleon activity over a wider temperature range than sympatric lizard species.

10.11 ANDERSON, P. S. L.; Univ. of Bristol; *Phil.Anderson@bristol.ac.uk*

The Effects of Dental Design on Fracture in Biological Tissues

A primary purpose of dental structures is the fragmentation of food items. It is important to study gnathostome dental morphology in terms of the material properties of the food being consumed. Few studies have examined the interplay between dental shape and fracture mechanics in prey materials. This research utilizes a combination of physical experimentation and FEA modeling techniques to test how different dental blade morphologies affect the cutting mechanics of biological tissues. I tested the effects of blade morphologies on the cutting mechanics of a variety of biological tissues (including fish muscle, cuticle and plant stems and leaves) using a unique double guillotine testing device developed for this project. The double guillotine allows measurement of the work to fracture (energy) required to cut biological tissues and allows a wide variety of blade designs to be tested. FEA software is used to model the biological tissues and calculate internal stresses and strains which occur during cutting. The experimental and modeling results are compared to explore the interaction between blade shape, cutting energetics and fracture mode in biological tissues. Experimental results show that certain blade configurations can reduce the work fracture measured during cutting of biological tissues by up to 50% in comparison with straight blades. Aspects of blade design affect measurements of work to fracture to different degrees depending on the tissue type. Materials with a high poisson ratio, such as animal muscle, show much lower work to fracture measurements when the material is constrained by a bladed notch, as opposed to simply altering the blades approach angle. Results from the FEA models indicate that these differences may be partly due to differences in the primary type of strain within the materials during cutting.

1.8 ANDERSON, R.A.; Western Washington University; *Roger.Anderson@wwu.edu*

Effects of Body Temperature and Distance to Refuge on Risk-Taking in a Lizard

Avoidance and evasion of predators are two complementary strategies contributing to an individuals survival. Terrestrial ectothermic animals such as the heliothermic lizards are hypothesized to vary in their vulnerability to predation as a consequence of body temperature and distance to refugium. Thus, after a lizard has been chased from a basking site back to its refugium, it is expected that both body temperature and distance between refugium and basking location should interact to influence when the lizard will re-emerge and resume basking. The effects of body temperature and distance of refugium from basking site on lizard anti-predator behavior were tested in male western fence lizards, *Sceloporus occidentalis*. Each individual was tested in paired combinations of distance and body temperature: a) warm-near, b) cool-near, c) warm-far, and d) cool-far. Order of tests was random. A test began when a lizard was just beginning to bask or in midst of its first bout of basking for the day, whereupon it was chased to its refugium by an ersatz predator. Time until re-emergence was recorded. The re-emergence times were ranked and non-parametric comparisons for the four treatments were made within and among lizards. There were strong influences of temperature and distance between refugium and basking site. It is inferred from these results that lizards act as though they perceive vulnerability to predation inversely with body temperature and directly with distance, thus altering their behavioral strategies accordingly.

48.1 ANDREW, J*; GEORGE, M; PATEK, S; SWANSON, B; Gonzaga University, University of California, Berkeley; *jandrew@gonzaga.edu*

Morphological and Biomechanical Variation in the Stomatpod Cuticle

The stomatopod crustacean dactyl, a highly derived appendage, can repeatedly smash open very hard snail shells, producing cavitation and impact forces in excess of 1000 N, while sustaining only slight damage to its surface. In this study, we attempt to quantify the microstructure and nanomechanical properties of the stomatopod dactyl that allow this impressive behavior. We examined several locations on the cuticle of the peacock mantis shrimp (*Odontodactylus scyllarus*), an extreme smasher. We also examined several additional species of stomatopods that have a variety of feeding behaviors and raptorial appendage morphologies. We used histology and SEM to image cross-sections of the cuticle. We also used nanoindention to determine hardness, elasticity, stiffness, and an estimation of toughness. We observe unprecedented variation in both cuticle properties and structure across locations on an individual and across species. We are now attempting to determine how the observed structural variation leads to material property variation. The results suggest that the cuticle of the stomatopod is highly derived relative to other crustaceans and that its structure and properties are adapted for multiple functions, including withstanding extreme impact forces.

91.4 ANGILLETTA, M.J.*; SEARS, M.W.; SCHULER, M.S.; RUSCH, T.W.; MITCHELL, W.A.; Indiana State Univ., Terre Haute, Southern Illinois Univ., Carbondale, Univ. of Wisconsin, Stevens Point ; *mangilletta@indstate.edu*

Testing models of behavioral thermoregulation in a spatially-explicit context: a large-scale field experiment

More than three decades after the birth of a quantitative theory of thermoregulation, we still cannot predict the body temperatures of animals in natural environments. For example, a recent comparative analysis indicated that lizards thermoregulated less accurately when the energetic costs of thermoregulation seemed low. Yet theory predicts the exact opposite! This discrepancy likely results from models and experiments that do not account for the spatial distribution of temperatures. We used computer simulations to predict the effect of spatial structure on the costs and benefits of thermoregulatory behavior. All else being equal, thermoregulation confers a greater net benefit in a patchy environment than it does in a clumped environment. We tested this model in replicated arenas (400 m^2) at Sevilleta National Wildlife Refuge, New Mexico. We manipulated the temperature and patchiness of each arena by attaching shade cloth to a wire scaffold. We recorded the body temperatures of 27 spiny lizards (*Sceloporus jarrovi*), each of which experienced the environments of three arenas. In general, lizards thermoregulated more accurately as their environments heated throughout the morning. However, lizards thermoregulated more accurately in patchy environments than they did in clumped environments. This observation accords with the predictions of our spatially explicit model of optimal thermoregulation.

76.1 ARENA, A.J.*; GIBB, A.C.; Northern Arizona University; *aja75@nau.edu*

What's for Dinner? Feeding Ecology of Two Native Fish in Fossil Creek, AZ

Understanding how native fishes obtain food from their environment is critical to understanding current and future threats to their existence. This study examines two native fish representing different trophic levels in the restored Colorado river tributary of Fossil Creek: roundtail chub (*Gila robusta*), a mid-water omnivore, and Sonora sucker (*Catostomus insignis*), a benthic feeder. Here, we examine the feeding behaviors employed by these fish and assess their potential efficacy as biological control agents for invasive crayfish. In laboratory trials, we offered different items representing ecologically-relevant food types (e.g. algae, insect larvae, feeder fish) and noted each species feeding behavior, preferences, and success on each item. Trials were recorded using high-speed video, and feeding kinematics were analyzed to determine which items were aggressively pursued and effectively captured and consumed. Roundtail chub were consistently aggressive feeders: attacking and consuming all food items with the exception of algae. Roundtail chub exhibited no aversion to crayfish; however, crayfish are most susceptible to predation by roundtail chub when crayfish body-depth is >0.5 the fishs gape. Sonora suckers were less aggressive in feeding, preferring to consume only food items on or just above the substrate. In addition, they were sometimes unsuccessful in removing attached food, and generally avoided crayfish. Based on this, we predict that Roundtail chub could be an effective biological control agent for invasive crayfish in Fossil Creek, but that crayfish will grow into a size refuge that will make them difficult or impossible for chub to consume.

70.1 ARMOUR, Maria T.; C.W. Post Campus of Long Island University; *m.t.armour@gmail.com*

Patterns of Variation in Chiropteran Wing Folding: With Special Attention to Differences in Joint Morphology

Bats (Chiroptera) are a diverse group, with more than 1,200 species worldwide, and flight is the synapomorphy that has permitted them to diversify in habitat, behavior, and morphology. All species of bat are similarly equipped with a handwing structure that houses the morphology needed to perform powered flight. Each bat must abide by the same aeromechanical demands placed on them during flight, yet the morphology of their wing structures exhibit significant interspecific variability. Previous phylogenetic studies of Chiroptera have identified differences in wing folding at the family level. This is the first broad-scale study focused on variability at the species level. I examined wing folding-related characteristics across 300 bat species, covering 18 families. Four basic wing folding patterns were described. Digital osteology was studied, in a subset of thirteen species, where I identified aspects of joint morphology involved in those four wing folding patterns. Morphological results showed extreme variation along articulating points of the handwing bones among bat species with correlations between joint morphology and wing folding patterns. The data collected have enabled me to approach several questions including: how do skeletal elements of the handwing vary among species, are there morphological suites of characters arising independently in different lineages, and does flexion pattern along the digits occur independently from the requirements of flight? Interpretation of these data supports my hypothesis that the handwing's joint composition varies across wing folding states.

82.5 ARONOWSKY, A.*; ANGIELCZYK, K.D.; Biodiversity Synthesis Center, Field Museum, Field Museum; *aaronowsky@fieldmuseum.org*

Teaching evolution and biology using 3D virtual worlds; the I Dig Tanzania! project.

In the summer of 2008, 17 teens from New York and Chicago participated in a pilot project using the 3D virtual world, Teen Second Life, to follow and learn from an international team of scientists as they excavated fossils in the Ruhuhu Basin of Tanzania. This digital learning project, called I Dig Tanzania!, was a collaboration between The Field Museum, Global Kids, and the Encyclopedia of Life. Virtual worlds are an ideal platform for teaching biology and evolution because they allow for a highly participatory learning experience where students can manipulate their environment, create and modify creatures, and increase or slow the passage of time. During the intensive online experience of I Dig Tanzania! students worked in virtual groups split between the two cities to study the paleontology, history, and culture of Tanzania. Students used their avatars to communicate and cooperate on projects, and group discussions took place using instant messaging in Second Life. Each day, the scientists in the field uploaded video clips of their activities and spoke with the students via satellite phone. Field Museum and Global Kids staff served as instructors, and designed the curricula each evening as the video came in from Tanzania. Using a custom-designed virtual learning space on Global Kids Island, students excavated virtual fossils alongside the paleontologists, conducted exercises on evolution and adaptation, and constructed virtual museum exhibits to summarize their findings. All of the students also attended a two-day workshop at The Field Museum where they met with members of the fieldwork team, saw newly-discovered fossils being prepared for research, and learned about African culture. Student assessments were based on the final virtual museum exhibits, as well as the daily blog entries students authored during the course of the project.

41.2 ASAKURA, A.*; IMAZU, M.; Nat. Hist. Mus. Inst. Chiba, Japan, Toho Univ., Funabashi, Japan; *asakura@chiba-muse.or.jp*

Occurrence of the rhizocephalan and isopod parasites on three intertidal hermit crabs in Japan

To examine the prevalence of rhizocephalan and isopod parasitism, we sampled three hermit crab species, *Pagurus filholi* (n=5738), *P. maculosus* (n=720), and *Clibanarius virescens* (n=2436) for 13 months from the intertidal rocky shore at Chiba in Pacific coast of the middle Japan. Species of the Peltogastridae (Rhizocephala: ?*Peltogaster paguri*) and species of the Athelginae (Isopoda: Bopyridae: ?*Athelges takanoshimensis*) were found on the abdomens of the crabs and, species of the Pseudioninae (Isopoda: Bopyridae: ?*Pseudione*) occurred in the branchial chambers of the crabs. In total, 10.06% of the collected individuals of *P. filholi*, 4.12% of *P. maculosus*, and 0.93 % of *C. viresens* were infected with these parasitic crustaceans. No conspicuous seasonal difference was detected in the infection rate of these parasites in the all crab species. In *P. filholi*, 12.21% of the males and 8.32% of the females were infected with the rhizocephalan, and 0.05% of the males and 0.06% of the females were infected with the athelgins; the infection rate of the rhizocephalan and the athelgins tended to increase with crab size. The rhizocephalan more frequently parasitized upon males than females, but the infection rate of the athelgins was not significantly different between the sexes. In *P. maculosus*, 1.40% of the males and 0.58% of the females were infected with the rhizocephalan, 2.80% of the males and 2.90% of females were infected with the athelgins, and the 0.35% of the males and no females were infected with the pseudionins; the infection rate was not significantly different between the sexes in all these parasites. In *C. virescens*, 0.27% of the males and 0.43% of the females were infected with the athelgins, and 0.36% of males and 0.78% of females were infected with the pseudionins; the infection rate was not significantly different between the sexes in these parasites.

65.4 ASTHEIMER, Lee B*; PRYKE, Sarah R; MAUTE, Kim; GRIFFITH, Simon C; BUTTEMER, William A; University of Wollongong, Macquarie University; *leeba@uow.edu.au*

Effects of diet quality on glucocorticoid characteristics in Gouldian finch: lessons for evaluating avian health

Estrildid grass finches, including the endangered Gouldian finch *Erythrura gouldiae*, are declining across the extensive tropical savannah habitats of northern Australian. Part of this decline is thought to be related to changing seed quality and availability with changing land use practises. We examined the physiological impacts of low and high quality diets on a captive population of Gouldian finch, including indicators of endocrine, immune function and reproductive function. The diets differed in complexity, seed types and protein content, but were available ad libitum for a 3 month period during which birds underwent moult and mating and attempted breeding. Males and females on the low quality diet exhibited significant reductions in mass, hematocrit, blood hemoglobin level, feather strength and PHA response and these females also had a dramatic reduction in reproductive output. Corticosteroid-binding globulin (CBG) levels in the males and females on the low quality diet were on average half those on the high quality diet, potentially increasing availability of free glucocorticoid. Interestingly, corticosterone levels were not different between females on the two diets, but were significantly lower in males consuming the low quality diet, suggesting the possibility of a gender difference in compensatory response to the increase in free glucocorticoids following a reduction in CBG. These preliminary results will be compared to similar data from free-living populations captured in disturbed and relatively undisturbed habitats.

69.4 ASTLEY, H.C.*; JAYNE, B.C.; Brown University, University of Cincinnati; *henry_astley@brown.edu*

Arboreal habitat structure affects the performance and modes of locomotion of corn snakes (Elaphe guttata)

Arboreal environments pose many functional challenges for animal locomotion including fitting within narrow spaces, balancing on cylindrical surfaces, moving on inclines, and negotiating obstacles. Many species of snakes are arboreal and their elongate, flexible bodies appear well-suited to meet many of these demands, but the effects of arboreal habitat structure on snake locomotion are not well understood. We examined the effects of surface shape (cylinder vs. rectangular tunnel), surface width, incline, and a row of pegs on the performance and modes of locomotion of adult corn snakes (Elaphe guttata). The addition of pegs allowed snakes to move on the widest and steepest surfaces that were impassable without pegs. Tunnels also allowed snakes to move on steeper inclines than cylinders with similar widths. The mode of locomotion changed with habitat structure. On surfaces without pegs, most snakes used two variants of concertina locomotion but always moved downhill using a controlled slide. Snakes used lateral undulation on most surfaces with pegs. The detrimental effects of increased uphill incline were greater than those of increased surface width on maximal velocity. Snakes moved faster in tunnels than on cylinders regardless of whether pegs were present. Depending on surface width, the addition of pegs to horizontal cylinders and tunnels resulted in 8 to 24-fold and 1.3 to 3.1-fold increases in speed, respectively. Narrower bare cylinders enhanced snake locomotor performance, contrary to the detrimental effects of decreased width on the speed of most arboreal limbed animals.

47.5 ATWELL, J.W.*; WHITTAKER, D.J.; KETTERSON, E.D.; Indiana University; *jwatwell@indiana.edu*

Testosterone, social behavior, and ornaments in two recently diverged dark-eyed junco populations

Many studies have confirmed the importance of specific hormones in mediating the expression of ecologically relevant behavior, physiology, and morphology in a wide variety of animals. Far less is known, however, regarding the degree to which hormone-phenotype relationships are predicted to respond in integrated versus independent ways when we look across populations, species, or taxa. For example, few studies have evaluated how changes in the developmental or selective environment experienced by individuals or populations may alter the expression of testosterone [T] and T-associated characteristics such as social behavior, sexual ornamentation, or immune function. Our studies take advantage of a unique colonization event to examine patterns of change in T levels, aggressive and parental behavior, and plumage ornamentation in two divergent populations (one colonist, one ancestral-range) of dark-eyed juncos in S. California. Previous studies have documented reduced male territorial aggression, increased male parental care, and reduced elaboration of sexually selected plumage in the colonist population. Early analyses indicate population-level differences in both the seasonal function and social sensitivity of T expression. We will also present data comparing patterns of hormone-phenotype co-variation within the two populations, and examine patterns of selection on testosterone and T-associated behavior and morphology in each population.

98.10 AZIZI, E*; ROBERTS, TJ; Brown University; *manny_azizi@brown.edu*

Muscle performance during frog jumping: influence of series elasticity on muscle length-tension behavior

The remarkable jumping ability of most frogs cant be explained solely from muscle properties. The maximum power available from hindlimb muscles has been shown to be insufficient to power these ballistic movements. Its been suggested that frogs utilize elastic energy storage in tendons to amplify muscle power during jumps. We explore this elastic mechanism by quantifying the activation timing and length changes of the bullfrog plantaris muscle during jumps. We hypothesize that the muscle will be active and begin to shorten prior to ankle extension, functioning to store elastic energy in tendons. This initial fiber shortening can be substantial and may limit the force generating capacity of fibers due to muscle's length-tension effects. Therefore, we also characterize the length-tension properties of the same muscle using the same transducers immediately following jumping experiments. This protocol allows us to map the *in vivo* muscle length changes onto the length-tension curve in order to test the hypothesis that significant muscle shortening against tendons decreases force output. We find support for the use of elastic energy storage by showing that the plantaris fibers become active and begin shortening in advance of ankle extension. We also find that the plantaris fibers do not develop passive force until stretched to relatively long lengths. This allows the resting length of the muscle to be shifted towards the descending limb of the active length-tension curve allowing most of the fiber shortening during a jump to occur over the plateau of the length-tension curve. The passive compliance of this muscle enhances active force production during an elastic energy storage mechanism reliant on muscle shortening. Supported by NSF grant 642428 to TJR.

S7.8 AZIZI, E*; ROBERTS, TJ; Brown University; *manny_azizi@brown.edu*

Mechanical Behavior of Aponeuroses

The elastic structures of many muscles include both an extramuscular free tendon as well as a sheet-like aponeurosis. Free tendons and aponeurosis are structurally similar with collagen fascicles being primarily oriented along the muscles line of action. Unlike free tendons, aponeuroses surround a substantial portion of the muscle belly and may therefore be loaded both parallel (longitudinal) and perpendicular (transverse) to a muscles line of action when contracting muscles bulge to maintain a constant volume. However, little is known about the biaxial strain patterns and mechanical properties of aponeuroses. Here we quantify the mechanical properties of the turkey lateral gastrocnemius aponeurosis in the longitudinal and transverse directions using uniaxial materials tests. We then quantify the pattern of biaxial loading during force production *in situ* using biplanar video fluoroscopy. We find that the aponeurosis has a significantly higher Young's modulus in the longitudinal than the transverse direction. Our results also show that aponeuroses can behave as efficient springs in both the longitudinal and transverse directions losing little energy to hysteresis. Results from *in situ* experiments show that aponeuroses are stretched in both longitudinal and transverse directions during force production and that transverse strains are on average 4 times higher than longitudinal strains. The presence of large transverse strains highlights an important difference between sheet-like aponeuroses and free-tendons. We suggest that biaxial loading potentially functions to alter aponeurosis stiffness dynamically during force production, thereby increasing the tissues capacity for elastic energy storage. Supported by NIH grant AR055295 to TJR and AR054246 to EA.

43.2 BAHLMAN, Joseph Wm*; RISKIN, Daniel K.; IRIARTE-DIAZ, Jose; SWARTZ, Sharon; Brown University, University of Chicago; *joseph_bahlman@brown.edu*

Aerodynamics of the northern flying squirrel (Glaucomys sabrinus)

Most studies on mammalian gliders deduce glide aerodynamics from the location of the launch and landing, using an assumption of steady-state aerodynamics. During steady-state gliding, all forces are balanced, velocity is constant, and motion is passive, powered only by gravity. However, considering the dynamic nature of the wings structure (articulated limbs and compliant membranes with muscles imbedded in the skin) and the complex forest environments where the animals glide, the assumption of steady-state aerodynamics may not be warranted. To test the hypothesis that mammalian gliders use steady-state aerodynamics we used high speed video to record the 3-D trajectories of wild flying squirrels over a variety of glide distances in their natural habitat. From these trajectories, we calculated velocities, accelerations, forces, force coefficients, glide ratios, and lift-to-drag ratios. Our results show that flying squirrels do not use steady-state aerodynamics at any point in glides of any of the distances examined. Instead, the squirrels generate more net aerodynamic force than their bodyweight, allowing significant upward and forward accelerations. Additionally, the squirrels show changes in their force coefficients and lift-to-drag ratios during glides, indicating active and coordinated control of non-steady glide paths. This way, squirrels achieve the same glide ratio as they would using steady-state aerodynamics, but with considerably greater total and horizontal velocity. Because the squirrels are able to change force coefficients, and redirect force upward or forward by adjusting the lift-to-drag ratio, they are able to modulate their lift and thrust generation.

43.5 BAIER, DB*; GATESY, SM; DIAL , KP; Brown University, Montana State University; *David_Baier@brown.edu*

Forelimb skeletal kinematics of chukar partridges (Alectoris chukar) during wing-assisted incline running and ascending flight

The origin of avian flight remains controversial. Recent studies have shown that birds use their wings not only for flight, but also when scrambling up steep inclines (ca. 60 to 90+) to an elevated refuge. Vulnerable fledglings can employ Wing-Assisted Incline Running (WAIR) to access otherwise inaccessible escape routes. Thus, WAIR presents a sound ecological basis for how forelimbs evolved into proto-wings and then into flight capable wings. Wing-stroke excursion differs superficially between WAIR and flight, but the underlying skeletal motions are masked by feathers and skin. We used the dual X-ray of the newly developed XROMM system (X-ray Reconstruction of Moving Morphology) to quantify 3-D skeletal kinematics in Chukar Partridges during WAIR up a 70 ramp to a perch and during ascending flight along the same trajectory. CT models of shoulder girdle and wing elements were positioned and oriented to match the two video views to measure shoulder, elbow and wrist joint motion. Overall, the patterns of motion are similar for all joints during both WAIR and ascending flight, but vary in a few key aspects. Glenohumeral elevation/depression ranges from ca. 80 to -5 during flight but depression is truncated to about 30 during WAIR. Glenohumeral pronation during flight is ca. 20 greater at the downstroke/upstroke transition. Wrist flexion and extension are also greater during ascending flight. Elbow motion is similar between both WAIR and flight.

S9.6 BAILEY, Michael; The Ohio State University; *bailey.494@osu.edu*

Impact of stressor exposure on intestinal microbiota

The field of PsychoNeuroImmunology (PNI) has clearly demonstrated that exposure to psychological stressors can disrupt immune functioning. For the most part, studies have focused on innate and adaptive immune responses, with few studies focusing on more basic defenses, such as the commensal microbiota. The healthy human is colonized by a vast array of microbes that exceeds cells of the body by a factor of 10:1 (i.e., 10^{14} microbes:10^{13} human cells). These microbes have many beneficial effects on the host and comprise a strong natural barrier to invading pathogens; disrupting the microbiota is known to enhance susceptibility to enteric diseases. The factors regulating the types of bacteria that comprise the intestinal microbiota, as well as the levels to which they can grow, are not well defined. But, it is known that certain components of gastrointestinal functioning strongly influence microbial populations. Moreover, these functions are altered during a stress response. Thus, it was hypothesized that stressor exposure would affect the intestinal microbiota. Initial studies in rhesus monkeys (*Macaca mulatta*) supported this hypothesis by demonstrating that exposure to stressors early in the lifespan significantly reduced levels of commensal lactobacilli that are thought to protect the intestines from infection. In more recent murine studies, exposure to a prolonged stressor (i.e., repeated restraint stress) led to a significant overgrowth of Gram-negative bacteria. Moreover, DNA sequencing, using pyrosequencing methodology, indicated that microbial diversity in the intestines was reduced from 1200 to 900 operational taxonomic units after stressor exposure. While the physiological importance of these alterations is currently being studied, the data indicate that prolonged stressors significantly alter intestinal microbial populations, and implicate an additional mechanism through which stress can affect health.

92.10 BAKER, D.M.*; MCCORMICK, S.D.; Univ. of Mary Washington, USGS, Conte Anadromous Fish Research Center; *dbaker2@umw.edu*

Seasonal and developmental expression of growth hormone regulatory neuropeptides in Atlantic salmon (Salmo salar).

In Atlantic salmon, *Salmo salar*, circulating levels of growth hormone (GH) are known to vary with developmental stage and season. GH levels increase dramatically in spring in fish transforming from freshwater-adapted parr to seawater-adapted smolts. The vernal increase in GH is entrained by photoperiod: early exposure to a long-day photoperiod advances the increase in GH. We investigated the role of the neurohormones pituitary adenylate cyclase-activating polypeptide (PACAP, a GH secretagogue) and somatostatin I and II (inhibitors of GH secretion) in mediating these changes in GH levels by measuring the respective mRNA transcript levels throughout the spring. In one study, brains were collected from parr and presumptive smolts throughout the spring months. In a second study, brains were collected from fish exposed to an advanced photoperiod in early spring. For both studies, RNA was extracted separately from the hypothalamus and telencephalon, and mRNA transcripts were measured by quantitative PCR. Hypothalamic somatostatin mRNA levels declined from March to May in both parr and smolts. Hypothalamic somatostatin mRNA levels also declined in fish exposed to an advanced long-day photoperiod, compared to natural photoperiod controls. No significant differences in levels of PACAP mRNA were detected in the hypothalamus. Analysis of the mRNA levels of these neuropeptides in the telencephalon is in progress and will also be presented.

85.4 BALDWIN, J. L.*; JOHNSEN, S.; Duke Univ.; *jamie.baldwin@duke.edu*
Pining for Pinups: the importance of color in mate choice of the blue crab Callinectes sapidus
Despite the economic and ecological importance of the blue crab *Callinectes sapidus*, their vision has been little studied, particularly in regard to sexual signaling and mating behavior. While one study suggested that blue crab males select female mates based on the redness of their claws, most research has focused on the use of pheromones for mate attraction. We examined the responses of male crabs to photographs of females in submissive sexual postures with differently colored claws using binary choice experiments. Mature male blue crabs were collected from Jarretts Bay, North Carolina and transported to Duke University, Durham, NC where they were kept in individual compartments of a 300-gallon recirculating sea system. In binary choice experiments, a photograph of a mature female crab with red claws was presented along with the same photograph in which the red coloration had been changed to black or to white. By observing and scoring courtship behavior, we found that 15 out of 17 males preferred females with red claws to females with black claws ($p < 0.002$; one-tailed Exact Binomial Test) and 9 out of 11 males preferred red claws to white claws ($p < 0.05$; one-tailed Exact Binomial Test). These results are evidence for color vision in blue crabs and also imply that a long wavelength photopigment may be present. They also show that visual cues are used in mate attraction and preference, and that courtship behavior can be stimulated in the absence of pheromones. Visual signals may play a larger role in mate attraction and courtship than previously considered. Thus, water quality should be considered in conservation efforts because increasing water turbidity in mating areas of *C. sapidus* may limit signal visibility.

97.1 BALTZEGAR, David A*; OZDEN, Ozkan; BORSKI, Russell J.; North Carolina State University, Raleigh; *dabaltze@ncsu.edu*
Claudin mRNA expression in Mozambique tilapia (Oreochromis mossambicus) gill tissue: implications for osmoregulation and salinity adaptation.
Claudins, a superfamily of tetra-spanning transmembrane proteins, are major constituents of epithelial tight junctions. Claudins are selectively expressed in different tissues, and the relative amount and composition of these proteins are thought to govern transepithelial resistance by selective ion permeability within the tight junction. In mammals, 24 claudins have been reported. A putative genome duplication event has led to a large expansion of claudin genes within the teleost lineage, with 56 claudins reported in the Japanese puffer. These claudins may function in hydromineral balance in teleosts by governing the paracellular ion transport properties of gill epithelia. Claudin regulation during salinity adaptation in fish is still not well understood. We have cloned and characterized three claudin genes: Cldn3c, Cldn28a, and Cldn30 in the Mozambique tilapia (Oreochromis mossambicus). Maximum likelihood phylogenetic analyses of tilapia Cldn28a and Cldn30 suggest distant homology to mammalian Cldn4, while Cldn3c is related to mammalian Cldn3. We found that the mRNAs of these claudins were expressed in a tissue-specific distribution profile in freshwater (FW; 0-2 ppt) and seawater (2/3 SW; 25 ppt) fish. Expression of these genes is most abundant in gill and skin, with Cldn30 and Cldn3c also showing significant abundance in posterior intestine. In the gill, Cldn3c expression is significantly lower in seawater fish ($p < 0.001$) compared to freshwater fish. Cldn28a and Cldn30 expression did not vary between long-term acclimated fish. Along with our previous studies, these results suggest that multiple claudins may be important in salinity acclimation in tilapia.

45.4 BALTZLEY, MJ*; GAUDRY, Q; KRISTAN, JR., WB; St. Mary's College of Maryland, University of California, San Diego; *mjbaltzley@smcm.edu*
Changes in synaptic connections between mechanosensory neurons in leeches mediates species-specific behavior patterns.
We characterized the behavioral responses of two species of leeches, *Hirudo verbana* and *Erpobdella obscura*, to mechanical skin stimulation. In response to mechanical stimulation, *Hirudo* showed the well-characterized local bending behavior, in which the body wall shortened only on the side of the stimulation. *Erpobdella*, in contrast, contracted both sides of the body in response to touch, producing a behavior we call tensing. To investigate the neuronal basis for this behavioral difference, we studied the interactions between the pressure mechanosensory neurons (P cells) that innervate the skin. Each midbody ganglion has four P cells; each cell innervates a different quadrant of the body wall. Consistent with the local bending behavior, activating any one P cell in *Hirudo* elicited polysynaptic inhibitory potentials in the other P cells. In contrast the P cells in *Erpobdella* had excitatory polysynaptic connections, consistent with the segment-wide contraction observed in this species. Preliminary data in a third leech species, *Macrobdella decora*, indicate that the P cells in *Macrobdella* have excitatory polysynaptic connections. Because *Erpobdella* and *Macrobdella* are basal to *Hirudo* within the leeches, these results suggest that *Hirudo* may have evolved a more localized pressure mechanosensory system through lateral inhibition of P cells.

2.5 BANET, Amanda I.*; AU, Arthur G.; REZNICK, David N.; University of California, Riverside; *amanda.banet@email.ucr.edu*
Testing an assumption of a model for the evolution of placentas
Trexler and DeAngelis presented the first mathematical model for the evolution of the placenta. The model predicts that placentas will evolve in consistent, high resource environments. Imperative to the model is the assumption that placental species can abort a subset of developing offspring in low food conditions. Without this ability, the range of resource conditions in which a placental species can out-compete a non-placental species is extremely narrow. We test this assumption using two independent origins of placentation in the genus *Poeciliopsis*. We found no evidence that placental species abort offspring. Instead, placental species appear to be tethered to a brood once it is initiated and sacrifice body condition to maintain reproduction when resources are restricted.

94.5 BARNES, BM; Univ of Alaska, Fairbanks; *ffbmb@uaf.edu*
Circadian rhythms in free-living arctic ground squirrels.
The persistence and function of circadian rhythms in hibernators is controversial. Hibernating mammals withdraw from the environment and undergo profound changes in body temperature (Tb), yet individuals require and demonstrate precise seasonal timing. We are examining expression of circadian and seasonal rhythms in free-living arctic ground squirrels under arctic field conditions by use of internal temperature-sensitive dataloggers and telemetry collars that indicate the timing of use of burrows. Prior to immergence into their hibernacula, ground squirrels showed robust diurnal rhythms of Tb and activity. After ground squirrels become sequestered in their dark burrows but prior to becoming heterothermic, circadian rhythms in Tb continued, but with lower amplitudes, declining averages, and freerunning periods. In some animals, indications of a circadian signal occurred during entry into the first torpor bout, but during the next 5-7 months there were no circadian or other rhythms expressed during torpor or during euthermic phases of arousal episodes. In spring after males resume euthermy but remain in their burrows for 1-3 weeks, the lack of circadian organization continued. Circadian (diurnal) rhythms abruptly resumed when animals first emerged on the surface. Throughout the active season, diurnal rhythms of Tb and activity remained remarkably well entrained to 24 h, despite 3 months without sunrise or sunset. We suggest that expression of circadian timing in arctic ground squirrels is suppressed during hibernation and reactivated in spring on first exposure to light. Thus timing of arousal episodes and termination of hibernation requires mechanisms separate from the circadian clock. Entrainment during the arctic summer appears to be sensitive to subtle light cues and may act to synchronize activity to minimize thermoregulatory costs.

S1.4 BARTH, F.G.; University of Vienna, Vienna;
friedrich.g.barth@univie.ac.at
Plenary Talk: Computational Biomechanics, Spiders, and the Sense of Senses
COMPUTATIONAL BIOMECHANICS,SPIDERS,AND THE SENSE OF SENSES Friedrich G. Barth,University of Vienna,Life Sciences,Department of Neurobiology and Cognition Research,Althanstr.14,1090 Vienna, Austria Despite the tiny size of their brain many *arthropods* show highly elaborate behavior.There is increasing evidence that one of the reasons for the existence of this seeming contradiction is a clever sensory periphery with highly selective sensory organs tuned to the specific needs of a particular behavior in a particular (noisy) species specific environment.In *spiders* the central nervous system (CNS) is made up of ca.10^5 neurons only. The sensory cells supplying their sensors by far outnumber the neurons in the CNS.The lecture will focus on *mechanosensory sensilla* which in many species of spiders dominate the guidance of behavior. Much of the technical perfection and diversity of these mechanoreceptors lies in the mechanical processes characterizing the uptake and trans-formation of the adequate stimuli. To understand these processes advanced engineering tech-nologies and mathematical modelling were applied in collaboration with engineers.The sensilla presented will be *tactile hairs, hairs sensitive to air flow, and cuticular strain and vibration detectors*. It will be seen that the sensitivity and selectivity of these sensors to a surprisingly large extent reflect properties of behaviorally relevant spatio-temporal stimulus patterns. Although the technical refinement is of interest in its own right and a source of inspiration for the development of artificial sensors, its bio- logical significance can only be fully appreciated when the behavior and ecology of the entire organism are taken into account. Clearly, much of the answer to the question why arthropods with small brains perform so well behaviorally lies in the sophisticated matched filter properties of their sensory periphery.

S7.9 BARTHELAT, Francois; McGill University; *francois.barthelat@mcgill.ca*
Structure and Properties of Mineralized Tissues: The Deformation and Fracture of Nacre from Mollusc Shells
For millions of years natural organisms have been incorporating minerals for structural purposes, mainly to achieve the stiffness required for mechanical support (bones), cutting and crushing aliments (teeth) or protection against predators (seashells). The individual components of these mineralized tissues are relatively weak, yet complex hierarchical microstructures provide them with remarkable mechanical performances and unique combinations of stiffness, hardness and toughness. A good example of such material is nacre, the material of pearls found in mollusc shells. Nacre contains 95% of the brittle mineral aragonite, which comes in the form of microscopic polygonal tablets tightly stacked to form a three dimensional brick wall. A small fraction (5%) of organic materials is found at the interfaces and bonds the tablets together, while enabling them to slide on one another under mechanical stresses. This unique mechanism makes nacre 3,000 times tougher than aragonite, a degree of improvement currently not matched by any manmade composite material. Using combinations of small-scale mechanical experiments and modeling we have discovered a key microscopic feature responsible for the spreading of tablet sliding over large volumes. The mechanical energy dissipated in this process explains the tremendous toughness of Red Abalone nacre. Nacre from Pearl Oyster has is slightly different microstructure, and recent experiments on this material have revealed an even greater toughness with patterns of deformation and fracture never observed before. Understanding nacres with different structures across different species is expected to yield new insights into the design and optimization rules underlying its construction. This will in turn guide the development of novel biomimetic materials with superior properties.

55.11 BARTHELL, J.F.*; CLEMENT, M.L.; WELLS, H.; CROCKER, K.C.; BECKER, E.C.; LEAVITT, K.D.; MCCALL, B.T.; MILLS-NOVOA, M.; WALKER, C.M.; PETANIDOU, T.; Univ. Central Oklahoma, Univ. of Tulsa, Cornell Univ., Portland State University, Oklahoma State Univ., Lewis and Clark College, Univ. of the Aegean, Lesvos; *jbarthell@ucok.edu*
Foraging Patterns of Bees in Response to Nectar Availability in Populations of the Invasive Thistle Species Centaurea solstitialis L. in Native (Greece) and Non-Native (USA) Island Ecosystems
We compared nectar flow and standing crop levels among populations of the highly invasive plant species yellow star-thistle, *Centaurea solstitialis* L., to test the hypothesis that nectar levels influence the guild composition and foraging patterns of bees. Specifically, we predicted that the invasive, eusocial honey bee (*Apis mellifera* L.) responds differently to nectar availability than do the predominantly native, non-social bee species. The work was conducted at two island ecosystem locales, including the Northeast Aegean island of Lesvos (Greece) and Santa Cruz Island (California, USA) where studies of honey bees have been conducted in the past. At both locales, we found that larger bodied and/or social bee species were associated with those plots with higher average nectar standing crop levels. Indeed, on Lesvos, we found that honey bees were more abundant on the nearby high nectar-secreting plant species *Vitex agnus-castus* L. These patterns are consistent with other data and at least one model described in the literature. Additionally, we report on levels of damage to flower heads by natural enemies (tephritid flies) and suggest how negative ecological interactions (e.g., phytophagy) may ultimately compromise the success of invasive plant species in newly invaded environments.

51.4 BASSETT, Daniel K; WEBB, Jacqueline F*; University of Rhode Island; *jacqueline_webb@mail.uri.edu*

Lateral line-mediated prey detection in the Lake Malawi cichlid, Aulonocara hansbaenchi

Among fishes, the lateral line system plays a role in navigation, communication, predator avoidance, and prey detection, but the functional significance of variation in lateral line morphology is still not well-understood. Peacock cichlids of Lake Malawi (*Aulonocara* spp.) have widened lateral line canals, a morphology that enhances sensitivity to local water flows such as those generated by invertebrate prey. We tested the hypothesis that the lateral line system mediates prey detection in *A. hansbaenschi*. Six live and six fresh frozen (dead) brine shrimp were tethered in pairs in six petri dishes randomly placed in a 3X4 grid in the sandy substrate of an experimental tank. Standard digital video was used to describe prey detection behavior of individual fishes. At night, prey detection was generally preceded by a glide, and a pause and a 180 swimming reversal that re-positions the prey under the mandible prior to strike. During the day, prey detection tended to be preceded by a glide and a change in orientation. More live (vs. dead) prey were eaten at night, but during the day high numbers of both live and dead prey were eaten. Deactivation of the lateral line with cobalt chloride virtually eliminates the ability to detect live prey at night. Thus, we have demonstrated that *A. hansbaenschi*: 1) can feed nocturnally, 2) uses its lateral line system for the detection of hydrodynamic stimuli produced by live prey especially at night, and 3) alters its prey search and detection behavior when feeding on the same prey under light and dark conditions. The widened lateral line canal morphology in *Aulonocara* is convergent with that in taxa in more than a dozen families, some of which are known to feed on infaunal benthic prey or in midwater. *Aulonocara* will be developed as a model to understand the developmental and genetic bases for functional evolution of the lateral line system among fishes.

54.1 BAUCHINGER, U.*; MCWILLIAMS, S. R.; University of Rhode Island ; *ulf.bauchinger@orn.mpg.de*

Carbon turnover in tissues of a passerine bird: allometry, isotopic clocks, and phenotypic flexibility in organ size

Stable isotopes are an important tool for physiological and behavioral ecologists, their usefulness depending on a thorough understanding of the dynamics of isotope incorporation into tissue(s) over time. In contrast to hair, nails and feathers, most animal tissues continuously incorporate carbon (and other elements) and so carbon isotope values may change over time depending on resource use and tissue-specific metabolic rates. Here we report the carbon turnover rate for 12 tissues from a passerine bird, the zebra finch (Taeniopygia guttata). We measured carbon half-life (Ct1/2) of 2.6 d for small intestine, 4-7 days for liver, proventriculus, gizzard, pancreas, and kidney, 10-15 days for heart, brain, red blood cells, and flight muscle, and 18-20 days for leg muscle and skin. We used these data, along with the few other published estimates, to confirm that fractional rate of isotopic turnover for red blood cells, whole blood, liver, and leg muscle scales with body mass to the approximately -1/4 power. Our data also support several key assumptions of the isotopic clock model that uses differences in isotope value between tissues, along with estimates of turnover rate of these tissues, to predict time elapsed since a diet shift. Finally, we show that between-tissue differences in turnover rate largely, but not completely explained the extent of phenotypic flexibility in organs of garden warblers during their long-distance flight across the Sahara desert during spring. More studies are needed that measure tissue-specific protein synthesis, metabolic rate, and elemental turnover in many tissues from a variety of animals.

55.5 BAUMANN, Hannes*; CONOVER, David O; Stony Brook University, Stony Brook; *hannes.baumann@stonybrook.edu*

Contrasting latitudinal patterns of countergradient growth variation in silverside fishes (Pisces: Atherinidae) from the Pacific vs Atlantic coasts

Growth capacity comprises an important trait in fish upon which natural selection can operate. Along latitudinal gradients, growth rate often displays countergradient variation (CnGV) as, for example, in the Atlantic silverside *Menidia menidia*. In this species, growth capacity increases greatly with latitude, a likely response to shorter growing seasons and the size selectivity of winter mortality. In this study we ask whether CnGV would also apply to Pacific silversides, and if so, how do the reaction norms of temperature-dependent growth compare between the two coasts? We conducted common garden experiments on topsmelt, *Atherinops affinis*, that were obtained by strip-spawning adults from populations in southern California (Tijuana Estuary, 33N), mid-California (Elkhorn Slough, 37N), and mid-Oregon (Coos Bay, 43N). Individuals were reared in 3 replicates at 15C, 21C, and 27C under ad libitum feeding conditions until approximately 35 mm total length. We found a clear pattern of increasing growth rates with latitude for any given temperature, consistent with what is known for Atlantic silversides. However, the magnitude of the effect was much smaller in Pacific compared to Atlantic silversides. For example, mean growth rates at 27C varied between 0.64 - 0.85 mm/d for southern- and northernmost topsmelt populations, respectively, while *M.menidia* growth rates at comparable temperatures have been reported to range between 0.8 1.4 mm/d. At low temperatures, the patterns appear to be reversed, with higher and latitudinally more variable growth rates in Pacific than Atlantic silverside populations. These results suggest that the thermal plasticity of growth evolves in direct correspondence with the temperature range normally experienced in nature.

88.4 BEATTY, B.*; WERTH, A.; WOOD, C. B.; New York College of Osteopathic Medicine, Hampden-Sydney College, Providence College; *bbeatty@nyit.edu*

Aprismatic enamel microstructure and tooth sharpness in odontocetes: economy or adaptation?

The evolution of enamel microstructure in cetaceans has been characterized as an early, simple reversal to the aprismatic condition considered plesiomorphic to mammaliaforms. Odontocete dentitions in particular are generalized as having simplified enamel microstructure, occlusion (non-occlusal, only interdigitating), and tooth morphology (peg-like, homodont). These are all interpreted as the result of a single modification from mastication to raptorial prey-capture and/or suction feeding. Our study of enamel microstructure, tooth sharpness, and gross dental wear of odontocetes and several archaeocetes allow identification of a positive, complex relationship between heterodonty (apomorphic in some), enamel microstructure, and dental wear (not simply breakage). Enamel thickness, the presence and type of prisms, and absence of Hunter-Schreger bands correlate with some loss of occlusal function. Breakage is evident among taxa that have thin and/or less prismatic enamel, such as Delphinapterus, but have returned to more damaging diets (sarcophagy). The generalizations of odontocetes as homodont and non-masticating are not applicable to the whole clade. Rather, a continuum exists in which some members continue some ancestral dental function to the present day, whereas others autapomorphically lose masticatory ability. When sarcophagous taxa are excluded, a negative relationship between sharpness and prismatic enamel is evident, suggesting the loss of prismatic enamel may have been an adaptation for increasing sharpness in odontocetes. Moderate homodonty and polydonty of toothed mysticetes indicates that some of these changes occurred before the split of the Odontoceti and Mysticeti. More fossils of stem Neoceti are needed to clarify the polarity of these changes.

76.2 BEEKEY, Mark A.*; MATTEI, Jennifer H.; Sacred Heart University; *beekeym@sacredheart.edu*

Project Limulus: What long term mark/recapture studies reveal about horseshoe crab population dynamics in Long Island Sound.

Project *Limulus* is a long-term study of the population dynamics of the American Horseshoe Crab, *Limulus polyphemus*, in Long Island Sound (LIS). Since 1997, we have tagged over 20,000 spawning adults ranging from Brooklyn, New York to Narragansett Bay, Rhode Island. Over 2000 individuals have been recaptured (9.3%). Analysis of recapture patterns indicates that both males and females exhibit moderate site fidelity within spawning seasons. However, across spawning seasons, only 45% of individuals are recaptured within a few miles of their original tag site. There is no significant difference between males and females with respect to the direction or distance of movement post spawning. Male and female horseshoe crabs appear to move east and west of the tag site with equal frequency. Of all recaptures, 99% of individuals were recaptured within LIS. The mark recapture data supports the idea of a closed population. Within LIS, individuals cross state lines supporting the need for the development of an integrated multi-state management plan. Finally, this past year we collaborated with many groups from MA and RI to conduct coordinated horseshoe crab spawning surveys on the new and full moons along the New England coast. Preliminary findings reveal similar spawning indices, sex ratios, and mating patterns across CT, the north shore of Long Island, RI, and MA beaches.

55.8 BELDEN, L.K.*; WOJDAK, J.M.; Virginia Tech, Radford University; *belden@vt.edu*

Combined impact of parasites and predators on wood frog tadpoles

Predators can have important impacts on host-parasite dynamics in natural systems. Some predators are hosts that become infected after consuming infected prey. In other cases, predators that are not themselves hosts can reduce transmission by removing the most heavily infected individuals from the population. Less is known about how predators might influence parasite dynamics in systems where the parasite relies on vectors or numerous different host species to complete their life-cycle. Digenetic trematodes are a diverse group of parasitic flatworms with complex life-cycles typically involving three host species. They can infect all vertebrate classes, and are common parasites in freshwater systems containing aquatic snails, which serve as obligate first intermediate hosts. In this study, we examined the impact of two trematode species (*Echinostoma trivolvis* and *Ribeiroia ondatrae*) and predatory larval salamanders (*Ambystoma jeffersonianum*) on short-term survival of larval wood frogs (*Rana sylvatica*). Both parasites and predators significantly reduced tadpole survival in experimental outdoor pools. After six days, tadpole survival was reduced from 100% in control pools to a mean of 46% in pools containing infected snails and a mean of 49% in pools containing predators. In pools containing both infected snails and predators, tadpole survival was further reduced to a mean of just 5%. These dramatic results suggest that non-host tadpole predators could potentially limit transmission of trematode parasites in systems with intense predation. In addition, the parasites themselves may cause substantial mortality to second intermediate hosts which could also limit transmission to the next host.

54.2 BEN-EZRA, E.*; HUMPHRIES, M.M; McGill University; *elad.ben-ezra@mail.mcgill.ca*

Intra-specific variation in the metabolic rate of the red squirrel (Tamiasciurus hudsonicus) across western Canada

Metabolic rate is a fundamental trait that determines the amount of energy an organism can process and allocate to growth, maintenance, and reproduction. While metabolic rate is known to scale with mass, there is a significant amount of residual inter- and intra-specific variation that can be partially explained by differences in climate, temperature, and habitat. Latitudinal gradients in intra-specific metabolism incorporate large variation in many of these factors and reveal how the physiological ecology of local populations varies within a species' range. We examined variation in the metabolic rate of the North American red squirrel, *Tamiasciurus hudsonicus*, by sampling individuals from seven populations along a latitudinal gradient in western Canada, spanning over 3000 km from northern Yukon to southern Alberta. We found that whole-body metabolic rate increased with latitude, while no relationship existed between latitude and mass-specific metabolic rate. This study is the first to examine large-scale intra-specific variation in the metabolic rate of a small mammal.

91.8 BEN-HAMO, Miri*; BAUCHINGER, Ulf; PINSHOW, Berry; Ben-Gurion University of the Negev; *miriammi@bgu.ac.il*

A reassessment of proximate factors that trigger hypothermia in Japanese quail

Food deprived Japanese quail (*Coturnix coturnix japonica*) were reported to enter hypothermia with no change in its depth, in terms of reduced body temperature (T_b) and metabolic rate at different ambient temperatures (T_a). Decreased T_b was most often associated with increased thermoregulatory demands and/or reduced energy availability. Since the proximate factors that regulate the use of hypothermia are not entirely clear, we hypothesized that, as in mammals and other birds, food availability and T_a together serve to trigger the use of hypothermia in quail, and we tested the prediction that birds kept at lower T_a and deprived of food will enter deeper hypothermia than quail at a thermoneutral T_a. Twenty Japanese quail were divided into two groups, one was maintained at a thermoneutral T_a (32.6±0.2 °C) for quail, and the other below their lower critical temperature (T_{lc}) at 12.6±2.9 °C. Hypothermia was induced by food deprivation, and changes in body mass (m_b) and T_b were compared between the groups for 11 days. Mean scotophase T_b of quail kept at thermoneutrality was significantly higher than of those kept at low T_a (40.8±0.6 °C vs. 40.1±0.5 °C, repeated measures ANCOVA $F_{(1,7)}$=7.3, $p<0.05$). Furthermore, both groups entered hypothermia upon food deprivation, but T_b decreased more (4.3±0.4 °C vs. 2.7±0.7 °C, repeated measures ANOVA $F_{(1,8)}$=23.6, $p<0.01$) and m_b loss was greater (12.1±3.6 % vs. 7.6±1.4 %, ANOVA $F_{(1,16)}$=12.4, $p<0.01$) in quail kept below their T_{lc}. The results support our hypothesis and are not consistent with previous the studies reporting no differences in hypothermic responses of quail at different T_a's.

S10.7 BENTLEY, GE*; UBUKA, T; MCGUIRE, NL; CALISI, RM; PERFITO, MN; TSUTSUI, K; WINGFIELD, JC; Univ. of California, Berkeley, Waseda University, Japan, Univ. of California, Davis; *gb7@berkeley.edu*

Regulation of Vertebrate Reproduction by GnRH and GnIH

Our initial studies on gonadotropin-inhibitory hormone (GnIH) focused on the avian anterior pituitary as the only physiological target of GnIH, and we now have several lines of evidence that GnIH directly inhibits pituitary gonadotropin synthesis and release in birds and mammals. Our histological studies on projections from hypothalamic GnIH neurons subsequently implied direct actions of GnIH within the brain. GnIH axons and terminals are present in multiple brain areas in birds, and GnIH receptor is expressed on GnRH (gonadotropin-releasing hormone)-I and II neurons. Thus, GnIH can act directly on GnRH-I and II neurons to regulate reproductive physiology and behavior. Our data imply that hypothalamic GnIH content is increased by stress, and thus might be a modulator of stress-induced reproductive dysfunction. Similar histological and functional data have since been gathered in mammals. In addition to actions on the GnRH system and on the pars distalis via the median eminence, we have demonstrated the presence of GnIH and its receptor in avian and primate gonads. One of the actions of GnIH in the gonads is to modulate production of gonadal steroids directly. In sum, our data indicate that GnIH is responsive to external stimuli and is an important modulator of reproductive function at the level of the GnRH neuron, the gonadotrope and the gonads.

105.5 BERG, Angela M*; BIEWENER, Andrew A; Harvard University; *aberg@oeb.harvard.edu*

Flight muscle function during takeoff, landing, and mid-flight, in the pigeon Columba livia

In order to achieve different modes of flight, such as takeoff and landing, a bird must move its wings differently. Variation in wing motion requires corresponding variation in activation and shortening patterns of the flight muscles. To explore variation in flight muscle function, we used EMG and sonomicrometry in the pectoralis, biceps, and triceps muscles of the pigeon *Columba livia*. To understand the effects of muscle function variation on wing motion, we coupled *in vivo* muscle recordings with high-speed video to record flight kinematics. The triceps, biceps, and pectoralis all showed small increases in length change during takeoff flight and during wingbeats prior to landing. In all wingbeats except the final landing wingbeat, the pectoralis and biceps tended to reach their shortest lengths simultaneously, reflecting the flexed wing posture observed at the end of downstroke. In the final wingbeat of landing, the pectoralis shortened less and the stroke amplitude correspondingly decreased. The biceps also shortened less in the final wingbeat, and continued to shorten after the pectoralis began to lengthen. The biceps was active during lengthening and remained active until after it began to shorten. This activation pattern may allow the production of high force at the elbow to accelerate the wing when it reverses direction at the end of the downstroke.

104.1 BERGMANN, P.J.*; IRSCHICK, D.J.; University of Arizona, University of Massachusetts Amherst; *pjbergma@email.arizona.edu*

Alternate pathways in the evolution of body elongation, locomotor performance and kinematics in two clades of lizards.

Variation in body shape is associated with variation in function in many animals. Body elongation and limb reduction has evolved repeatedly, frequently and to varying degrees in all major clades of vertebrates. However, phylogenetically-informed studies of locomotion and functional morphology in animals ranging from elongate to stocky are lacking, as is a consideration of the evolution of stockiness as a corollary of elongation. We study the evolution of body shape in lizards of the genus *Lerista* and the phrynosomatines, and relate these different body shapes to locomotor kinematics, performance and habitat selection. We show that *Lerista* evolve an elongate body shape through changes in different body parts from those involved in the evolution of stockiness in the phrynosomatines. The former lengthen their bodies and shorten their limbs, while the latter broaden their heads and bodies while shortening their bodies and limbs. In general, species with relatively longer limbs increase their velocity by taking longer, quicker strides. The two clades adopt different locomotor strategies that are related to their body shapes. Namely, more elongate *Lerista* rely on axial bending to move quickly, while the phrynosomatines rely on changes to their limb kinematics to achieve faster locomotion. However, locomotion in unaffected by different substrates, and differently shaped species do not select different substrate habitats. Evolution of these lizards follows multiple pathways, and species with different body shapes can exploit a similar range of habitats through modulation of their locomotor kinematics.

21.3 BERGOU, A.J.*; RISTROPH, L. G.; COHEN, I; WANG, Z.J.; Cornell University; *ajb78@cornell.edu*

Pitching, Deformation and Control in Insect Flight

The complex wing motion of a flying insect is due not only to muscular activation but also fluid, inertial, and elastic forces. Thus, it may be that not all aspects of the wing motion are actively controlled by the insect. As with conventional airfoils, the orientation of a wing to an oncoming flow, otherwise known as the angle of attack, is an important kinematic parameter for a flapping wing. Even small changes in this angle can drastically change the forces a wing experiences. Additionally, wing pitch reversal, the sudden change of angle of attack at the end of a stroke, represents an important difference between flapping wings and a continuously rotating blade (e.g. helicopter flight). Here, we ask whether changes in the angle of attack of wings of flying fruit flies are modulated actively by insect muscles, or do wings turn over passively like the fluttering of falling paper. By applying a three-dimensional reconstruction technique to high-speed films of flying fruit flies, we are able to image an elastic wave on the wings whose direction of travel indicates passive pitching. To further analyze passivity of wing rotation, we extract the detailed wing kinematics of flies using a novel motion tracking algorithm and compute the forces acting on the wings. Finally, we infer whether flapping flight is possible without pitching control.

55.4 BERKE, Sarah K*; CRUZ, Veronica; Smithsonian Environmental Research Center, Florida State University; *skberke@gmail.com*

Sublethal predation in an ecosystem engineering polychaete

Sublethal predation, in which a prey organism is partially eaten but not killed, is an important process in terrestrial and marine ecosystems. When sublethal predation involves ecosystem engineers, it may potentially influence spatial and temporal variation in bioengineered habitat. We examined sublethal predation in a marine ecosystem engineer, the tube-building polychaete *Diopatra cuprea*. *D. cuprea* tubes form dense assemblages that facilitate infaunal and macroalgal communities, enhancing local diversity and productivity. *D. cuprea* commonly loses its antennae and portions of its anterior to predator attacks; lost body portions are subsequently regenerated. We asked (i) whether the intensity of sublethal predation differs for *D. cuprea* populations in Virginia versus Florida, (ii) whether sublethal predation varies seasonally in each region, (iii) whether sublethal predation influences activity and tube-building rates, and (iv) how sublethal predation contributes to secondary productivity. Within Florida, we also drew comparisons between *D. cuprea* and the closely related onuphid *Americonuphis magna*. Surprisingly, we found that that sublethal predation is more intense in Virginia compared to Florida, likely constituting an important link in regional food webs. Within Florida, sublethal predation was more intense in late summer than in early summer. Both antennae loss and anterior loss affected *D. cuprea* activity rates. Anterior loss dramatically reduced tube-construction rates for many days post-injury. Although *D. cuprea* and *A. magna* have similar ecologies and life-histories, *A. magna* is incapable of anterior segment regeneration, raising interesting questions about the evolution of anterior regeneration within the Onuphidae.

84.3 BERMAN, Gordon*; RISTROPH, Leif; LYON, Brad; BERGOU, Attila; COHEN, Itai; WANG, Z. Jane; Cornell University; *gjb28@cornell.edu*

The ascent of freely-flying fruit flies

Insects are graceful and varied locomotors -- flying, darting, and hovering with ease and sophistication. This apparent effortlessness is frequently the result of the remarkably slight adjustments in wing kinematics necessary for an insect to switch from one type of flight maneuver to another. The small scale of these adaptations, however, often makes the mechanisms behind these flights difficult to investigate, as differences between maneuvering kinematics can be problematic to distinguish by studying only one or a small number of flight sequences. In this talk, we present the results from analyzing many sequences of freely-flying fruit flies ascending at various speeds in hopes of uncovering the mechanisms by which their aerodynamic climbing is accomplished. We also show how the wing kinematics of ascending insects differ from those which are hovering. The data sets used to perform this analysis are obtained from high-speed video images of a custom-made flight arena with a launch pad designed to reliably instigate ascending flight. Three-dimensional kinematics are reconstructed via a novel automated motion tracking algorithm. We show that fruit flies ascend by flapping their wings in an asymmetric ladder which counteracts the reduction in wing angle of attack accompanying a vertical trajectory.

100.1 BESSLER, Scott M.*; SECOR, Stephen M.; University of Alabama; *besslers@gmail.com*

To Regulate or Not to Regulate; Stomach Acid Production in Amphibians and Reptiles

For amphibians and reptiles there is an adaptive link between feeding habits and the capacity to regulate gastrointestinal performance. Frequently feeding species maintain stable intestinal performance between feeding bouts, whereas infrequently feeding species widely regulate intestinal performance with each meal. Given the apparent high cost of gastric acid production, we predicted a similar pattern; frequently feeding species maintain acid production between meals and infrequently feeding species shut down acid production during their long periods of fasting. To explore this hypothesis, we measure gastric pH from fasted and digesting individuals for 11 frequently feeding species (anurans, lizards, snakes, and alligator) and 8 infrequently feeding species (*Xenopeltis*, boas, and pythons). All frequently feeding species, with the exception of the snakes *Nerodia rhombifer* and *Homolopsis buccata*, maintained an acidic pH (pH = 1.1-2.5) within their stomachs while fasting and thus experience no significant change in gastric pH with feeding (pH = 1.0-3.0). In contrast, all infrequently feeding snakes greatly reduced acid production while fasting (pH = 5.0-7.7) and thereby had to rapidly increase acid production after feeding. During the digestion of their large intact meals, gastric pH was maintained at 1.5-2.5. For infrequently feeding snakes, the ability to downregulate both gastric and intestinal performance apparently serves to reduce their energy expenditure during their long predicted episodes of fasting. For the majority of frequently feeding amphibians and reptiles, as well as for fishes and mammals, the selected strategy is to maintain constant acid production between meals.

58.2 BIERMAN, H.S.*; TOBIN, A-E; REHM, K.J.; MARDER, E.; Brandeis University, Waltham, MA; *hilaryb@brandeis.edu*

Dye- and electrical-coupling between gastric and pyloric neurons in the stomatogastric ganglion of the lobster Homarus americanus,

The importance and prevalence of electrical synapses in vertebrate and invertebrate systems has been increasingly noted. To examine how electrical synapses contribute to network function we focus on the well-defined stomatogastric system that controls rhythmic chewing and filtering in the stomach of the lobster *Homarus americanus*. This system is ideal for studying electrical synapses because the 30 large neurons which compose the network are individually identifiable between animals, and much of their chemical connectivity is known. This system generates two separate but coordinated rhythms (gastric and pyloric). Neurons such as the dorsal gastric (DG) neuron, which show both rhythms, may be coupled to neurons in both rhythmic networks. Previously, no electrical connections to DG have been identified. To determine DG's electrically coupled partners, we used both dye-coupling and electrophysiological techniques. Recordings were made to identify each cell in the ganglion, and neurobiotin was injected into DG. Following processing with fluorescently tagged streptavidin, the dye-coupled partners were determined by confocal microscopy. Electrical coupling was measured by injecting current into DG and recording voltage responses in other cells. Both techniques identified a number of neurons coupled to DG including the pyloric dilator neuron (PD) and the lateral posterior gastric neuron (LPG). Supported by NIH grants NS059255(AET) and T32 NS007293(Brandeis).

74.3 BIEWENER, A A*; ROS, I; LEE, D V; ANTONNEN, J; HIGGINS, T; Harvard University, UNLV; *abiewener@oeb.harvard.edu*

Ground Reaction Force and Center of Mass Dynamics of Goats and Dogs during Trotting and Galloping.

How does the center of pressure (CoP) resulting from distributed limb ground reaction forces (GRF) track the center of mass (CoM) of an animal as it moves using different gaits? What are the patterns of pitch, roll and yaw moments that result from mismatches in CoP and GRF-CoM tracking? We recorded GRF, CoP and limb and body kinematics to estimate CoM location of goats and dogs as they trotted and galloped steadily across four force platforms, providing a full stride cycle map of CoP/GRF-CoM tracking and CoM moments. We hypothesized that pitch moments would be greatest for galloping due to fore-hind timing asymmetry and that roll moments would be greatest due to contralateral fore-hind contact during trotting. We found that pitch moments were greatest in both species during trotting and galloping. However, supporting our hypothesis, pitch was 2-3x greater during galloping. Dogs galloped with larger size-normalized CoM pitch moments compared with goats. CoM roll moments were 33-50% of pitch moments and yaw moments were least (15-22% of pitch). Head-up and head-down pitch was associated with fore vs hind timing of deceleration and acceleration in the direction of travel. The timing and distribution of limb GRFs during trotting and galloping in dogs and goats enables the CoP-GRF to track CoM closely, keeping CoM moments low. These studies are applied to developing more stable legged robots (supported by DARPA Biodynotics).

74.2 BIKNEVICIUS, A.R.*; MCELROY, E.J.; JOHNSON, S.D. ; BENNETT, M.B. ; REILLY, S.M. ; Ohio University College of Osteopathic Medicine, Athens, College of Charleston, South Carolina, University of Queensland, Gatton, Australia, University of Queensland, Brisbane, Australia, Ohio University, Athens; *biknevic@ohio.edu*

Primitive, Protected and Pendullar: Locomotor Dynamics of Echidnas and Hedgehogs

When small terrestrial mammals travel at steady speeds they predominately move their center of mass (COM) in a manner consistent with spring-mass (running) mechanics. In order to determine whether this is a primitive condition in mammals, we investigated COM mechanics in echidnas (*Tachyglossus aculeatus*) and hedgehogs (*Atelerix albiventris*). The skeletons of both species have a suite of characters that have been considered by some to be primitive for the Mammalia. While the gait used by both species at slow speeds was typically either a lateral-sequence (LS) diagonal-couplet or LS singlefoot, speed-related gait changes differed between species; *Atelerix* shifted toward the trot and *Tachyglossus* tended toward the pace. Across all speeds *Tachyglossus* moved exclusively with pendulum-like (walking) mechanics. This was also the principal mode in *Atelerix*, although hedgehogs were also capable of moving with spring-mass mechanics at higher speeds. These observations are in contrast to the predominantly running mechanics in other small mammals. Mammals with armored integument may not be under the same selective pressures as unarmored mammals; instead, they may have been selected to move customarily at moderate to slow speeds, relatively undisturbed, as they forage for widely distributed prey. Our observations support a hypothesis that the predominant use of spring-mass mechanics during steady speed locomotion in other small mammals may reflect their tendency to use flight-mode locomotor speeds for steady speed locomotion, more so than an inability to move with pendulum-like mechanics.

92.3 BIGA, P. R. *; BRASCHAYKO, E.; GALT, N; PAKALA, K. P.; JENSEN, J.; North Dakota State Univeristy, Fargo; *peggy.biga@ndsu.edu*

Does myostatin play a regulatory role outside of muscle growth and metabolism?

Myostatin (MSTN) is known to function as a negative regulator of muscle growth and has been shown to play a role in energy homeostasis in mammals. MSTN has been identified in many fish species and recent evidence supports similar functions in fish as seen in mammals. It appears that MSTNs actions are antagonistic to that of growth hormone (GH), as earlier work demonstrated decreased MSTN expression in GH-treated trout. Also, in trout and giant danio primary myoblast cells, MSTN gene expression is lowest during rapid cellular proliferation and increases as cells differentiate into myofibers. In determinate and indeterminate growing species that are closely related, MSTN is differentially expressed in response to GH. These results suggest that MSTN plays a role in muscle growth regulation and might be important in satellite cell fate in indeterminate growing fish. In addition to growth regulation, new evidence is emerging that MSTN might play a pivotal role outside of growth and metabolism. In mice, high-fat diet induced obesity induces an initial pro-inflammatory response, with an accompanying increase in muscle and spleen MSTN gene expression. In mice resistant to high-fat diet induced obesity, MSTN gene expression is significantly elevated in muscle and initially down-regulated in spleen tissue. In addition, a novel down-stream target of MSTN, *mighty*, plays an important role in innate immunity through NF-kappaB-dependent IL-6 production. Mighty also appears to be a positive growth-regulating factor, as gene expression is down-regulated during fasting, while MSTN is up-regulated. Circumstantial evidence supports a potential role of MSTN in regulating growth, metabolism, and immune responses in a possible combinatorial fashion.

S9.7 BILBO, S.D.; Duke University; *staci.bilbo@duke.edu*

Early life environment influences on neuroimmune interactions and behavior in adulthood.

Events within the perinatal environment have significant consequences for the development and function of physiological systems throughout life, a phenomenon termed perinatal programming. For instance, early life exposure to infectious agents influences reactivity to stress, immune regulation, and susceptibility to disease in adulthood. We have demonstrated that rats infected neonatally with live E. coli exhibit markedly altered fever, cytokine expression, and brain inflammatory markers following a simulated immune challenge (e.g., lipopolysaccharide, LPS) in adulthood. Notably, these animals also exhibit profound behavioral changes: memory is significantly impaired in neonatally-infected rats that receive a challenge of LPS around the time of learning, and this is causally-linked to exaggerated pro-inflammatory cytokine production. In contrast to these deficits however, neonatally-infected rats are remarkably protected from stressor-induced changes in depressive-like behavior and recover from peripheral inflammation more quickly than controls. These data suggest that early-life infection should be considered within a cost/benefit perspective, in which outcomes in adulthood may be differentially protected or impaired. This talk will address two related questions: 1) what changes occur in the neonatal brain in response to the infection that render the brain vulnerable versus resistant to a later challenge? and 2) what are the long-term consequences for host morbidity and mortality?

72.2 BIRD, Nathan C.*; HERNANDEZ, L. Patricia; George Washington University; *nbird@gwmail.gwu.edu*

Constructing a complex morphological novelty: Insights from growth, development, and genetics of the cypriniform Weberian apparatus

Vertebrate morphologists have long examined hearing capabilities in fishes, with particular emphasis on so-called hearing specialists. However, less emphasis has been placed on investigating the morphogenetic mechanisms involved in the origin of these specialized morphologies. We present a broad review of the mechanisms responsible for development of the Weberian apparatus, a hearing specialization unique to otophysan fishes, which include minnows, loaches, catfishes, characins, and electric fishes. While thoracic vertebrae in unmodified species serve as protective elements and sources of muscle attachment, otophysan anterior thoracic vertebrae have morphologies uniquely adapted for hearing. Given that otophysan fishes utilize vertebral elements to conduct sound pressure rather than moving the swimbladder into closer proximity to the ear, significant selection must have existed to break the constraints of typical thoracic vertebrae. Such forces may have led to changes in growth rates and gene expression within the context of changing environmental influences. We take advantage of some of the molecular tools used by developmental biologists to describe the early development and growth of the vertebral elements of this novelty in the zebrafish, a cyprinid, with a specific focus on genes involved in early skeletal development. Growth rates are examined to determine broad-scale allometric changes within the thoracic vertebrae. These data are then used to shed light on the morphological variation seen within cypriniform fishes as a proxy for the variation seen within Otophysi. Identifying the developmental mechanisms responsible for the origin of this hearing adaptation will enhance our understanding of how such functional novelties form and evolve.

83.1 BISHOP, K.L.*; WAINWRIGHT, P.C.; HOLZMAN, R.; University of California, Davis; *kvwbishop@ucdavis.edu*

Anterior to Posterior Wave of Buccal Expansion in Suction Feeding Fish is Critical for Optimizing Fluid Flow Velocity Profile

In fish that employ suction feeding, coordinating the timing of peak flow velocity with mouth opening is likely to be an important feature of prey capture success because this will allow the highest forces to be exerted on prey items when the jaws are fully extended and the flow field is at its largest. Although it has long been known that kinematics of buccal expansion in feeding fish are characterized by an anterior to posterior wave of expansion, this pattern has not been incorporated in most previous computational models of suction feeding. As a consequence, these models have failed to correctly predict the timing of peak flow velocity, which the empirical data currently available suggest should occur around the time of peak gape. In this study, we use a simple fluid dynamic model to demonstrate that the inclusion of an anterior to posterior wave of buccal expansion can correctly reproduce the empirically determined flow velocity profile, although only under very constrained conditions, whereas models that do not allow this wave of expansion inevitably predict peak velocity earlier in the strike, when the gape is less than half of its maximum. The conditions that are required to produce a realistic velocity profile are: 1) a relatively long time lag between mouth opening and expansion of the more posterior parts of the mouth, 2) a short anterior portion of the mouth relative to more posterior sections, and 3) a pattern of movement that begins slowly, then rapidly accelerates. Greater maximum velocities were generated in simulations without the anterior to posterior wave of expansion, suggesting a tradeoff between maximizing fluid speed and coordination of peak fluid speed with peak gape.

40.1 BLEVINS, E.*; LAUDER, G.V.; Harvard University; *eblevins@fas.harvard.edu*

Stingray Swimming in 3D: Pectoral fin locomotion

Stingrays swim by undulating their expanded pectoral fins, passing a propulsive wave from anterior to posterior. Basic 2D waveforms have been described for some species, but we have shown that the extreme flexibility of stingray fins allows complex deformations in three dimensions. Therefore, detailed 3D data are essential to understand undulatory locomotion and generate hypotheses about fluid flow around rays flexing fins. In this study, we present an analysis of the 3D kinematics of pectoral fin motion in freshwater stingray *Potamotrygon hystrix*. Three synchronized, one megapixel high speed video cameras (250 frames/s) were calibrated via direct linear transformation and used to film rays (mean disc length (DL)=13cm) swimming at two speeds (1.5 and 2.5 DL/s) in a flow tank. Multiple finbeats per individual, per speed, were analyzed to determine x, y, and z excursions of over 30 points across the fin surface. Kinematic variables including wave speed, frequency and amplitude were determined at each point and compared to other locations on the fin and between speeds. Maximum finbeat frequency nearly doubles with a 1 DL/s increase in speed, from 2.4 to 5.2 Hz. Maximum amplitude does not vary with speed, remaining about 30mm, but the pattern of amplitude increase along the disc changes significantly, with more of the disc reaching higher amplitudes at the faster speed. This follows a general theme in our analysis, where kinematic patterns, rather than the magnitude of particular variables, are key to understanding thrust production. Several observed fin deformations have significant hydrodynamic implications, including active cupping at the distal edge and changes in the form of the propulsive wave as it moves along the fin. Preliminary studies using particle image velocimetry are underway to characterize flow patterns around the fin and explore the effects of rays unique kinematics.

3.3 BLOB, R.W.*; KAWANO, S.M.; MAIE, T.; CEDIEL, R.A.; PTACEK, M.B.; BRIDGES, W.C.; SCHOENFUSS, H.L.; Clemson Univ., St. Cloud State Univ.; *rblob@clemson.edu*

Predator-induced Selection on Body Shape in Waterfall-climbing Gobiid Fish from Hawai'i

Amphidromous gobiid fishes of the Hawaiian Islands face two major functional demands as their juveniles return to freshwater after months of oceanic development: (1) avoiding predators in lower stream reaches, and (2) climbing tall waterfalls to reach adult habitats using ventral suckers. Different body shapes should be best suited to meet each of these demands, with a deep, taller body improving predator avoidance and a lower profile body improving climbing success. Adult fish from islands where different selection pressures predominate show such differences: *Sicyopterus stimpsoni* from Kauai have deeper bodies, correlated with the longer, predator-filled estuaries that must be traversed before reaching adult habitats, whereas *S. stimpsoni* from the Big Island have bodies lower in height, which should reduce drag in the waterfalls that must be scaled shortly after juveniles enter streams. Our previous selection experiments showed that morphological selection induced by waterfall climbing likely contributes to the shape differences seen between goby subpopulations from different Hawaiian Islands. Here, we evaluate the potential selective pressures of predation on Hawaiian gobies by exposing groups of juvenile *S. stimpsoni* to the native predatory fish *Eleotris sandwicensis* and comparing the body shapes of survivors to those of control groups. Predation imposed differing and often opposing patterns of selection on body shape than waterfall climbing. For example, predation survivors had lower fineness ratios than control fish, indicating greater body depth for a given length (as predicted). Thus, shape differences between goby subpopulations may also be strongly influenced by predators. NSF IOS-0817794, IOS-0817911.

46.2 BOETTGER, SA*; ROWLEY, BD; WALKER, CW; West Chester University, University of New Hampshire; *sboettger@wcupa.edu*

Chronic occurrence of disseminated neoplasia in different populations of Mya arenaria in New England.

Disseminated neoplasia in bivalve mollusks is characterized by mitotic hemocytes with a nuclear to cytoplasmic ratio of 1:1. Efforts to link environmental contaminants to the initiation of this fatal disease have depended on data collected followed episodic contamination events. No studies have characterized the prevalence of this cancerous disease in sites with different pollution levels/concentrations over an extended period of time. Here we examine the prevalence of a disseminated neoplasia in the soft shell clam, *Mya arenaria*, at numerous sites in New England where clam fisheries have been negatively impacted and provide the first evaluation of clam neoplasia at three sites over a period of five years. Our surveys document the highest frequency of neoplasia in *Mya arenaria* in New Bedford Harbor in December (9.49% + 0.78), when seawater temperatures were low and the lowest frequency in July (1.082 + 0.4) at high seawater temperatures. These results may indicate vulnerability of neoplastic clams to increased temperature and oxidative stress. Based on shell measurements and a theoretical mathematical age model, we point out that *Mya arenaria* is susceptible to this disease only between one and two years of age when clam populations begin reproducing (33.5% at age 1 year and 62.57% at age 1.5 years). (Saltonstall/Kennedy NA08NMF4270416 to CWW)

91.7 BOILY, P.; Western Connecitcut State University; *boilyp@wcsu.edu*

Voluntary motor activity contributes to the increase in body temperature caused by menthol application to the skin of gerbils

In mammals, the perception of innocuous cold temperatures is partly mediated by the activation of TRPM8 ion channels found on the membrane of some sensory neurons. Menthol can activate these channels, thus causing the well-known cooling sensation produced when applied to the skin or oral mucosa. Further, the topical application of menthol to the skin of mice causes vasoconstriction and increased thermogenesis, and therefore appears to mimic cold exposure. These physiological responses, without being associated with a real cold exposure, result in an increased body temperature (Tajino et al. 2007). Because the body temperature of small rodents is highly dependent on motor activity, I hypothesized that the increase in body temperature induced by topical menthol applications is also, in part, the result of increased motor activity. Body temperature and voluntary motor activity of six Mongolian gerbils (*Meriones unguiculatus*) were monitored by telemetry after topical applications of menthol solutions (0, 5, 10% w/v). Menthol applications caused a dose-dependent increase in body temperature, by 2C and lasting more than 2 hours for the 10% concentration. Menthol application also induced a dose-dependent increase in motor activity. Regression analyses indicated that 25 to 38% of the menthol-induced increase in body temperature was related to voluntary motor activity (log transformed), depending on whether the data was analyzed separately for each menthol concentration or pooled. These results suggest that voluntary motor activity contributes to the increase in body temperature caused by menthol application to the skin of gerbils.

9.11 BONIER, F.*; MARTIN, P.R.; MOORE, I.T.; ROBERTSON, R.J.; WINGFIELD, J.C.; Queen's University, Virginia Tech, University of California, Davis; *bonierf@queensu.ca*

Interpreting baseline corticosteroid measures: are they useful predictors of fitness?

Baseline corticosteroid (*cort*) measures are routinely used to infer an individual's stress level. The term stress has ambiguous meaning, and the significance of a high or low cort level for an individual animal is difficult to interpret. Nevertheless, researchers finding high cort levels in free-ranging animals generally interpret these levels as negative, reflecting poor condition and, presumably, reduced fitness relative to individuals with lower cort levels. The assumption that baseline cort accurately predicts fitness is questionable, and has rarely been validated. I will discuss two studies that look at natural relationships between cort levels and fitness components in free-ranging birds. Results suggest cause for caution in interpreting these hormone levels. First, in free-ranging white-crowned sparrows, I found sex-specific differences in the relationship between cort and a fitness component (number of genetic offspring fledged in one season) within one population: male birds' cort levels did not correlate with fitness, whereas females with high cort had lower fitness. Second, in a study of free-ranging female tree swallows, I found changing correlations between fitness components and baseline cort levels across breeding stages in the same individuals. Early in breeding, I found a negative relationship with high cort levels associated with reduced fitness, but by late breeding cort was actually positively correlated with fitness. These two studies, along with others, emphasize the challenges of interpreting cort levels in the field, and point to several means of addressing these challenges.

26.5 BORDA, E*; HALANYCH, KM; Auburn University; *ezb0004@auburn.edu*

Mitochondrial genome evolution of Amphinomidae (Annelida: Amphinomida)

The sequencing of complete mitochondrial (mt) genomes is becoming easier and the availability of these data continues to play important roles for the inferring evolutionary histories of diverse animal groups. This is particular the case for poorly understood invertebrate phyla, such as Annelida. Previous work on annelid mt genomes has examined gene order, base content, codon bias and base skewness; however, to date no study has assessed mt evolutionary rates in annelids. In this study we examine the evolutionary rates across annelid mt genomes and include new mt genome sequences from another annelid lineage belonging to the marine Amphinomidae, better known as fireworms. Fireworms are typically coral dwelling species and best known for the lingering "fiery" stinging sensation and inflammation caused by urticating chaetae that easily penetrate the skin. Although gene order has previously been reported to be conservative across most published annelid mt genomes, amphinomids appear to deviate from this trend. In addition to gene order, the rates of evolution of mt genes are examined in order to identify alternate mt markers and infer the phylogenetic efficacy of mt genes for reconstructing evolutionary history by utilizing Amphinomidae as a model - a group lacking an inclusive phylogenetic hypothesis. This work complements the ongoing effort to increase annelid (and lophotrochozoan) representation of mt genomes, while highlighting the need for mt gene exploration and assessment of relative rates within Annelida.

57.6 BORMET, A.K.*; MARCOT, J.D.; SEARS, K.E.; Univ. of Illinois;
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Evolutionary rates and patterns of artiodactyl limb reduction

Many clades of artiodactyls show evolutionary reductions in the number of distal elements of their limb skeleton, either through the fusion of two bones or the loss of bones entirely. This reduces the limbs distal weight and provides more stability among elements of the distal limb. It is, therefore, likely an adaptation to cursorial locomotion. Cenozoic environmental changes that led to the spread of open environments (e.g., savannas) might have provided an impetus for artiodactyl limb adaptation. To establish the historical pattern of artiodactyl limb reduction, we began by defining 31 characters of artiodactyl limbs that describe the reduction, fusion or loss of elements. We then determined the character states of a sample of living and extinct artiodactyl genera, and mapped these onto a composite phylogeny of artiodactyls to determine the timing of evolutionary changes. We then calculated the rate of evolution of these characters in each of thirty two-million-year-long intervals. There is a considerable peak in evolutionary rate around 38Ma, at the end of the Middle Eocene. Notably, this coincides perfectly with an observed peak in ungulate origination rate suggesting a possible relationship between the radiation of the major groups of living artiodactyls and the reduction of their limbs. The rate of limb evolution gradually declines throughout the Oligocene, but increase again around the Oligocene-Miocene boundary at 23Ma. Interestingly, this coincides with some recent estimates of the spread of grassland ecosystems in North America, suggesting a possible link between environmental change and artiodactyl limb evolution.

25.2 BOSTWICK, Kimberly/S*; ELIAS, Damian; MASON, Andrew; MONTEALEGRE-Z, Fernando; Cornell University, University of British Columbia, University of Toronto Scarborough, University of Bristol;
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Resonant Feathers Enable Sound Production in Machaeropterus deliciosus (Aves)

Male Club-winged manakins produce a unique, sustained, tonal sonation while perched during courtship. The sound is hypothesized to result from excitation of resonance in a modified secondary feather at or near the fundamental frequency of the sound produced in nature. Here we use laser vibrometery to measure and compare the resonant properties of the secondary feathers of the Club-winged manakin relative to other non-sonating manakin species to test the resonant part of the resonant stridulation hypothesis. While the control species show no resonant peaks above ~100 Hz, we determined that the enlarged 6th and 7th secondary feathers demonstrate a pronounced frequency peak near 1500 Hz, and further exhibit Q properties exceptionally high for a biological object. The other secondary feathers of the wing do not exhibit strong resonant frequency properties when measured by themselves. However, when measured in the context of the modified secondary feathers they are induced to resonant at the 1500Hz frequency. These results lend critical support to the resonant stridulation hypothesis of sound production in Machaeropterus deliciosus.

S8.6 BOUGHMAN, JANETTE W.; University of Wisconsin-Madison;
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Genetics and the nature of selection on reproductive isolation in sticklebacks

Integrating genomic and ecological approaches into the study of phenotypic evolution promises great advances in our understanding of adaptive evolution. My work combines studies of selective mechanisms with quantitative genetics and genomics to understand the forces responsible for adaptive divergence and speciation in threespine stickleback fish. We have shown previously that premating isolation in threespine sticklebacks is driven by a combination of natural and sexual selection on nuptial color and color perception, body size, and possibly body shape. With the explosion of genetic resources for threespine sticklebacks, including a complete genome sequence, we can now dig into the genetic basis of traits conferring premating isolation and adaptation to distinct environments. We focus here on the genetics of male color, which my prior work has shown to be adapted to distinct light environments in the mating habitat of two stickleback species: the limnetics and benthics. Sensory drive has contributed to divergence in color and color perception between species and appears to be a driving force in the evolution of premating isolation. We use mapping studies to identify genomic regions that underlie red or black nuptial color, and have developed an approach based on admixture mapping in a hybridizing species pair. Our mapping work reveals several genomic regions associated with red or black color. We also find that other adaptive traits co-localize to the same regions, including other traits involved in premating isolation. Genetic associations such as these should facilitate the evolution of color based premating isolation and the coevolution of male color and female color preference; they may also be generated by selection. Thus, our ongoing work combines experimental and genetic studies to investigate the nature of selection on the suite of traits that confer premating isolation.

95.2 BOURDEAU, Paul/E; Stony Brook University;
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Stuck between a rock crab and a hard place: phenotypic responses to multiple predators in a marine snail.

I examined the single and combined effect of chemical cues from crabs and seastars, two predators with contrasting attack modes, on the shell morphology of the marine snail *Nucella lamellosa*. Snails were subjected to three nonlethal predator treatments: seastar (*Pisaster ochraceus*), crab (*Cancer productus*), a combination of seastar and crab, and a no predator control. Shell shape, shell thickness and resistance to shell entry and shell breaking were quantified. I also analyzed whether shell shape or thickness plasticity was actively modulated in response to predators or an indirect effect of reduced feeding and growth. Predator-specific responses reflected the foraging mode of the predator that induced them. Chemical cues from the seastars induced elongate shells with tall spires, which facilitated soft tissue withdrawal, whereas crab chemical cues induced thicker, more rotund shells, which were more resistant to crushing. Shell phenotypes that reduced susceptibility to one predator increased susceptibility to the other, indicating a functional tradeoff. Snails in the combined predator treatment showed a directional response to the more dangerous crab predator. Although crabs induce thicker shells, this response is a passive by-product of reduced feeding and growth rather than a direct physiological response to predation risk. My results provide an intriguing and previously unknown mechanism for inducible defenses and suggest that prey can distinguish between functionally different predators and prioritize conflicting morphological responses according to risk in multiple predator environments.

48.5 BOUTRY, C.*; BLACKLEDGE, T.A.; University of Akron;
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Evolution of supercontraction in spider silk

Spider silk is a high performance material renowned for its tensile properties. However, silk can also strongly contract when exposed to high humidities (~70%) and shrink by up to 50%, generating high stresses (~50 MPa). Supercontraction poses a challenge for biomimetic applications of silk, therefore its mechanism and function must be understood. Supercontraction is thought to result from silk's complex protein composition and highly oriented molecular structure. It may allow orb-webs to remain tight under the added weight of raindrops or dew. However, most work on supercontraction has focused solely on orb-weavers. Investigating supercontraction in non orb-weaving spiders, with different silk structure and composition, may shed light on the mechanisms and evolutionary role of this phenomenon. In this study, we measured supercontraction in dragline silk from phylogenetically and ecologically diverse spider taxa. In particular, we found supercontraction in many non-orb weaving spiders. These results suggest that supercontraction may be a relatively ancestral trait within spiders and challenge current hypotheses about its mechanism and function.

86.3 BOWTELL, M V*; TAN, H; WILSON, A M; Royal Veterinary College;
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Effect of varying weight and inertia on maximum attainable running speed in humans

Attainable running speed in humans has been presented as limited by the amount of force which can be withstood by the legs when in contact with the ground, as well as the time required to protract the legs. Increased effective weight by bend running decreases maximum running speed in a predictable manner. With force as a limiting factor it would be expected that increased body mass (and therefore increased body weight and inertia) will cause a decrease in attainable speed, but that only an increase in inertia would have no effect. In this study we independently vary weight and inertia, and therefore the demand for vertical and horizontal force.

A large horse treadmill has been adapted to allow self-selected speed running and to gain measurements of maximum attainable speed. The system uses proportional and derivative (PD) control to alter the speed of the treadmill belt dependent on the position and relative speed of the runner. Eleven participants took part in trials to test the repeatability of gaining maximum speed. Nine of these participants also took part in trials in which mass and inertia were independently varied with the addition of lead weights and by partial suspension.

We found that maximum attainable speed increased by 3.3% with 30% decreased weight (s.e.=1.4 %) and unchanged inertia but hypothesise that leg swinging quickly became limiting. We also found that unchanged weight and 30% increased inertia caused a 4.8% decrease in attainable running speed (s.e.=1.7%); both are a much smaller effect than 30% increased weight and inertia (a 15% decrease in maximum speed). This demonstrates the apparent existence of a limit to running speed that is not the direct result of effective gravity or leg swinging. Potential mechanisms will be discussed.

S2.3 BOXSHALL, G.A.; The Natural History Museum, London;
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The comparative biology of Copepoda parasitic on three host taxa: fishes, polychaetes and crustaceans.

The Copepoda is one of the mega-abundant arthropod taxa on Earth and, although most copepods are free-living, about one third of known species live in symbiotic associations. They have moved into symbiotic life-styles independently on numerous occasions, in distinct lineages, and have come to exploit an enormous range of phyla as hosts, from sponges to chordates (including mammals). In this account I focus initially on aspects of the biology of copepods that utilise fishes as hosts. Over 2000 copepod species are parasitic on fishes and these are currently classified within 27 families. The largest of these families is the Caligidae, the sea lice, which includes some of the most serious pests in commercial finfish aquaculture, and causes economic losses in excess of $100 million per year. At the other end of the host spectrum are the crustaceans which, if we exclude the various taxa that live in loose symbiotic relationships with their crustacean hosts, serve as hosts to only a single family of parasitic copepods, the Nicothoidae. Between these host spectrum extremes lie the polychaetes which serve as hosts to 16 families of copepods, but most of these are rarely encountered. This paper compares aspects of the biology of the copepods found on fishes, polychaetes and crustaceans as hosts, including life cycles, extreme morphologies, feeding mechanisms and patterns of species richness.

11.8 BOYER, Sarah L.*; SZUMOWSKI, Suzy C.; HOWE, Alex A.; HOVE, Mark C.; HORNBACH, Daniel J.; Macalester College;
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Comparative Phylogeography and DNA Barcoding of Freshwater Mussels

Freshwater mussels (Order Unionoida) are sedentary organisms that accomplish dispersal during larval development. During this portion of their life history, these animals employ a strategy unique among bivalves: they parasitize fishes. Mussels may attract fish hosts by using lures that are modifications of the mantle or by releasing conglutinates of eggs that resemble food items. Interest in the evolution of host specificity and in the conservation of freshwater mussels, which are greatly imperiled in North America, has spurred laboratory studies aimed at identifying fish hosts of individual mussel species. However, few studies have surveyed larvae from wild-infested fishes, in part because morphology is inadequate for species-level identification of mussel larvae. We describe a pilot study that tests the efficacy of DNA barcoding for identification of freshwater mussel larvae recovered from wild-caught fishes. In addition, we explore the relationship between the number of fish hosts used by a mussel species and the genetic diversity of that species. Our findings have implications for both the evolution of host specificity and management strategies for imperiled freshwater mussels.

S2.1 BOYKO, Christopher B; American Museum of Natural History; *cboyko@amnh.org*

Bopyrids of the Thalassinidean Transition: First Phylogenetic Data and Evolutionary Implications

In 1986, John Markham proposed the term thalassinidean transition for those bopyrid isopod taxa that appeared to link the subfamilies Pseudioninae, Ioninae and Phyllodurinae and which occurred on thalassinoid hosts. Thalassinoids are an important host group for bopyrids with 56 species of bopyrid parasites (37 Pseudioninae, 17 Ioninae, 1 Phyllodurinae, and 1 Entophilinae) known from this group, behind only Anomura and Caridea in terms of percentage of host species infested by bopyrids. Markham proposed a non-cladistic pattern of evolution from the putatively primitive Pseudioninae (including the likely para- or polyphyletic type genus) through the Ioninae (both branchial parasites) to the advanced Phyllodurinae and the Athelginae (both abdominal parasites, with the Athelginae found only on paguroids).It is possible that these transitional forms may represent stem groups. Recently, several studies have called into question the monophyly of the Thalassinidea, providing an opportunity to examine the monophyly and relationships within the bopyrid subfamilies found on thalassinoids and to compare their patterns of evolution with those of their hosts. Six species of bopyrids parasitizing both upogebiid and callianassid hosts were studied from both a morphological and molecular perspective and the concept of the thalassinidean transition is analyzed in light of these results.

S4.9 BRADY, S.G.*; DANFORTH, B.N.; CARDINAL, S.; Smithsonian Institution, Cornell University; *bradys@si.edu*

Phylogeny and evolution of eusocial insects: a comparison of origins and losses in ants and bees

We review recent progress toward understanding the evolutionary history of eusocial insect societies, which are characterized by cooperative brood care, generation overlap, and reproductive division of labor. Eusociality has evolved in several insect groups, most prominently in ants, bees, wasps, and termites. Ants and bees both originated approximately at the same time in the Cretaceous (approximately 120-140 million years ago) yet these two taxa contrast notably in their manifestations of eusociality. In ants, eusociality evolved only once and has never been lost. Ant groups have evolved specialized versions of eusociality that incorporate highly complex morphological caste systems and behavioral innovations such as pack hunting and fungal agriculture. The vast majority of bee species are solitary, and eusociality has evolved 5-6 separate times in bees alone. The highly eusocial honey bee, focus of much current developmental and genomic research, thus represents only one of several distinct eusocial bee lineages. Eusociality in halictid bees evolved much more recently compared to other major eusocial insect groups, with three independent origins approximately 20-25 million years ago. These bees display substantial diversity and flexibility in their expression of eusociality and show frequent reversals back to solitary condition. These characteristics may allow halictid bees to provide a more direct window into the origins and early development of social insect societies.

90.3 BRAKORA, Katherine*; KHUC, Kim; University of California, Berkeley; *kbrakora@berkeley.edu*

Ontogenetic convergence in ventral skull shape between males and females of a sexually dimorphic antelope

Although antelope provide many classic examples of sexual dimorphism among mammals, their morphology has not been systematically quantified in terms of sexual differences in size, shape or ontogeny. Furthermore, it is unknown whether the obvious sexual differences in the frontal region of the skull caused by the presence or enlargement of horns in males correlate with shape differences in other regions of the skull. We performed two-dimensional geometric morphometric analyses on the ventral skull of 25 female and 14 male springbok antelope (*Antidorcas marsupialis*), ranging from 7 months to >5 years old, which were harvested and age-estimated from a wild population in northern Namibia from 1992-1994. 22 paired and 5 midline landmarks of the ventral basicranial, zygomatic, palatal and maxillary regions were digitized, standardized for shape using Procrustes superimposition, and analyzed using standard software. Principle component analyses revealed a primary ontogenetic component characterized by lengthening of the tooth row, loss of the second adult premolar, and extension of the face and posterior palate. In a secondary sexual component, males had a longer, more posterior palatine bone, shorter tooth row, wider anterior palate, and more anterior facial tuberosity. In juveniles (12-14 months), the sexes differed more in shape than they did in sub-adults (22-24 months) or in adults (>3 years), although they were not statistically different in each age group. In dorsal view adults males are easily distinguished from females by their horn size and related frontal bone modifications, whereas the sexes are difficult to distinguish in juveniles. This suggests that the sexes become more similar through ontogeny in the ventral skull, while diverging markedly in the dorsal skull.

11.9 BRANNOCK, P. M.*; HILBISH , T. J. ; Univeristy of South Carolina, Columbia, University of South Carolina, Columbia; *brannockp@biol.sc.edu*

Breakdown in mitochondrial inheritance within the Mytilus edulis complex around Hokkaido, Japan

Hybridization between species within the *Mytilus edulis* complex (*M. edulis*, *M. galloprovincialis*, and *M. trossulus*) is prevalent in sympatric locations. In addition to advanced hybridization and introgression, previous research has reported breakdown in the mitochondrial inheritance in some of these species hybrid zones. This species complex has an unusual inheritance of mitochondria, commonly referred to as double uniparental inheritance (DUI). Under this mode of inheritance mothers pass their mitochondrial DNA (mtDNA) to all offspring, while sons obtain an additional copy of mtDNA from their fathers through the sperm. This unusual mode of inheritance adds another element that can be potentially affected by hybridization. Two of the species, *M. galloprovincialis* and *M. trossulus*, are sympatric and hybridize only in the North Pacific. The hybrid zone on the northwest Pacific coast has been less extensively examined in comparision to the northeast Pacific coast. Samples collected in 2006 have revealed a potential mitochondrial inheritance breakdown within individuals around Hokkaido, Japan. Mitochondrial results illustrate a high proportion of amplification at the male 16s mtDNA region for some locations surveyed. In addition, some individuals express multiple (two or all three) male 16s mtDNA haplotypes while maintaining a female 16s mtDNA haplotype. To further explore this potential DUI breakdown and to determine the extent to which it is occurring, some locations around Hokkaido were re-surveyed in 2008. Gender of all individuals collected was recorded to explore the potential relationship between individuals illustrating this breakdown and their gender or nuclear genotype.

26.11 BRAYER, K.J.*; LYNCH, V.J.; WAGNER, G.P.; Yale University, New Haven; *kathryn.brayer@yale.edu*

Evolution of physical interactions among the transcription factors HoxA-11 and FOXO1a during the evolution of pregnancy in mammals.

Decidualization of endometrial stromal cells is a critical step in the successful establishment of pregnancy. Although the molecular mechanisms that regulate decidualization are poorly understood, the importance of elevated levels of prolactin, which are maintained throughout pregnancy, has long been recognized. Endometrial prolactin expression is a derived character of eutherian mammals and is regulated by a tissue specific promoter comprised of two transposable elements, MER20 and MER39, located upstream of the transcription start site. MER20 contains binding sites for numerous transcription factors, including HoxA-11 and FOXO1A. Recently we demonstrated a phylogenetically derived functional interaction between these two proteins resulting in upregulation of expression from the MER20 promoter. Here we examine physical interactions between ancestral and derived HoxA-11, FOXO1A and MER20. Specifically we want to test whether the derived functional interaction involves novel or stronger binding affinity among the molecules or whether it also includes a derived transcriptional activity by the transcription factor proteins. Implications for the evolution of prolactin regulation will be discussed.

9.1 BREUNER, CW*; PATTERSON, SH; HAHN, TP; The University of Montana, University of California at Davis; *creagh.breuner@umontana.edu*

A 'Good' Stress Response? Searching for relationships between the acute glucocorticoid response and fitness

The assumption that the acute response to stress is adaptive is pervasive in the literature, but there is little direct evidence regarding potential positive fitness consequences of an acute stress response. If robust acute glucocorticoid (GC) elevation increases lifetime reproductive success (fitness), in what contexts does this occur, and through what combination of effects on annual reproductive output and interannual survival? Here we present an analysis of studies examining acute GC reactivity and direct measures of fitness, as well as those comparing GCs to less direct measures of intermediate performance.

S4.7 BRISCOE, AD; Univ. of California, Irvine; *abriscoe@uci.edu*

Evolution of color vision in insects

The eyes of insects are remarkable. Much of eye diversity can be traced to alterations in the number, spectral properties, and spatial distribution of the visual pigments. Visual pigments are light-sensitive molecules composed of an opsin protein and a chromophore. Most insects have eyes that contain visual pigments with a wavelength of peak absorbance, lambda-max, in the ultraviolet (UV)(300-400 nm), blue (B)(400-500 nm) and long wavelength (LW)(500-600 nm) part of the visible light spectrum, respectively, encoded by distinct UV, B and LW opsin genes. Most of what we know about the molecular basis of vision in insects is based upon studies of holometabolous insects. In the compound eye of flies, bees, moths and butterflies, each individual ommatidium is composed of eight or nine photoreceptor cells (R1-9) that generally express only one opsin mRNA per cell, although in some fly and butterfly eyes, there are ommatidial subtypes in which two opsins are co-expressed in the same photoreceptor cell. Based on a phylogenetic analysis of opsin sequences from red flour beetle, honey bee, silkmoth, and butterflies, and comparative analysis of opsin gene expression patterns, I propose a model for the patterning of the ancestral holometabolous insect eye that is most closely aligned with the honey bee and butterfly eye. The R1 and R2 cells of the main retina expressed either UV-UV, UV-B or B-B absorbing visual pigments while the R3-9 cells expressed an LW-absorbing visual pigment. Visual systems of existing insects then underwent an adaptive expansion based on lineage-specific UV, B and LW opsin gene multiplications and on alterations in the spatial expression of opsins within the eye. In at least two instances, that of the fly and red flour beetle, this has also involved the loss of the blue-green and B opsin genes, respectively. Understanding the molecular sophistication of insect eye complexity is a challenge, which if met, has broad biological implications.

100.2 BRZEK, P.*; CAVIEDES-VIDAL, E.; KARASOV, W.H.; University of Wisconsin, Madison, Universidad Nacional de San Luis-CONICET, Argentina; *pbrzek2@wisc.edu*

Paracellular and total glucose absorption increase with age in nestling House sparrows

Diet digestive efficiency has been found to increase with age in nestling birds. Age-specific changes in activity of digestive enzymes have been shown, however, nothing is known about developmental changes in capacity for absorption of products of digestion. We studied for the first time developmental changes in glucose absorption in an altricial bird, House sparrow (*Passer domesticus*). Nestlings on days 3, 6, and 12 post-hatch were either fed or injected intramuscularly with radiolabeled L-glucose (absorbed only passively across intestinal tight junctions - paracellular transport), and 3-O-methyl-D-glucose (3-OMD-glucose, absorbed both actively and passively). We applied a pharmacokinetic method to estimate the proportion of glucose that was absorbed by fed nestlings (fractional absorption, FA). FA was lowest in youngest nestlings (0.70 for L-glucose, 0.79 for 3-OMD-gluocose) and increased significantly to essentially unity in oldest nestlings. The values in 6- and 12-d old birds were similar to those found previously in adult House sparrows. We conclude that the paracellular absorption pathway is relevant during ontogeny accounting for the majority of the water-soluble absorption in the intestine, and its magnitude increases with age. Supported by NSF IOS-0615678 to W.H.K.

100.3 BRZEK, P.; KOHL, K.; CAVIEDES-VIDAL, E.; KARASOV, W.H.*; University of Wisconsin, Madison, Universidad Nacional de San Luis-CONICET, Argentina; *pbrzek2@wisc.edu*

Activity of intestinal carbohydrases responds to multiple dietary signals in nestling House sparrows

A simple adaptive modulation hypothesis predicts that digestive enzyme levels are matched to relative levels of dietary substrate so that energy does not escape the digestive tract unabsorbed and available membrane space and synthetic energy are not wasted on enzymes far in excess of need. But curiously, a predicted increase in intestinal maltase activity in individuals fed high carbohydrate diet has been observed in only two of seven studies on Passerine birds. We investigated whether differences in dietary lipid might account for the confusing results. We raised house sparrow (*Passer domesticus*) nestlings on a starch free diet A (0% starch, 20% corn oil, 60% protein), and two diets containing starch but with different oil contents: diet B (25% starch, 8% oil, 46% protein) and diet C (25% starch, 20% oil, 34% protein). On diets with similar lipid content (A and C), maltase and sucrase activities summed over entire small intestine were specifically almost doubled in birds fed diet with starch. But, on diets with similar starch content (B and C), summed carbohydrases activities were one third lower in birds fed more lipid. There was no significant effect of diet on summed activity of aminopeptidase-N. The changes in carbohydrase activities were thus consistent with the adaptive modulation hypothesis, but high oil had a counteracting effect on carbohydrase activities of nestlings. The emerging picture is that digestive enzyme levels respond in a complex manner to multiple dietary signals probably via multiple regulatory pathways. Supported by NSF IOS-0615678 to W.H.K.

87.3 BUCHWALD, Robert*; DUDLEY, Robert; University of California, Berkeley; *rbuchwald@gmail.com*

Maximum accelerations during takeoff in the bumblebee (Bombus impatiens)

Limits to locomotor performance can vitally influence the outcome of diverse behavioral interactions (e.g., predation), but studies of maximum acceleration have received little attention, especially for flying animals. To better understand limits to insect flight performance, we studied maximum linear accelerations during takeoff of the bumblebee, *Bombus impatiens*. Insects were released into a dark chamber with a perforated floor so as to preclude ground effects, and were filmed at 1000 frames/s during takeoff following visual stimulation with an overhead light. Velocity and acceleration profiles were calculated from digitized video sequences using a quintic spline function; accelerations averaged 3.8 m/s/s. Leg contributions to the takeoff were minimal; power estimates will be compared to those characterizing maximum load-lifting performance.

78.4 BUCHWALTER, DB*; FLIPPIN, JL; XIE, L; North Carolina State University; *david_buchwalter@ncsu.edu*

Mercury (II) bioaccumulation and antioxidant physiology in four aquatic insects

We examined Hg(II) bioaccumulation and compartmentalization patterns in conjunction with antioxidant responses in four aquatic insect species two mayflies (*Maccaffertium modestum* and *Isonychia sp*) and two caddis flies (*Chimarra sp* and *Hydropsyche betteni*). Global antioxidant capabilities differed among unexposed larvae, with both caddis fly species exhibiting elevated antioxidant activities relative to the mayflies. We were able to account for these differences by examining the constitutive activities of catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase (GPx), and glutathione S-transferase (GST), in the four species. We also examined levels of reduced and oxidized glutathione and cysteine in the insects. Glutathione peroxidase and SOD were the most responsive to Hg exposure, with GPx catalytic activity increasing between 50 to 310%. Superoxide dismutase activity decreased between 35 and 50%. This SOD suppression was shown to be dose-dependent in both caddis flies, but the strength of this suppression did not appear to be related to rates of uptake. Surprisingly little Hg (<10%) was found in heat-stable cytosolic protein subcellular compartment in each of the four species, suggesting that Hg was not well detoxified. By combining bioaccumulation studies with other physiological measures, we can begin to better understand the consequences of trace metal pollutants in nature.

30.4 BUEHLER, D. M*; TIELEMAN, B. I.; PIERSMA, T.; Univ. of Groningen, Univ. of Groningen; Royal Netherlands Insitute for Sea Research; *d.m.buehler@rug.nl*

Bottlenecks, budgets and immunity: the possibility of immune strategies in long distance migrant birds

How do migrating birds deal with disease threats and allocate resources needed for immune function over the annual cycle and in different environments? To find out, we studied red knots, a species of long distance migrating shorebird. We measured immune function once a month for a year in knots living in captivity. We also manipulated air temperature to see whether increased energy expenditure (spending energy on staying warm) affected immune function. In a separate experiment, we manipulated food availability to see whether decreased energy intake affected immune function. We used assays for measuring different aspects of constitutive immune function from a single blood sample, and in the food availability experiment we also induced an acute phase response. We then used multivariate statistical techniques to examine whether different aspects of immune function group together into strategies. We found that immune function varied significantly over the annual cycle, even in captive birds. Furthermore, covariation between immune indices suggested that birds use different immune strategies during different annual cycle stages. Strategies based on phagocytosis increased during spring migration, but decreased during peak feather molt. We also found that neither increased energy expenditure nor decreased food availability affected constitutive immune function. However, aspects of the acute phase response were adjusted in birds experiencing limited access to food. Thus, constitutive immunity persists under conditions that challenge energy balance while birds save energy on more costly aspects of immunity. Based on these findings we conclude that some immune strategies may be more costly than others and should be used only when their benefits outweigh their costs.

23.2 BULLOCK, J.M.R.*; FEDERLE, W.; University of Cambridge; *jmrb3@cam.ac.uk*

comparison of attachment performance in the hairy and smooth adhesive pads of insects

Despite a strong interest in biomimetic adhesives, the biomechanics of natural adhesive systems are still poorly characterised. Many insects can cling to surfaces via thin films of secreted fluid and can dynamically control adhesion during locomotion; however they achieve this using two fundamentally different designs. While smooth pads possess a very soft cuticle to allow close surface contact, 'hairy' adhesives compensate surface roughness with arrays of fine micro-metre sized hairs. The hairy design is thought to offer a number of functional advantages over smooth systems, but no study has yet directly compared their performance. As such we used a 2-D strain gauge to record the adhesion and friction forces of single tarsal pads of beetles and stick insects, whilst simultaneously recording contact area. Sliding experiments showed that forces strongly increased with decreasing amounts of fluid secretion in both systems. Shear stresses were also strikingly similar between hairy and smooth pads and strong dependence on direction was observed. Hairs readily detached when moved distally (against their natural angled orientation) and in both systems tarsal buckling caused peeling and loss of contact. This directional dependence of forces is achieved both at the level of the whole tarsus and for hairy systems, at the level of the single hairs.

S7.3 BURGERT, I*; FRATZL, P; Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; *ingo.burgert@mpikg.mpg.de*

The Plant Cell Wall Acts as a Sophisticated Mechanical Device

Plants are hierarchically organised and possess remarkable mechanical properties. The unique performance of plant biomaterials is based on sustained optimization processes of the organism, which become obvious in the shape of the organs and in the adapted molecular structure. Depending on tissue function, plant cells are formed in various ways with respect to shape, thickness and arrangement of cell wall layers, orientation of the cellulose microfibrils as well as chemical composition. At the molecular level cell walls consist of a few nanometer thick semi-crystalline cellulose fibrils embedded in amorphous matrix polymers such as hemicelluloses, pectins or lignin. The orientation of the parallel cellulose microfibrils in the cell wall, known as microfibril angle (MFA) is one of the main parameter to adjust their mechanical properties. The talk will focus on the mechanical performance of plant cell walls and their stress generation capacities which allow the actuation of organ movement. Particular attention will be paid to organ movements due to moisture changes in cell walls which do not require any metabolism and are controlled by the architecture of the cell walls by means of the orientation of stiff cellulose fibrils embedded in swellable matrix polymers. This general principle by which active gels can be directed in their swelling behaviour by stiff fibres distributed in a suitable way makes humidity-based actuation systems in plants particularly interesting for biomimetic materials research. Recent findings on the stress generation in tension wood (hardwoods) and compression wood (softwoods) which enable trees to orient leaning stems and branches, and the bending movement of wheat awns which provide motility to the seed in a daily cycle are presented.

50.6 BURNS, Darren J*; BAUCHINGER, Ulf; MUKHERJEE, Shomen; PINSHOW, Berry; Ben-Gurion University of the Negev; *darrenjo@bgu.ac.il*

Physiological and behavioral responses of molting house sparrows to protein stress

Birds use both physiological and behavioral mechanisms to gain and conserve protein when they molt. Therefore, we hypothesized that molting birds will forage for longer and enter deeper nighttime hypothermia, than birds not undergoing molt. We divided 18 house sparrows (*Passer domesticus*) into three equal groups: unmanipulated controls; a group from which we plucked 5 retrices and 5 flight feathers from each wing; and a sham-plucked group with the same feathers cut off above the calamus (to control for the energy expenditure of molt). Each bird had a thermosensitive transmitter implanted in its peritoneal cavity. The birds were fed 50% of their average daily food requirement for 2 days, to induce nighttime hypothermia. By day, we measured their foraging rates. Contrary to our predictions, we found that plucked birds had significantly lower foraging rates (p=0.008) than the unmanipulated control group (1.94±0.29 vs. 2.24±0.29; SE=0.96,). There were no significant differences in foraging rate between the plucked birds and the sham controls. However, a P value of 0.07 for the difference between the sham-plucked and unmanipulated control groups (sham-plucked 2.16±0.22 vs. control 2.24±0.22; SE=0.96) hints that flight was the major energy cost and the addition of the extra energy needed for molt contributed to making the difference significant between the plucked and control birds. Although resting, food-limited birds lowered their body temperatures more than those fed *ad libitum*, there was no significant difference among the groups. We concluded that it of greater benefit for molting birds to reduce activity to conserve protein, than to forage more in order to take in extra protein.

60.1 BURPEE, Jessica L*; KINSEY, Stephen T; University of North Carolina Wilmington; *jlb7346@uncw.edu*

Scaling with body mass of mitochondrial respiration in fish white muscle.

White muscle in black sea bass (*Centropristis striata*) grows hypertrophically, and fiber sizes increase during development from <50 m in juveniles to >250 m in adults. This leads to increases in intracellular diffusion distances that may impact the scaling of metabolic properties. We have previously analyzed the scaling with body mass of aerobic capacity (mitochondrial volume density; b=-0.06), and the maximal rate of an aerobic process (post-contractile phosphocreatine recovery rate; b=-0.07) in isolated white muscle. In the present study, we examined the mass-specific scaling of state 3 respiration in isolated mitochondria in the presence of excess substrates (malate, pyruvate and ADP). In contrast to prior studies, these measurements are in no way limited by the diffusion of oxygen or metabolites to the mitochondria. The small scaling exponent of state 3 respiration (b=-0.004) was not significantly different from zero over a 50 fold range in body mass. This is consistent with the similar scaling exponents for mitochondrial volume density and phosphocreatine recovery rate, and implies essentially no effect of diffusion on metabolic rate, despite the long diffusion distances in these muscle fibers.

65.1 BUTLER, L.K.*; RIES, L.; HAYDEN, T.J.; BISSON, I.-A.; WIKELSKI, M.; ROMERO, L.M.; Tufts Univ., Univ. of Maryland, Engineering Research and Development Center, Princeton Univ., Max Planck Inst. for Ornithology; *luke.butler@tufts.edu*

Physiological and demographic effects of roads on an endangered, old-growth specialist and a common generalist

The Golden-cheeked Warbler (*Dendroica chrysoparia*) is an endangered migratory bird that prefers to nest in large tracts of mature forest and suffers increased nest predation as forest edge increases. We tested the hypothesis that forest edge in the form of roads, a threat to habitats and interior-dependent animals around the world, would cause stress in breeding adult warblers. We tested the prediction that baseline and stress-induced corticosterone (CORT) concentrations would differ in males near edge than in males far from edge. Based on the common understanding of glucocorticoid function we might predict higher corticosterone in more stressed males, but growing evidence suggests that chronic stress can result in lower CORT concentrations. In agreement with this new view of chronic stress, baseline CORT appeared to decrease as road density increased in the breeding habitat of Golden-cheeked Warblers. We also tested the predictions that males breeding in areas with more edge would have lower body condition than interior males, and that older, more experienced males would be more common in interior patches and less common near roads. For comparison, we tested the same predictions in the White-eyed Vireo (*Vireo griseus*), a common and widespread migrant that does not appear to avoid edges and breeds in a variety of habitats including Golden-cheeked Warbler habitat. We also injected White-eyed Vireos with adrenocorticotropic hormone (ACTH) to test the prediction that road density affects adrenal sensitivity to stimulation by the pituitary. Our results illustrate whether an endangered bird is more susceptible to stress due to habitat alteration than a common bird breeding in the same place.

57.5 BUTLER, MA*; KING, AA; University of Hawaii, University of Michigan; *mbutler@hawaii.edu*

Multivariate comparative analysis using OUCH

Correlated evolution, the hypothesis that evolutionary forces are acting on characters jointly, is a major feature of evolutionary theory. For example, whether genome size evolves in correlation with basal metabolic rate is a question which has interested biologists for decades. Adaptation can often be even more complex, involving suites of characters. For example, birds and bats which fly in close quarters amongst the trees have shorter wingspan and lower aspect ratio, which reflects their need for greater maneuverability. Recently, methods have been developed for adaptive evolution which model the evolutionary response of a continouous phenotype in response to multiple (hypothesized) adaptive regimes. These methods often greatly improve the fit of comparative data over pure Brownian motion models. However, they have not been fully extended to the multivariate case. Here we generalize the model-based approach to adaptive evolution (Hansen 1997, Butler and King, 2004) for the bivariate or multivariate case. We illustrate how one may model adaptive evolution by hypothesizing the operation of different selective regimes on various branches of the phylogeny. We illustrate the method by reanalyzing the evolution of genome size and basal metabolic rate in archosaurs, and male and female body size in Caribbean *Anolis* lizards, and comparing with a univariate analyses.

53.4 BUTTEMER, W.A.*; O'DWYER, T.W.; HOYE, B.J.; KLASING, K.C.; ASTHEIMER, L.B.; University of Wollongong, Australia, Univesity of California, Davis, Netherlands Institute for Ecology, The Netherlands, University of California, Davis, Univesity of Wollongong, Australia; *buttemer@uow.edu.au*

Interactive effects of testosterone and immune challenge on aerobic performance in House Sparrows

There is a common perception that rises in circulating testosterone result in immunosuppression in breeding male vertebrates. Because immune responses are believed to come at a cost, immune challenge is more likely to result in reduced peak aerobic performance in pre-breeding than in breeding males. We examined this question by measuring basal and peak metabolic rates in male and female sparrows under four different treatments: 1) testosterone treated/immune challenged, 2) testosterone treated/sham injected, 3) empty implants/immune challenged, and 4) empty implants/sham injected. The immune challenges consisted of three consecutive intraperitoneal injections of sheep red blood cells along with an intramuscular injection of keyhole limpet haemocyanin (KLH). Peak metabolic rate (during repeated takeoff and short flight) and basal metabolic rate were measured before and after each of these treatments. Testosterone significantly reduced specific immunity in males, but had no significant effect on antibody formation to KLH in females or on constitutive immunity in either gender. Neither peak metabolic rate nor basal metabolic rate were affected by testosterone or by immune challenge. We therefore conclude that testosterone-induced immunosuppression is very limited in male sparrows and has little consequence on energetically costly activities.

43.1 BYRNES, G*; LIM, N; SPENCE, A. J.; Univ, of California, Berkeley, National Univ. of Singapore, Royal Veterinary College; *byrnes@berkeley.edu*

Integrating locomotor mechanics and transport costs in a free-ranging gliding mammal

Gliding has evolved independently at least six times in mammals. One hypothesis for the origin of gliding is that it is an energetically efficient form of locomotion. Using mathematical models of the costs of locomotion, it is possible to determine for a given glide distance if gliding is energetically favorable to quadrupedal locomotion. According to predictions of these models, large gliders must glide a longer distance in order for gliding to be more efficient. To determine if a free-ranging gliding mammal, the colugo (*Galeopterus variegatus*), minimizes locomotor costs by gliding, we examined the locomotor behavior of free-ranging colugos using custom-designed data-loggers. Using the logged center of mass dynamics data, both the glide distance and vertical distance climbed prior to each individual glide were estimated. From these data, the metabolic cost of gliding a given distance can be estimated. Comparing the cost of vertical climbing and gliding to quadrupedal locomotion, we found gliding locomotion to be more energetically costly for all but the longest glides. This suggests that the selective pressures shaping gliding behavior are more complex than maximizing locomotor efficiency. Examining locomotor mechanics and transport costs in the natural environment allows insights into the links between biomechanics, energetics, and the ecology of organisms.

25.8 BYWATER, CL*; WHITE, C; WILSON, RS; University of Queensland; *c.bywater@uq.edu.au*

Geographic variation in weapon size, strength and colouration among populations of the two-toned fiddler crab (Uca vomeris).

Males of many species possess specialized weapons that are often displayed to resolve territorial disputes without direct physical contact. Theory predicts that the evolution of increased weapon size should be associated with increased competition for resources and weapon strength should increase simultaneously with size (reliable signals). In this study, we tested this association by examining inter-population variation in the size and maximum strength of the enlarged claw of the two-toned fiddler crab (*Uca vomeris*) and examined its association with population density, habitat variation and weapon colouration. Fiddler crabs represent an ideal group for studying the evolution of weaponry as males possess one enlarged and brightly coloured claw that is used both as a weapon during disputes with other males and to attract females during courtship. We examined ten populations of *U. vomeris* in the creeks and bays along the south-east coast of Queensland between the Gold Coast and Noosa. We predicted that the increased competition that results from high population densities would be associated with larger relative claw sizes and greater strength. For each population, we estimated population density and quantified the habitat type, orientation and average tidal exposure. We collected more than 100 males from each population and measured the body size, claw size and maximum claw closing strength for each individual using a custom built force transducer. We will discuss the variation observed among populations in relative and absolute size of their weaponry and its association with maximum strength, weapon colouration and population density.

17.5 CABLE, AE*; KANATOUS, SB; Colorado State University; *amber.e.cable@gmail.com*

Understanding regulation of adaptive changes in skeletal muscle physiology of Weddell seals: A proteomics approach

Weddell seals (*Leptonychotes weddelli*) are elite diving mammals that use aerobic respiration in their swimming muscles during prolonged periods of hypoxia. Upon cessation of weaning and commencement of diving, Weddell seals generally experience developmental changes in muscle physiology that parallel changes in activity. In contrast to terrestrial mammals, where this developmental trend in increasing exercise capacity occurs from birth, Weddell seals pups have the highest percentage of type I slow oxidative fibers as well as the highest mitochondrial densities of any age class. The purpose of this study was to use proteomics to gain further understanding on mechanisms regulating adaptive changes in muscle physiology between three distinct age classes: pups (3-5 weeks old/non-divers), juveniles (1-2 years old/novice divers) and adults (7+ years old/expert divers). Juveniles showed the highest expression of myoglobin (9.9% volume compared to 8.8 and 7.2 in adults and pups, respectively). These initial results support previous findings that myoglobin concentrations differ with behavioral differences in diving activity, which is supported by aerobic metabolism in the skeletal muscles. With this success, we anticipate finding unique protein identifications in the three age classes that parallel age-related changes in diving activity. Knowledge of regulatory mechanisms of muscle development in this unique model is valuable due to potential pharmacological implications for treating human disease, specifically those that involve hypoxic conditions such as cardiovascular and pulmonary diseases. Furthermore, protein identification of the pups highly oxidative skeletal muscle can potentially provide insight on human obesity by linking energetics, brown adipose progenitors, and skeletal muscle.

47.6 CAIN, K.E.*; AINSWOTH, K.L.; KETTERSON, E.D.; Indiana University, Spelman College; *caink@indiana.edu*

Is Testosterone a Mediator for Aggressive Behavior in Female Dark-eyed Juncos?

Recent interest has focused on suites of correlated behaviors, termed animal personalities or behavioral syndromes, as a framework for studying behavioral variation and its effects on fitness. Because steroid hormones regulate a wide array of traits including behavior, they are a potential proximate mechanism underlying such relationships. Testosterone (T) in particular is a well-studied mediator of aggressive and reproductive behavior in male animals. In dark-eyed juncos (*Junco hyemalis*), a socially monogamous temperate songbird, individual variation in the degree to which males respond to stimulation of the hypothalamic-pituitary -gondal axis has been shown to co-vary with mating and parenting efforts such that high levels of response lead to more aggressive intrasexual interactions but lower provisioning of offspring. In females much less is known about natural variation in T and its role in mediating aggressive and reproductive behaviors, but experimentally elevated T has been shown to increase intrasexual aggression and decrease some parenting behaviors. However, understanding how natural variation in T in females relates to behavior is essential to predicting how selection may act. To elucidate this relationship we measured aggressive displays in free-living female juncos in two contexts, first towards a same-sex conspecific and second towards a simulated nest predator, to determine whether these behaviors are correlated with each other and with natural T profiles. If findings indicate a positive relationship between T and aggressive behaviors then this would suggest that T is an important mediator for behavioral phenotype in females as well as males and have important implications for the role of testosterone in mediating suites of correlated behaviors.

45.5 CAIN, S. D.*; OHMES, L. B.; TRUMAN, G. A.; Eastern Oregon University; *shaun.cain@eou.edu*

Nervous control of cilia during sniffing behavior of Tritonia diomedea

How the brain of animals make decisions based on conflicting sensory information is an important component of the nervous control of behavior. In this study, we investigated the control of sniffing behavior that is turned off during movements activated by non-odor cues. The lateral tips of the oral veil in nudibranchs serve as a primary sensory organ, derived from the anterior tentacle of the ancestral gastropod. One feature of this organ is a dense field of cilia that line a channel on the ventral surface of the lateral tip. The beating of these cilia is hypothesized to create water currents that move odors from the substrate to the sensory cells that are clustered at the base of the lateral tips. In *Tritonia diomedea*, this field of cilia is innervated by a pair of peptidergic giant neurons (left and right pedal 7) that appear to function in the control of motor cilia. These same neurons have previously been shown to be inhibited by stimuli that promote directed crawling, such as magnetic field rotations. Here, we tested the role of the Pd7 in stimulating motor cilia by application of TPeps (the neurotransmitter produced by these neurons) and direct stimulation of the Pd7 neurons in a brain-lateral tip preparation. Initial results suggest that the both application of TPeps and direct stimulation of Pd7 increase the rate of ciliary transport in the ciliated channel. Further work suggests that the inhibition observed during crawling is controlled by the Swim CPG. The results suggest that one function of the CPG is to decrease or abolish olfactory information entering the brain by turning off the motor cilia of the lateral tip. This could potentially eliminate activation of neuronal networks conflicting with directed movements (*e.g. magnetic orientation*) or the escape response to predators.

83.2 CAMP, A.L.*; KONOW, N.; SANFORD, C.P.; Hofstra University, Johns Hopkins Medical Institute; *acamp1@pride.hofstra.edu*

Trapezoids and tongues: the evolution of prey-processing mechanics in teleost fish

Mechanical models aid evolutionary analyses of complex biological systems by permitting quantitative comparisons between species and lineages. The independent origin of raking, a novel prey-processing behavior using the tongue-bite apparatus (TBA), in two lineages of teleost fishes (salmonids and osteoglossomophs) provides a model system in which to examine the relationship between structure and function in evolution. Salmonids exhibit a pronounced degree of similarity in morphology, muscle-activity and kinematics, while osteoglossomorphs display structurally and functionally diverse TBAs and raking behaviors. Using a planar 4-bar linkage to model raking mechanics, the functional consequences of structural differences on output motion were directly related to the degree of behavioral stereotypy or diversity within and between lineages. Additionally, force and velocity trade-offs, as predicted by the 4-bar configuration and existing kinematic data, were examined in several lineage-representatives. Salmonids are united by a specialized 4-bar configuration which enables optimized raking, but the unique functional properties of this system are easily compromised by even slight structural changes. In contrast, osteoglossomophs have 4-bar architecture that is modifiable via relatively minor structural changes, without loss of function, to prioritize either force or velocity-output. We show that 4-bar mechanisms provide useful models for interspecific comparisons in an evolutionary context and may explain the unprecedented degree of stereotypy among the trophic generalist salmonids. Supported by the NSF (IOS#0444891, DBI#420440).

18.5 CAMPANALE, J. P.*; TOMANEK, L.; ADAMS, N. L.; California Polytechnic State Univ., San Luis Obispo; *jpcampan@calpoly.edu*

Proteomic Response of the Sea Urchin, Strongylocentrotus purpuratus, Early Cleavage Embryo to Ultraviolet Radiation

Increasing solar ultraviolet radiation (UVR, 290-400 nm), especially ultraviolet B, (UVB, 290-320 nm) is reaching Earths surface due to ozone depletion and global climate change. Embryos of the purple sea urchin, *Strongylocentrotus purpuratus*, provide an ideal system for modeling the protein mediated cell cycle response to stressful UV-irradiation. Six batches of *S. purpuratus* embryos were exposed to UVR and monitored for delays in mitotic cleavage. Protein expression profiles from UV-treated and UV-protected embryos were obtained using two-dimensional gel electrophoresis (2D GE). Eggs were fertilized, exposed to UVR using a Q-Panel UV-340 lamp and allowed to develop for 30 and 90 mins. Subsequently, proteins were isoelectrically focused (pH 4-7) and separated by molecular weight using SDS-PAGE. UV-treated embryos cleaved an average of 21.69 mins later than the UV-protected embryos. At least 987 protein spots were detected in the gels containing either UV-protected or UV-treated cell lysates. Our preliminary results indicate that 141 protein spots show a significant change in expression density between UV-treatments for all batches of embryos at all time points (2-way ANOVA, P= 0.01). We are evaluating these protein spots for promise as markers of UV-induced stress by identification using matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF-TOF) mass spectrometry. Our findings indicate that protein expression profiles obtained using 2D GE and MALDI-TOF mass spectroscopy are valuable tools for identifying how embryos respond to UVR -irradiation. Identification of these proteins may allow us to further ascribe functional stress responses at the cellular level.

90.5 CAMPAS, O*; MAHADEVAN, L; Harvard University; *ocampas@seas.harvard.edu*

Tip growth of pollen tubes

Plant cells have the ability to remodel their shape while sustaining an internal turgor pressure that can reach values up to 10 atmospheres. This is achieved by a tight and simultaneous regulation of cell wall assembly and mechanics. It remains unclear though how the interplay between mechanics and growth shapes the cell. We address this question in the particularly simple geometry of tip growth, which consists of the assembly and expansion of cell wall at the apical region of a cylindrically shaped tubular structure. Specifically, we theoretically describe the tip growth of pollen tubes accounting for both the mechanical properties of the cell wall and its assembly process. The observed irreversible expansion of the cell wall during growth is modeled as the extension of a viscous fluid shell under the action of turgor pressure, similarly to the process of glassblowing. Both the radius of the pollen tube and its growth velocity are derived in terms of the relevant physical parameters, as the turgor pressure or the secretion rate of new cell wall material. Identifying these parameters is essential to understand what magnitudes cells might regulate during morphogenesis. We show that although pollen tube shapes may depend on many details, their variability can be understood with a single dimensionless parameter that characterizes the interplay between cell wall assembly and expansion. Our description provides a framework to understand the shape variability observed in tip growing cells of different species, both in plants (pollen tubes, root hairs, et cetera) and fungi (hyphal growth).

S5.9 CANNON, J.P.*; LITMAN, G.W.; University of South Florida; *jcannon@health.usf.edu*

Plasticity Of The Immunoglobulin Domain In The Evolution of Immunity

Immune receptors are omnipresent in multicellular organisms and comprise a vast array of molecular structures that serve to detect and eliminate pathogenic threats. The immunoglobulin (Ig) domain, a central structural feature of the antigen binding receptors that mediate adaptive immunity in jawed vertebrates, appears to play a particularly widespread role in metazoan immunity, as recent reports have also implicated Ig domains in the immune responses of protostomes such as flies and snails. We have focused on the utilization of the Ig domain in chordate immunity and have identified numerous multigene families of Ig domain-containing receptors that appear to serve roles distinct from the adaptive antigen binding receptors. Three families have received particular focus: variable region-containing chitin-binding proteins (VCBPs) of amphioxus, modular domain immune-type receptors (MDIRs) of cartilaginous fish and novel immune-type receptors (NITRs) of bony fish. All three families are present in highly diversified forms and exhibit a striking dichotomy of apparent universal presence but extensive sequence diversification among the particular taxonomic groups in which they are found. Crystal structures of VCBPs and NITRs demonstrate significant similarity to those of antigen binding receptors but at the same time exhibit key differences that imply acquisition of separate ligand binding functions. The tremendous plasticity of the Ig domain makes it a strong focus for studies of evolutionary events that have shaped modern integrated immune systems. Current data are consistent with a model of extremely rapid emergence and divergence of immune receptors, perhaps specific to individual species, as organisms contend with environments filled with pathogens that are continually selected for variation of their own molecular signatures.

56.4 CANNON, JT*; RYCHEL, AL; SWALLA, BJ; HALANYCH, KM; Auburn University, University of Washington; *cannojt@auburn.edu*

Hemichordate evolution: Derived body plans and suspect families

Hypotheses of deuterostome and early chordate evolution have commonly focused on hemichordates as typifying ancestral forms. Traditional taxonomic schemes divide Hemichordata into two classes, the solitary, free-living Enteropneusta, and the colonial, tube-dwelling Pterobranchia. There are two major hypotheses regarding hemichordate evolution: 1) pterobranchs are sister to a monophyletic Enteropnuesta; and 2) enteropneusts are paraphyletic, with pterobranchs originating from within the direct developing saccoglossid enteropneust lineage. Whether enteropneusts or pterobranchs are basal hemichordates has important consequences for reconstructing the last common ancestor of the deuterostomes. In the present study, we expand the number of hemichordate taxa used in phylogenetic analyses for 18S rDNA data and also employ more quickly evolving mitochondrial gene sequences. Two deep-sea hemichordate worms appear to be members of traditional enteropneust clades, not separate families. Pterobranchs fall within Enteropneusta as sister to Harrimaniidae, concordant with previous results based on 18S rDNA. These results suggest that colonial pterobranchs evolved from a solitary acorn worm-like hemichordate ancestor. Thus, pterobranchs are unlikely to represent the deuterostome ancestral form as has been suggested by many traditional theories of deuterostome evolution.

S8.7 CARLETON, Karen L; University of Maryland; *kcarleto@umd.edu*

The diversity of cichlid vision

Cichlids are well known for their diverse morphologies and color patterns. We have found that their visual systems are also highly diverse with some of the largest known differences in visual sensitivities amongst closely related species. This diversity is a result of cichlids having seven unique cone opsin genes. Because these genes are sensitive from the ultraviolet to the red ends of the spectrum, and because species differ in which sets of these genes they express, visual sensitivities can show large shifts between species. Cichlids can also more finely tune visual pigments through alterations in opsin amino acid sequence. Both of these tuning mechanisms likely play an important role in cichlid ecology and communication. We will discuss our progress to determine the molecular mechanisms which control cichlid visual sensitivities as well as their possible role in driving cichlid diversification.

88.6 CARMODY, R.N.*; CONE, E.; WRANGHAM, R.W.; SECOR, S.M.; Harvard University, University of Alabama; *carmody@fas.harvard.edu*

Cooking and the net energy value of meat: implications for human evolution

The emergence of *Homo erectus* ~1.9 MYA is characterized by energetically costly increases in body size and relative brain size, coupled with reductions in the gut and dentition. This suite of adaptations suggests that *Homo erectus* ate foods of higher energy density than did its australopithecine ancestors. Among anthropologists, the relative roles of increased meat-eating and the advent of cooking in supporting this energetic transition are debated. However the two are not mutually exclusive: if cooking improves the net energy value of meat, cooking may have played an important role regardless of the timing of its adoption or the extant degree of carnivory. Recent reviews of the diffuse literature suggest several positive effects of cooking, but no studies have addressed its net contributions experimentally in mammals. As a first test of the hypothesis that cooked meat provides more net energy than raw meat, we compared growth and caloric intake between two groups of weanling BALB/c mice (n = 24; 14.1 ± 1.2 g) that we reared for 40 days on diets comprised of *ad libitum* raw or cooked (microwaved) flank steak and a supplemental ration of chow equivalent to 30% of caloric requirements. Results appear to contradict our hypothesis. We observed no differences in the weight gain of cooked-fed mice (n = 12; 9.7 ± 1.0 g) compared to raw-fed mice (n = 12; 9.6 ± 1.2 g). Moreover, preliminary analysis of intake patterns suggests that more calories were consumed by cooked-fed mice (609.8 ± 34.3 kcal) than raw-fed mice (563.3 ± 34.8 kcal) to achieve a similar level of weight gain (p = 0.003). Freezing, desiccation and excessive lean protein consumption are evaluated as factors that limit the potential benefits of cooking, and their implications for the energetic significance of cooking in human evolution are considered.

98.1 CARR, J.A.*; MARSH, R.L.; Northeastern University; *carr.je@gmail.com*

Muscle Function in a Complex Muscle During Terrestrial and Aquatic Locomotion

Understanding the mechanical function of muscles with extensive origins and insertions is challenging. The Iliotibialis lateralis pars postacetabularis (ILPO) is one of the largest muscles in the hindlimb of cursorial birds, but this muscle has been reduced or lost in many orders of birds that locomote primarily via swimming. I hypothesized that the ILPO would not be actively contributing to the work done by the hindlimb during swimming. Common Moorhens (*Gallinula chloropus*) and Mallards (*Anas platyrhynchus*) were used to test this hypothesis. Common Moorhens and Mallards were used because these species have an ILPO and they employ both swimming and running to different degrees during routine locomotion in the wild. Using sonomicrometry and electromyography, we measured the strain and electrical activity in the ILPO during swimming and running at different speeds. Histological techniques, combined with sonomicrometry, were used to normalize the measured strain patterns to sarcomere length. Results show that in the both the Common Moorhen and the Mallard, during running, the ILPO shows a pattern of activity that is similar to the activity seen in the cursorial Guinea Fowl. However, during steady swimming, the ILPO shows reduced activity and experiences much smaller strains. These results are consistent with the hypothesis that the large ILPO in cursorial birds evolved in the context of selection for running ability, and its reduced size in swimming birds resulted from its lesser importance in propulsion during swimming. Supported by NIH AR47337 and NSF IOB-0542795 to RLM.

MOORE.1 CARROLL, S.; Univ. Wisconsin-Madison
Into The Jungle: Great Adventures in the Search for Evolution and What Students Can Learn From Them
TBA

71.4 CARROLL, Andrew M.*; HUSKEY, Steve; WAINWRIGHT, Peter C.; University of Evansville, Evansville, IN; *ac204@evansville.edu*
Muscle mass limtis suction feeding performance among three centrarchid species.
The influence of musculoskeletal design on suction feeding performance (i.e. volumetric expansion and sub-ambient pressure generation) is not quantitatively or generally established. It has been hypothesized that mechanical work and power, and thus suction feeding performance are limited by available energy from suction feeding muscle contraction. Here, we measured external kinematics, buccal sub-ambient pressure, and available epaxial muscle volume to determine whether available muscular capacity in fact limits suction feeding performance. Silicone casts of buccal dimensions were used to estimate internal buccal volume change from external kinematics (videoed at 500 or 1000 Hz), while sub-ambient pressure was measured directly. Measurements where made on a broad size range of individuals from three species of centrachid fishes, largemouth bass (*Micropterus salmoides*), bluegill sunfish (*Lepomis macrochirus*), and green sunfish (*Lepomis cyanellus*), feeding on evasive prey. Muscle mass was found to have a strong correlation with mechanical work ($r=0.85$; $p<0.001$) and power ($r=0.83$; $p<0.001$). The slopes of these correlations where found to be realistic estimates of mass-specific muscle work (11.82 J Kg-1) and power (634127 W Kg-1). Interestingly, the relative proportion of suction feeding muscle to body mass was found to strongly correlate with suction feeding work ($r=0.84$; $p<0.01$) and power ($r=.88$; $p<0.01$) among <i>Lepomis individuals (but not when *Micropterus* were included). Finally, a strong ($r=0.81$; $p<0.001$) trade-off between sub-ambient pressure magnitude and volume was found, but only when the latter was normalized to available muscle mass. Thus, suction feeding fish are limited first by their proportion of available muscle mass available for suction feeding, then by the trade-off between volumetric expansion and sub-ambient pressure production.

8.9 CASKEY, J.L.*; WATSON, G.W.; BAUER, R.T.; University of Louisiana, Lafayette; *shrimpgirl@gmail.com*
The role of glucosamine in mate recognition of the caridean shrimp Palaemonetes pugio
Chemical communication plays a major role in regulating many animal behaviors. It has been proposed that mating in crustaceans is highly dependent upon chemical cues that are a part of a highly adapted signal/receptor complex of a mate recognition system (MRS). Experimental evidence has shown that the MRS of *Palaemonetes pugio* involves a non-diffusible chemical signal produced by the female that elicits copulatory behavior from males upon contact. Two forms of carbohydrates utilized by crustaceans as chemical signals are oligosaccharide residues of glycoproteins and modified amino sugars hydrolyzed from proteoglycans. Several studies have demonstrated the importance of carbohydrate residues, particularly N-acetylglucosamine, in mate recognition in several species of harpacticoid copepods. The purpose of this experiment was to determine the role, if any, that glucosamine plays in mate recognition. A mating experiment showed that glucosamine significantly reduced the number of copulations (6 of 20) when compared to glucose (14 of 20). A 20 min time course series monitoring intracellular Ca^{2+} levels of male receptors showed an increase in Ca^{2+} levels when exposed to glucosamine (5 of 10) but not when exposed to glucose (0 of 10). When this same experiment was performed in Ca^{2+}-free seawater, the same increase was seen, indicating that the intracellular Ca^{2+} appears to be an internal source. Based on these findings, male receptors appear to be lectin-like proteins capable of binding glucosamine, which inhibits mating. The binding of glucosamine to the receptors increases intracellular Ca^{2+} levels, which is hypothesized to be a second messenger molecule facilitating signal transduction.

27.2 CATENAZZI, A*; KUPFERBERG, S; University of California, Berkeley; *acatenazzi@gmail.com*
Growth and development of stream tadpoles in relation to drainage network position
An open question in amphibian ecology is the extent to which distribution and abundance of populations are determined by the performance of early life stages. Monitoring of the stream-breeding Foothill Yellow-legged frog (*Rana boylii*) in northern California suggests that variation in larval survival induces population fluctuations. Although frogs use all lotic habitats at the Angelo Reserve, oviposition occurs only in wide, sun-lit channels. We focused on 4 streams varying in primary productivity and temperature. Egg mass censuses indicate a dense population in the S. Fk. Eel River, which is intermediate in watershed size (130 km^2) and temperature, a smaller population in warm Tenmile Ck. (180 km^2) and no reproduction in cooler tributaries, Elder and Fox (16.8 and 2.6 km^2). To understand the consequences of thermal regime and food requirements to frog recruitment, we reared tadpoles in enclosures in these streams. In half of the enclosures, we supplemented ambient epilithic periphyton with macroalgae epiphytized by nutritious *Epithemia* spp. diatoms. Survival to metamorphosis in the Eel was higher with algal supplements (46 7%) than it was with ambient periphyton (26 8%), and significantly lower in other locations. Although cool temperatures greatly lengthened the larval period, food supplements allowed some individuals to reach metamorphosis in the small tributaries. With food, the first metamorphs appeared in the two warm sites at day 69, but not until day 111 and 118 in cooler streams. Regardless of algal supplementation, tadpoles grew to larger size at the Eel and Tenmile, contrary to the expectation that tadpoles grow to larger size at lower temperatures. Our results suggest that the distribution of frogs in the drainage network is explained by factors affecting early life stages, such as food availability and water temperature.

16.2 CECILE , Helmstetter; ROBERT , Pope; STEPHEN, Secor; JEAN-HERVE, Lignot*; University Louis Pasteur, University of Alabama; *J-H.Lignot@c-strasbourg.fr*

Plasticity of the intestinal enterocytes of the Burmese Python.

Morphological changes observed in the intestinal lining of fed and fasting Burmese pythons were studied using immunohistochemistry, Western blotting, scanning and transmission electron microscopy techniques. During the first half of the postprandial period, absorbing enterocytes of fed snakes are enlarged, filled with lipids and possess elongated microvilli. Furthermore, the expression of the sodium pump is readily activated after feeding but mostly along the lateral membranes. Animals examined during the second part of the postprandial period as well as fasting snakes, possess numerous endosomes and related organelles such as numerous apical multivesicular bodies, early and late lysosomes as well as large lamellar lysosomes filled with concentric rings of lipid membranes. During this period, while some lysosomes are phagocytised by intraepithelial macrophages, others are moved to the chorion and submucosa where degradation inside macrophages takes place. Enterocytes also hypotrophy and drastically reduce the length of their apical microvilli. Furthermore, a new cell type within the mucosal epithelium is described that has an apical crypt that is empty in fasting animals. This cell type is only present in the proximal part of the intestine, is connected to the basal membrane, is devoid of large lipid droplets, possesses a large nucleus, and is less stained than its neighbouring absorbing enterocytes. In fed animals, the crypt is usually filled with a multi-layered spheroid particle made of calcium and phosphorus indicating therefore that this cell type is involved in calcium and phosphorus trafficking coming from the meal. Gut plasticity is therefore of crucial importance in Burmese pythons and relies mostly on rapid and massive morpho-functional changes of the enterocytes.

28.4 CHANEY, N.L.*; DEMAINTENON, M.J.; University of Hawaii, Hilo; *chaney@hawaii.edu*

Connectivity Patterns of Two Hawaiian Marine Gastropods Posessing Nonpelagic Development

Connectivity of benthic marine gastropods in Hawaii is poorly understood due to the lack of extensive studies. In species lacking a pelagic larval phase, connectivity between populations would be expected to be low because of limited dispersal ability. To test if geographic distance is related to genetic distance, we sampled two nonpelagic developers from the Superfamily Buccinoidea, *Mitrella fusiformis* and *Peristernia chlorostoma*. These two species both occur in the subtidal marine environment within shallow, protected inlets along the coast of the Hawaiian Islands. Samples of *Mitrella fusiformis* were collected from three locations on the island of Hawaii and from two locations on the island of Kauai. Samples of *Peristernia chlorostoma* were collected from numerous sites across the Hawaiian archipelago. Overall, the neighbor joining tree analysis of both species places geographically nearer populations closer together on the tree. The resulting DNA sequences from *Mitrella fusiformis*, spanning a 360 base pair (b.p.) section of the mitochondrial COI gene, show evidence that there is clustering in genetic variability of within island populations. The 656 b.p. COI sequences from *Peristernia chlorostoma* also exhibit this clustering of within island populations. In addition, there are differences in sequence between populations that are located less than 1 km apart from each other. These data support the concept that some nonpelagic developers form distinct, localized populations and that connectivity between populations may be very low. Understanding these gastropods connectivity may provide information important to other nonpelagic species, and help to associate and utilize these patterns within the context of marine conservation.

94.3 CHAPPLE, T.K.*; JORGENSEN, S.J.; ANDERSON, S.D.; VAN SOMMERAN, S.; KLIMLEY, A.P.; BOTSFORD, L.W.; BLOCK, B.A.; Univerisity of California, Davis, Stanford University, Inverness, CA, Pelagic Shark Research Foundation, University of California, Davis; *tkchapple@ucdavis.edu*

A comparison of spatial and temporal habitat use by male and female migrating Great White Sharks (Carcharodon carcharias) in the eastern Pacific

Current advances in electronic tagging technology have provided information regarding marine animal movements and behavior that can be used to estimate population size. Recent work with pop-off archival tags has revealed large scale movements of Great White sharks (Carcharodon carcharias) during yearly migrations between coastal and pelagic habitats (Boustany et al. 2002; Bonfil et al. 2005). However, constraints on the precision of location estimates from these tags preclude information regarding fine scale movements. Therefore, we have placed acoustic tags on white sharks off of California and deployed acoustic receivers to collect more localized movement data. A combination of these two tagging technologies has given us a more complete understanding of white shark movements. Our data show sex specific patterns, both temporally and spatially, during their seasonal migrations. Here we analyze the behavior of these sharks in both time and space to determine the probability of capture of individuals. These probabilities are critical components for population estimates and overall assessments of white sharks.

58.3 CHARVET, CJ*; SANDOVAL, AL; STRIEDTER, GF; Univ. of California, Irvine; *ccharvet@uci.edu*

The goose (Anser anser f. d.), a precocial species, enlarged its telencephalon before neurogenesis onset

Many altricial and some precocial species of birds enlarged their telencephalon relative to other birds. Previous work has shown that parakeets, an altricial species, enlarged their telencephalon by delaying neurogenesis. To determine whether precocial species also enlarged their telencephalon by delaying neurogenesis, we examined brain development in geese and turkeys, two precocial species. Whereas the telencephalon occupies more than 70% of the total brain volume in geese, it occupies only 50% in turkeys. To discover how this species difference in adult brain proportions arises we examined neurogenesis onset and estimated the volume of the telencephalon, tectum and medulla from serial Nissl-stained sections of embryonic geese and turkeys. All comparisons were done in terms of Hamburger-Hamilton stage and age. We found that the telencephalon is proportionately larger in geese than in turkeys before neurogenesis onset (stage22/ED5). We also found that telencephalic neurogenesis is not delayed in geese relative to turkeys. Therefore, precocial and altricial species appear to have enlarged their telencephalons by altering different developmental parameters.

65.5 CHEEK, A.O.; Houston Baptist Univ.; *acheek@hbu.edu*
Hypoxia alters gonadal androgen synthesis in the estuarine fish Fundulus grandis
Estuarine and coastal hypoxic zones are increasing in frequency, duration, and area worldwide. The sub-lethal impacts of prolonged hypoxia on fish are predicted to include loss of habitat, suppressed growth, and impaired reproduction. In salt marshes, hypoxia develops and dissipates in tandem with diel cycles of photosynthesis and respiration, particularly during summer. At marsh sites with moderate (2.5 mg/L dissolved oxygen) to severe (0.93 mg/L DO) diel hypoxia, wild *Fundulus grandis*(Gulf killifish) have smaller ovaries and testes, lower sex steroid hormone concentrations, and are more likely to be reproductively regressed than killifish at sites without diel hypoxia. In order to investigate potential mechanisms by which hypoxia reduces sex steroid concentrations, androgen production was measured in testis explants incubated under normoxia or hypoxia. Hypoxia dramatically reduced 11KT production, but had no effect on testosterone production when progesterone was supplied as a precursor. With 11 -hydroxytestosterone (11 OHT) supplied as precursor, hypoxia did not change 11KT production, suggesting that hypoxia specifically inhibits 11 -hydroxylase (CYP11B1), the enzyme that converts T to 11 OHT. Inhibition of the terminal steps of gondal steroidogenesis is consistent with the observation that circulating T concentration was unaffected by diel hypoxia in wild fish, but 11KT concentration was significantly reduced. In *F. grandis*, diel hypoxia appears to alter specific steps in gonadal steroid production, rather than centrally inhibiting the reproductive axis.

14.6 CHEN, Y.; SIBLE, J.C.; MCNABB, F. M. A.*; Virginia Tech, Blacskburg, Virginia Tech, Blacksburg; *cyrain@vt.edu*
Effects of pre- and post-hatching perchlorate exposure on the thyroid function and expression of thyroid-responsive genes in Japanese quail embryos and chicks
The current study examined the effect of maternal exposure to perchlorate, a thyroid disruptor, on Japanese quail embryos and the effect of perchlorate exposure on young Japanese quail chicks. Laying Japanese quail hens were treated with 2000 and 4000 mg/l ammonium perchlorate in drinking water. Eggs from these hens were incubated. Embryos, exposed to perchlorate in the eggs, were sacrificed at day 14 of the 16.5 day incubation period. Quail chicks, 4-5 days old, were treated with 2000 mg/l ammonium perchlorate in drinking water for 2 and 7.5 weeks. Thyroid status and the expression of thyroid-responsive genes, type 2 deiodinase (D2) and RC3 in the brain as well as D2 and spot 14 in the liver, were evaluated. Maternal perchlorate exposure led to embryonic hypothyroidism, which decreased body growth and increased D2 mRNA level in the liver but did not affect the mRNA levels of D2 and RC3 in the brain. Spot 14 mRNA was not detected in embryonic liver. Quail chicks showed early signs of hypothyroidism after 2 weeks of perchlorate exposure and became overtly hypothyroid after 7.5 weeks of exposure as indicated by all thyroid variables measured. D2 mRNA level was increased and spot 14 mRNA level was decreased in the liver of chicks after 2 weeks of exposure but no difference was observed in the mRNA levels of D2 and spot 14 in the liver after 7.5 weeks of exposure. The mRNA level of D2 and RC3 in the brain was not affected by perchlorate-induced hypothyroidism in quail chicks after either 2 or 7.5 weeks of exposure. Perchlorate exposure, both pre-hatching and post-hatching, disrupted thyroid function and affected the expression of hepatic thyroid-responsive genes in developing Japanese quail.

92.1 CHEN, Ming*; JOCOBS, Molly/W; LAUFER, Hans; Univ. of Connecticut; *laufer@uconn.edu*
Competition of tyrosine with alkylphenols during shell hardening in new cuticle of lobsters
Alkylphenols, anthroprogenic estrogenic endocrine distrutors, were found in naturally occurring lobsters (*Homarus americanus*) with or without epizootic shell disease. We hypothesize that alkylphenols interfere in shell hardening during molting, weakening cuticular structure, and making the cuticle susceptible to microbial invasion. Tyrosine, an alkylphenolic amino acid, is a starting component of normal sclerotization crosslinking proteins. In this study, we used an *in vitro* cuticle bioassay to investigate the effects of one of these compounds, 2,4-bis-(dimethylbenzyl) phenol, on tyrosine incorporation during hardening of new cuticle during lobster molting. We measured incorporation of ^{14}C-tyrosine during shell hardening in the presence and absence of the alkylphenol, and found that it inhibited tyrosine incorporation by 59.43.7%. This process was phenoloxidase dependent, since it was inhibited with phenylthiourea by 79.29.4%. The cold tyrosine inhibited ^{14}C-tyrosine incorporation by 56.37.4%. We also found that alkylphenols inhibited hypodermal cells from transporting tyrosine by 25.68.5% during the shell hardening process. We tested shell hardening following molting *in vivo* by measuring the force required to indent the shells. When lobsters were injected with alkylphenol, their new shell required a 5 lb. force by an average of 12 days. Control lobsters new shells could resist a 5 lb. force by 5 - 8 days. Our results suggest that alkylphenols appear to delay shell hardening during the molting process. The weakened shell may be a possible contributor to lobster shell disease.

87.2 CHEN, Jian*; RISKIN, Daniel K.; BREUER, Kenneth S.; SWARTZ, Sharon M.; LAIDLAW, David H.; Brown University; *jchen@cs.brown.edu*
Bookstein coordinate-based shape analysis of bat wing kinematics
Bats are known to fly with amazing maneuverability and agility, in part because of their unique aeromechanical features such as highly elastic wing membranes and deforming wing bones. However, the details of how the wing membrane changes shape during flight are poorly understood, including the relative importance of distinct portions of the wing. This work quantifies changing wing morphology during five flights from each of six species of pteropodid bats using Bookstein's coordinate-based measurement. We acquired three-dimensional wing motions by tracking the positions of seventeen anatomical markers on the wing and body. We then partitioned the wing into eighteen triangles distributed across distinct anatomical regions: the propatagium, the proximal and distal plagiopatagium, and the dactylopatagium. We found that the subareas of the dactylopatagium exhibited smaller shape variances compared to the propatagia. The smallest shape changes occurred close to the wrist in the dactylopataguim region. The largest change in wing shape occurred in the middle part of wing, in the plagiopatagium . These results suggest that we should attend to the most extensible region while analyzing the wing.

49.6 CHEN, Wei-Jen*; MAYDEN, Richard L.; Saint Louis University; *wjchen.actinops@gmail.com*

In search of evolutionary origin of cichlids among percomorph fishes

The family Cichlidae is one of the most diverse clades of freshwater fishes. Species from this group are a major component of the modern ichthyofauna in their native freshwater habitats, and constitute important subsistence fisheries worldwide and are important in the aquarium trade. In addition to their fundamental importance in both ecosystems and human activities, these fishes also provide remarkable examples of species diversity and adaptive radiations, and have attracted a great deal of attention from evolutionary biologists focusing on systematics, behavior, ecology, functional morphology, and genomics. In recent years, with extensive efforts investigating the systematics and population genetics of the group, more valuable insight into the diversity and evolution of cichlid fishes has rapidly emerged. However, one of the more interesting aspects of this group has been a traditional lack of understanding of the higher-level sister-group relationships of the Cichlidae relative to other teleosts. Their phylogenetic placement has varied over time according to different authors studying cichlid affinities to different perch-like lineages. In this paper, we review historical hypotheses and recent molecular evidence regarding sister-group relationships of cichlids. We also examine the phylogenetic relationships of major clades of percomorph fishes using 5 nuclear genes (c.a. 5 kb) with a tentative attempt to resolve this long-stand systematic problem in cichlids. Taxonomic sampling is composed of the taxa from labroid families (cichlids, and their putative allies: wrasses, parrotfishes, damselfishes, and surfperches), and many others from a diverse array of percomorph fishes, with a total of more than 100 taxa for the analyses. The resulting molecular phylogenetic hypothesis will be compared with previous hypotheses of relationships of these fishes and used in historical biogeographic interpretations.

21.2 CHENG, Bo*; FRY, Steven; HUANG, Qingfeng; DICKSON, Will; DICKINSON, Michael; DENG, Xinyan; University of Delaware, ETH/University of Zurich, Switzerland, California Institute of Technology; *deng@udel.edu*

Dynamics and control of turning during saccades in fruitfly drosophila

By analyzing the wing and body kinematics of free flying fruitfly drosophila during rapid maneuvers, we investigate the role of inertia and damping during saccade of insect flight. During turning, the body angular velocity induced passive aerodynamic damping is indentified both in simulation through quasi-steady state aerodynamic model and through experiments on a dynamically scaled robotic wing. In the turning yaw axis, the estimated damping coefficient on the wing induced by body turning velocity is greater than the value estimated previously on body frictional damping alone. This indicates the passive decelerating at the end of the saccade, while active stabilizing attempts for body posture is also identified. By simulating insect to rotate at six principle axes of inertial and body frames, linearized damping coefficient matrices are calculated. The result reveals the passive stability for flapping flight and can be critical in flight control either during body saccade or stabilizing movement of fruit fly.

S8.9 CHESLER, E.J.*; ZHANG, Y.; PHILIP, V. M.; CULIAT, C.T.; LANGSTON, M.A.; CHURCHILL, G.A.; MANLY, K.F.; VOY, B.H; Oak Ridge National Lab., TN, Univ.of Tennessee, Knoxville, Univ. of Tennessee, Knoxville, Univ. of Tennessee, Knoxville, The Jackson Lab., Bar Harbor, ME, Univ. of Buffalo, NY; *cheslerej@ornl.gov*

From genome to systems genetics: The Collaborative Cross mouse genetic reference population

Systems genetics is a systems biological approach in which allelic variation is studied as a natural perturbation of a biological network. Aggregation of trait data, from biomolecular to whole-organism in a single population enables the simultaneous analysis of polygeneity and pleiotropy. Advances in genetic analysis made possible through the mouse genome have uncovered both the phenomenal potential of this approach to mouse genetics, along with enhanced knowledge of the limits to genetic analysis in extant populations. The Complex Trait Consortium has devised a novel mouse population to meet the demand for a resource suited to systems genetics, with high allelic diversity, power, precision, accuracy and independence of recombinations. Fundamental to many applications in systems genetics, the population must be retrievable, consisting of a panel of isogenic lines. The resulting population, the Collaborative Cross, consists of a systematic cross of 8 divergent inbred strains, followed by inbreeding to generate a highly polymorphic population with dense recombinations and haplotype breakpoints. Breeding of the population has been in progress at the Oak Ridge National Laboratory since 2005, with additional lines being produced at other sites. Phenotypic characterization has been performed through the course of breeding and includes behavioral, physiological and morphological traits. Genotypic characterization of the population has allowed a comparison of genetic architectures with existing mouse genetic reference populations and is expected to provide insight into the underlying genetic architecture of vertebrate phenotypes.

30.5 CHESTER, E.M.*; FRENCH, S.S.; DEMAS, G.E.; Indiana University, Bloomington; *emcheste@indiana.edu*

Evidence for a trade-off between immunity and reproduction in the pregnant Siberian hamster?

One assumption in life-history theory is that resources available for competing life functions (i.e., growth, reproduction and somatic maintenance) are limited, and resources allocated towards one function are unavailable for other functions. It is now well-established that immunity is energetically costly and immune activation can impair other energetically expensive responses such as reproduction in adult animals. Furthermore, mounting an immune response during pregnancy may result in long-term consequences for offspring due to a trade-off between investment in immune function and investment in reproductive effort. Here we test this hypothesis by examining Siberian hamsters (*Phodopus sungorus*) born to mothers injected with either lipopolysaccharide (LPS; 0.0625 mg/kg) or saline during pregnancy. LPS is the active fragment of the cell wall of Gram-negative bacteria that elicits an inflammatory response, providing a valid and reliable simulator of sickness in the absence of the actual pathogen. Preliminary results indicate that LPS induced a decrease in food intake but not mass in mothers following injection. Further, male growth rate was greater in LPS offspring. Additional offspring measurements, including a comprehensive immune profile, as well as behavioral responses to a resident-intruder interaction will be presented. Collectively, the results of this study contribute to our understanding of the epigenetic (i.e., maternal) effects of immune system activation on offspring physiology and behavior in vertebrates.

73.5 CHI, K. -J.*; SCHMITT, D.; ROTH, V. L.; Duke University and National Chung-Hsing University, Taiwan, Duke University; *kjchi@phys.nchu.edu.tw*

Different functional mechanisms of foot-footpad complex for plantigrade and digitigrade mammals in the context of locomotion

All terrestrial mammals have footpads and, as the first point of contact between foot and substrate, footpads must often serve multiple mechanical roles. To meet competing (and sometimes opposite) functional demands the structure or material of the footpad may need to have different mechanical properties for each of various functions during locomotion: Pads must be compliant to cushion impact, but stiff to effectively transmit force; damped for stable foot-ground contact, but resilient to return elastic energy. To explore how these competing needs are met, this study compares kinematics of the foot-footpad complex in plantigrade humans and digitigrade dogs. The results show that humans and dogs use different mechanisms to meet the multiple functional demands placed on the footpad. A single heel pad of plantigrade humans can accommodate both compressive and shear force through mechanical anisotropy. In digitigrades dogs, by contrast, the compressive force is accommodated mainly in the footpads, while the shear is through the bar-linkage system of the paw. One adaptive explanation for the decoupling of compression and shear in the foot-footpad complex of digitigrade animals is that, by removing the requirement of accommodating shear within the pads, the digitigrade footpads can have higher compressive stiffness through the incorporation of additional tensile material. This may compensate for any increase of tissue stress due to greater plantar pressure produced in the evolutionary transition in some mammalian lineages from plantigrady to digitigrady.

57.4 CHOINIERE, Jonah N*; CLARK, James M; XING, Xu; FORSTER, Catherine A; George Washington University, Washington, DC, Institute for Vertebrate Paleontology and Paleoanthropology, Beijing, China; *jonahc@gwu.edu*

A dynamic approach to digital homology in Tetanura (Dinosauria: Theropoda)

A long-standing issue in evolutionary biology is the conflict between the identities of the three manual digits in tetanurans, the theropod clade whose crown lineage is Aves and whose stem members include large terrestrial predators such as *Allosaurus*. In Aves, embryological data strongly suggest that the manual digits correspond with digits II, III and IV of the primitive tetrapod bauplan. However, paleontological data identifies the three manual digits of non-avian tetanurans as I, II and III. This apparently non-homologous relationship has been frequently cited to falsify the theropod origin of birds. The tetanuran manual digit homology problem is analagous to biochemical sequence alignment because uncertainty of the positional identity of tetanuran manual elements implies multiple possible sets of statements of primary homology of manual digits across the clade. A dynamic homology approach is an appropriate means of selecting an optimal hypothesis of primary homology via maximum congruence. We therefore employ a dynamic homology approach to resolve the identity of tetanuran digits, incorporating information from the unique manual morphology of a new Chinese theropod closely related to tetanurans. This approach is the first of its kind for the Dinosauria. Assuming that the digits of birds have been positionally identified without error, our data indicate that for tetanurans the digits of the hand optimally align with II, III, and IV of the avian manus. Our results are compatible with a range of developmental models that have been proposed to resolve the digital homology conflict.

57.2 CLAESON, Kerin M.; The University of Texas at Austin; *kclaeson@mail.utexas.edu*

Synarcual Variation in the Purportedly Invariable Clade, Rajidae

Batoid fishes (electric rays, sawfishes, skates, guitarfishes, and stingrays) are united by a suite of characters including the presence of the synarcual, a tube-like skeletal element hypothesized to be the fused anterior-most vertebrae of the axial skeleton. The morphology of the synarcual is highly variable among the batoid subgroups and appears linked to the evolution of disparate locomotory styles associated among these groups. Until now, synarcual characters have been underutilized in phylogenetic analyses, especially of non-stingray taxa. For this study, I examined the ontogenetic and systematic variation of synarcual morphology in fossil and extant skates and rajid-guitarfishes, which are known to possess a morphologically conservative body plan. Fifteen fossil and extant species were prepared and studied using camera lucida, histology, traditional dissection and skeletonization, x-radiography, and 3D reconstruction from CT-scanning. New data permit me to describe previously undocumented synarcual characters, specify those suitable for use in phylogenetic analysis, and shed light on the development of the synarcual over geologic time. For instance, the number of spinal nerve foramina are too variable to be used within a rajid-specific analysis, however, when considered alongside guitarfish outgroups, foramen number increases among derived skates. Additionally, the relative position of the first vertebral centrum in the synarcual base varies only slightly within genera and in fossil representatives the first centrum is comparatively more anterior than in extant taxa. Thus within Rajidae, although the total length of the synarcual remains the same relative to that of the vertebral column, the number of true centra surrounded by the posterior flanges of the synarcual decreases systematically, effectively becoming a more massive skeletal element.

68.3 CLARK, A/J*; MARAVILLA, E/J; SUMMERS, A/P; Univ. of California, Irvine; *aclark@uci.edu*

Biomechanics of feeding in a jawless fish

Despite lacking jaws and substantial rigid support for feeding muscles, hagfishes can forcefully grasp and ingest chunks of flesh from their prey. It is surprising that the amount and arrangement of hard and soft tissue in the hagfish feeding apparatus (HFA) does not constrain the transmission of forces produced by the musculature. When feeding, bilaterally folding dental plates repeatedly protrude from the mouth. Dental plate movement occurs over a rigid basal plate in a manner resembling a pulley system. The retractor muscles, which exert the most direct force on the dental plates, originate in the posterior 50% of the HFA where rigid support is absent. Determining how large magnitudes of force can originate from soft origins is important for understanding how hagfish feed. We investigated motor patterns of the three largest muscles in the HFA: the deep protractor muscle (DPM), clavatus muscle (CM), and tubulatus muscle (TM). Individuals normally used four gape cycles to ingest food and four gape cycles to intraorally transport food. We measured burst duration from each muscle, TM and CM onsets relative to the DPM (reference muscle), and onsets of each muscle relative to kinematic events. The DPM fired during protraction, while the CM and TM fired during retraction. CM burst duration significantly decreased during transport. Relative to DPM onsets, TM onsets preceded CM onsets by approximately 40 ms in both capture and transport stages. Burst onsets of the retractor muscles occurred either before or after the onset of retraction during capture, but usually followed the onset of retraction during transport. Our study corroborates anatomical predictions about DPM and CM function and demonstrates that activating the circumferentially arranged TM fibers around the CM produces a stiff origin for the generation of retractile forces.

105.4 CLARK, CJ; UC Berkeley; *cclark@berkeley.edu*
Hummingbird courtship displays reveal limits to avian flight performance
Courtship displays are a common feature of breeding behavior. While the information these displays convey between suitors and potential mate remains debated, the remarkable behaviors that result can be used to study the limits of locomotor performance. I provide an example of this paradigm based on the kinematics of the display dive of the Annas Hummingbird. I filmed diving male Annas Hummingbirds with a combination of high-speed and conventional video cameras. The dive consisted of five distinct stages based on stereotypical wing and tail kinematics. After powering the initial stage of their dive with flapping wings, males fold their wings and bound, at which point they reach an average maximum velocity of 27.3 m/s (385 body lengths /s). This suggests they have a body drag coefficient of less than 0.3. They then spread their wings to pull up, reaching centripetal accelerations of nearly 9 G, and concomitant torques. This acceleration appears to be higher than those attained by diving raptors, and may be limited by the torque the shoulder can withstand.

98.11 CLAVERIE, Thomas*; PATEK, Sheila N.; Univ. of California, Berkeley; *tclaverie@berkeley.edu*
Force transmission versus speed amplification in a four bar linkage mechanism: counterintuitive results in the mantis shrimps strike
Four bar linkages are simple mechanical systems that can amplify or reduce rotation. Most biological four bar systems have been studied in the context of rotational amplification with relatively little analysis of force transmission. Mantis shrimp (Stomatopoda, Crustacea) use a four bar linkage system to power their fast predatory appendages. Some species capture elusive prey (spearers) using highly elongate appendages while others break shelled-prey (smashers) with short, massive appendages. We examined the variation in force transmission versus speed amplification in this linkage system across 14 stomatopod species. We measured the four bar linkage configuration, geometrically simulated the contraction and release of the linkage system, and calculated the resulting force and speed transmission. Most species exhibited relatively small force transmission (up to 0.4 mechanical advantage (MA)) and a large rotational amplification (typically 10-fold). The transmission of speed and force during a strike was not synchronized and followed this sequence: maximal speed, maximal force, minimal speed, minimal force and then maximal speed again. Surprisingly, the four bar model did not predict greater MA in smashers than in spearers, but species having a large MA had the lowest speed amplification. Also, species with longer predatory appendages (spearers) exhibited a maximum force transmission earlier in the strike cycle. Thus, the spatial and temporal dynamics of the four bar linkage system may be as important, or more important, than the average behavior predicted by link length ratios. These results highlight the surprising dynamics between simple mechanical systems and evolutionary variation.

74.5 CLIFFORD, Andrew/B; Brown University; *andrew_clifford@brown.edu*
The Evolution of Unguligrady and Forefoot Mechanics in Even-Toed Ungulates
Most extant even-toed ungulates adopt an unguligrade foot posture whereby body weight is supported through hoofed distal phalanges. This foot posture is derived from a petadactyl and digitigrade foot comparable to extant canids. The digitigrade-unguligrade transition is marked by variable digit loss, except for the emphasis of digits III and IV, and ligamentous replacement of interosseus muscles. In order to test the hypothesis that interosseus ligaments (IL) resist torque at the metacarpophalangeal (MCP) joint during stance, I compared data collected *in vivo* with data collected through *in vitro* preparations. Extant suids possess characteristics similar taxa that first adopt an unguligrade stance, so minipigs were run in a trackway connected to a forceplate and filmed using bi-planar cinefluoroscopy to determine the total joint torque-by-angle relationship at the MCP joint during stance. Reduced preparations of the IL permitted calculation of the torque-by-angle relationship of the IL alone. These two relationships yield the proportion of joint torque taken up by a novel ligamentous structure present only in unguligrade species. Results indicate that IL in forefeet perform a majority of work during stance at the MCP and that this proportion increases with MCP extension. IL increase step length by permitting a functionally longer foot that does not require more metabolic energy through muscle contraction to maintain an elevated stance. Unguligrady may have first evolved to permit longer leg length without incurring additional metabolic cost, since longer legs generally permit cheaper locomotion. The extremely modified and highly cursorial limbs of most extant even-toed ungulates may be an exaptation of a limb originally modified to reduce the cost of locomotion.

11.5 CLOUSE, Ronald M.*; GIRIBET, Gonzalo; Harvard University, Cambridge, MA; *clouse@fas.harvard.edu*
Ancient signals of South East Asia's history found in mite harvestmen sequence and morphological data
Phylogenetic hypotheses of the cyphophthalmid family Stylocellidae (Arachnida: Opiliones), a type of harvestman, are used to test geologic reconstructions of South East Asia. Phylogenies based on molecular and morphological data recover close relationships among inhabitants of most major landmasses and place derived groups on more recently formed areas. Molecular data consisted of approximately 6 kb from two mitochondrial and four nuclear markers, and they were analyzed with the program POY. Morphological data consisted of 60 scaled measurements and were analyzed using the program TNT. The ancestral home of the family is apparently in the Central Thai-Malay Peninsula, which is also the ancestral terrane that rifted from Gondwana 255 million years ago. Sulawesi appears to have been populated by descendants of an ancestor on West Sulawesi, in concordance with geologic reconstructions of the island, and Borneo is almost exclusively populated by descendants of a single ancestor. Sumatra and to a lesser extent Java, which have had complicated histories of exposure above sea level and connection to the Thai-Malay Peninsula, appear to house multiple lineages. Species in North East India and China are closely related to each other, and, remarkably, to certain Thai species, a relationship that agrees with novel geologic hypotheses for the history of the Indian subcontinent.

45.1 COHEN, Jonathan/H*; FORWARD, JR., Richard/B; CRONIN, Thomas/W; Eckerd College, Duke University Marine Laboratory, University of Maryland, Baltimore County; *cohenjh@eckerd.edu*

Visual spectral sensitivity underlying orientation and rhythmic behaviors in the talitrid amphipod Talorchestia longicornis

Talorchestia longicornis is a supratidal talitrid amphipod inhabiting coastal and estuarine sandy beaches along the Atlantic coast of the US. It is nocturnal, spending days in shallow nonpermanent burrows in damp sand, emerging at night to forage along the beach. An endogenous rhythm entrained by light:dark, tidal, and/or temperature cycles controls its diel activity pattern. Visually-mediated behaviors including y-axis orientation using sun- and moon-compasses have been found in the European species *Talitrus saltator*, yet little is know about the visual physiology of the talitrid eye that underlies these behaviors. The present study examined the visual physiology of the *Talorchestia longicornis* eye, and the functional role of its visual pigments in the behavior of this amphipod. Visual spectral sensitivity was determined using behavioral, electrophysiological, and microspectrophotometric methods. All three approaches suggest dual visual pigments in *T. longicornis*, with sensitivity maxima near 420 and 520 nm. The distal and proximal regions of the retina have short and long-wavelength sensitivity, respectively. Behavioral studies using broadband-filtered light sources targeting each visual pigment individually suggest *T. longicornis*, in addition to its routine visual functions, specifically uses the short wavelength visual pigment for y-axis orientation, while the long wavelength visual pigment functions for entrainment of the endogenous activity rhythm.

21.1 COHEN, I.*; RISTROPH, L. G.; BERMAN, G. J.; BERGOU, A. J.; WANG, Z. J.; Cornell University; *ic64@cornell.edu*

Probing insect flight stability and control by inducing aerial stumbles

Flying insects are both marvelously stable and annoyingly evasive. Whether awe-inspiring or frustrating, flight must be guided by a sophisticated system of controls. Here, we introduce a new experimental and analytical approach for exploring the flight stability and control system of free-flying fruit flies. We have devised an apparatus that applies physical perturbations to flying insects and simultaneously captures videos of the in-flight response to such perturbations. From these videos, we use a new motion tracking method to extract the complete, three-dimensional motion of the insect body and wings as the insect cruises, then stumbles due to the perturbation, and finally recovers. We focus on two methods for exploring the fast response of the flight control system. In one set of experiments, we perturb the insect with a time-dependent body force of our choosing. In the second, our stimulus is a brief puff of air, which is aerodynamically complex, yet naturalistic. In both cases, the insects are induced to stumble in mid-air, and we find that fruit flies are capable of strikingly accurate and fast course-correction. We explore how this course-correction behavior offers insights into the control algorithm of flying insects.

38.4 COLAYORI, Samantha E*; BAKKEN, George S.; Indiana State University, Terre Haute; *gbakken@indstate.edu*

Optics of an alternative imaging system, the facial pits of Pitvipers (Viperidae: Crotalinae)

Facial pits are specialized organs possessed by pitvipers (Viperidae: Crotalinae) that detect emitted thermal radiation. Optically, they apparently function like a pinhole camera eye. The image is formed by differential thermal radiation heating of a temperature-sensitive membrane suspended within the facial pit. The first step in understanding the image available to inform the snake's behavior is to define the optical properties of the pit, and then use optical parameters to construct simulated images of thermographs recorded in natural and artificial conditions. The fundamental imaging property of an optical system is the spread function, which is the distribution of radiation from a point source over the image detector. The geometry of the facial pit is such that the spread function is different for source points at different azimuth and elevation angles relative to the snake. We determined spread functions for several crotalid species (including *Crotalus atrox, C. horridus atricaudatus,* and *C. oreganus*). We first constructed geometric models from serial x-ray CT sections of fresh (frozen and thawed once) specimens. We placed markers on the reconstructed pit membrane and determined the azimuth and elevation for the point source that would place each marker in the center of the spread function. We then defined spread functions for each azimuth and elevation over a 160 horizontal and 60 vertical range centered on the axis of the head. We noted significant interspecific differences in spread functions and field of view, as well as considerable variation in spread function over the field of view. We will present spread function maps and images reconstructed using the actual spread function arrays appropriate to each of the study species.

71.5 COLLAR, D.*; REVELL, L.; Harvard University; *dcollar@oeb.harvard.edu*

Correlated evolution of feeding morphology in piscivorous versus non-piscivorous centrarchid fishes

We used a new phylogenetic comparative method to test whether an inferred shift in selective regime associated with the evolution of piscivory in centrachid fishes has led to changes in the pattern of diversification of feeding morphology in this group. The new method is based on maximum likelihood and allows the fitting of multiple evolutionary rate matrices to species values for two or more continuous characters and a phylogenetic tree for the included taxa. The evolutionary rate matrix is a square symmetric matrix containing the evolutionary rates for individual characters on its diagonal and the evolutionary covariances elsewhere. The evolutionary correlation between two characters is a function of their evolutionary variances (rates) and covariance, and, as such, our method is the first to allow for the estimation of different evolutionary correlations on different parts of a phylogenetic tree. We found that a two rate matrix model, where different evolutionary rate matrices were assigned to lineages that differed in the binary diet condition of piscivorous *versus* non-piscivorous, fit the evolution of gape width and buccal length better than did the single matrix model, in which a single rate matrix was assumed to prevail for all centrarchid lineages. The two rate matrix model suggests very strong correlation between the two characters in piscivorous lineages, implying that the demands of a piscivorous trophic strategy impose severe constraints on the evolution of buccal cavity shape in centrachids.

2.2 COLLIN, R; Smithsonian Tropical Research Institute; *collinr@si.edu*
Intraspecific Variation of Egg Size and Hatching Size in Crepidula : Effects of Temperature and Population Structure
A single egg size and hatching size are often attributed to each species of marine invertebrate, and little attention is paid to intra-specific variation. For many species, however, several different egg sizes have been reported in the literature. Presumably, egg size can vary among females, among populations or among habitants. If differences are due to genetic variation, such differences may reflect location adaptation and indicate one of the first steps in the evolution of different modes of development. I examined the effects of temperature, population, and female on egg size and hatching size for two sympatric species of marine gastropods, *Crepidula atrasolea* and *Crepidula ustulatulina*. Both species show significant effects of temperature and female on egg size and hatching size. Egg size and hatching size are larger in the low temperature treatment than at high temperatures. *Crepidula ustulatulina*, the species with significant population structure, also shows a significant effect of population. Hatchling shape also differs among populations of *C. ustulatulina*. Overall most of the variation (60%) in both egg size and hatching size was due to variation among females. However, only a single brood was examined for each female. When multiple broods were examined, significant variation among broods from a single female were evident. The variation between broods from the same female and significant effects of temperature suggest that it may be difficult for selection to act directly on egg size or hatching size in these species.

84.2 COMBES, S.A.*; PALEN, W.P.; Harvard University, Simon Fraser University; *scombes@oeb.harvard.edu*
Flight performance and aggression in jousting orchid bees: What determines success in competitive interactions?
Many animals engage in competitive interactions to establish territories, gain access to resources, and attract mates. Locomotion is often central to these interactions, yet the relative importance of locomotory performance *versus* behavioral strategy is unknown. Male orchid bees perform aggressive aerial jousting matches over sources of aromatic oils, which the bees collect from plants and store in their hind legs for courtship. These jousting matches can include extended aerial maneuvering bouts, chases, and aerial collisions. We filmed wild, Panamanian orchid bees jousting over a fragrance source, and analyzed videos to determine the 3-dimensional movements of each bee during the interaction. We also categorized and recorded several distinct aggressive behaviors, and determined the proportion of time that bees spent engaged in various activities. We find that bees involved in aggressive interactions spend less time collecting fragrance, less time hovering, and more time engaged in fast, maneuvering flight. The time spent on these activities, as well as mean flight velocity, depends on the number of bees involved. Traditional measures of flight performance such as velocity and acceleration are not correlated with an individual bee's success (time spent on the fragrance source), although other biomechanical traits such as collision stability may play a role. Overall aggressiveness does appear to be related to success in these encounters, but behavioral strategy varies depending on the number of interacting bees. These results highlight the importance of considering biomechanical performance in the context of the complex locomotory behaviors performed by wild animals.

91.10 CONDON, C.H.*; CHENOWETH, S.F.; WILSON, R.S.; The University of Queensland; *c.condon@uq.edu.au*
Mixed signals: thermal performance of zebrafish Danio rerio in uncertain environments.
Thermal performance curves (TPC) represent the performance of an individual across a temperature range. Reversible acclimation can alter the thermal performance of a plastic trait via changes in the height (vertical shift), the thermal optimum (horizontal shift), or in a trade-off between the height and width (generalist-specialist shift) of a TPC. Here we investigate variation in TPC of two traits in the zebrafish, *Danio rerio* by examining the effect of environmental cue reliability on thermal performance. The TPC of a reversible plastic trait is predicted to be narrow and specialised when an individual receives highly reliable cues, while less reliable cues should induce a broad, generalist phenotype to cope with uncertain conditions. We acclimated *D. rerio* to reliable and contrasting seasonal temperature (16 and 30C) and day-length (10:14, 12:12, 14:10 L:D) cues and examined the thermal performance of burst swimming and feeding rate between 8-38C. Acclimation temperature had a significant effect on TPC shape for both traits via a horizontal shift in the thermal optimum. For feeding performance, day-length and day-length x temperature interactions altered both the thermal optimum and the performance maximum of TPC but not the width. Cue reliability did not induce a significant generalist-specialist trade-off in TPC shape. Horizontal and generalist-specialist variation together captured 66% of the total variation in swimming TPCs and 95% for feeding rate. Our results suggest that TPCs for reversible performance traits in *D. rerio* vary chiefly in these two directions. As far as we are aware, this study represents the first use of the template mode of variation (TMV) method for examining TPCs of reversible phenotypes in multiple environments.

26.4 CONNELLY, SJ*; TAYLOR, DJ; Rochester Institute of Technology, University at Buffalo; *sandra.connelly@rit.edu*
Accelerated mtDNA evolution in microcrustaceans (Daphniidae) that lack an ultraviolet-radiation refugium
Ultraviolet radiation (UV-R) has been shown to negatively affect exposed organisms through induced DNA mutations, the formation of DNA photolesions, and an overall decreased fitness. Most zooplankton can reduce UV-R exposure by behavioral changes (vertical migration), acquisition of UV-filtering pigments and DNA repair processes. Nevertheless, these defenses may be overwhelmed or costly in high UV-R environments, leading to genomic evolution that minimizes DNA damage. *Scapholeberis* (Daphniidae) are potential candidates for UV-R mediated evolution because they spend much of their lives suspended from the waters surface. Predicted genomic changes in response to high UV-R are altered base composition (GC rich), reduced bipyrimidine sites and an increased mutation rate results in changes in the UV-R target sites of the DNA. Seventy *Scapholeberis* populations and representatives of each daphniid genus were sequenced for the mitochondrial regions comprised of 12s, 16s rDNA and tRNAVal (~1200 base pairs). Analysis revealed a significant increase in percent GC (%GC) base composition in several *Scapholeberis* species and a reduction of CC (a reported diagnostic UV mutation site) in one *Scapholeberis* sp. Additionally, relative rate tests showed a marked increase in the evolutionary rate between *Scapholeberis* and other daphniids. The results are consistent with the theory that extreme UV-R conditions can lead to genomic evolution in zooplankton. Additional daphnids are being assessed for similar genomic patterns under controlled UV conditions.

S4.5 CONTRERAS, HL*; BRADLEY, TJ; Univ. of California, Irvine; *tbradley@uci.edu*

Osmoregulation in Insects

Insects occupy thousands of ecological niches in terrestrial and aquatic habitats. In highly desiccating terrestrial environments, a major challenge is the acquisition of water. While most insects obtain water from their food, some can take up water from subsaturated air. This capacity has arisen several times independently. A second critical need for terrestrial insects is the production of concentrated excreta. This is achieved in the insects rectum. Freshwater insects face an entirely different physiological challenge, i.e. dilution of the hemolymph by osmotically-driven influxes of water across the external cuticle. The rectum in these insects plays an entirely different role, producing very dilute urine and preserving precious ions within the body in the process. Many aquatic insects also have specialized cells in the integument that actively transport ions into the hemolymph from the external medium. Such mechanisms have evolved independently in many insect orders. Both terrestrial and aquatic insects face an acute need to obtain sodium. To reduce the need for sodium, herbivorous insects use organic and often compatible solutes as major osmolytes in the hemolymph. This strategy is particularly well developed in highly derived insects such the lepidoptera and coleoptera. Although insects are conspicuously absent from the open oceans, insects can be quite abundant in inland saline waters. A number of distinct osmoregulatory strategies are found in these insect groups. The osmotic strategies found in extant insects will be discussed in an evolutionary and phylogenetic context.

12.5 COOPER, Lisa Noelle*; THEWISSEN, J.G.M.; NEOUCOM; *l.noelle.cooper@gmail.com*

The role of Fgf8 in the origin of interdigital webbing in cetaceans

Cetaceans (whales, dolphins, and porpoises) evolved a soft-tissue flipper that encases the bony digits and generates lift during feeding maneuvers and locomotion. This flipper impedes individual digital movement and creates a smooth contour in which laminar flow of water may be maintained during locomotion. Although several studies have described embryonic development and adult variations in flipper shape, no studies have identified the genes and their associated proteins responsible for development of this structure. Utilizing bat wing membrane development as a comparison, this study aimed to identify the proteins active during flipper development by employing immunohistochemical techniques in embryos and fetuses of pantropical spotted dolphins (*Stenella attenuata*). Results indicate that, as in bats, dolphins exhibit fgf8 protein signals throughout the interdigital tissue. Within these tissues, fgf8 probably causes cell survival and proliferation, thereby inhibiting interdigital cell death. Based on the morphology of the metapodials and phalanges of the earliest fossil cetaceans (pakicetids), and their sister group (raoellids), it appears that these taxa possessed interdigital webbing. These fossils were recovered from sedimentary rocks indicating they inhabited freshwater streams that were rich in fine muds. Their webbing may have initially evolved as an adaptation for mud-based locomotion in the common ancestor to cetaceans and raoellids, but cetaceans later exapted the limb for aquatic locomotion by evolving a lift-generating hydrofoil.

34.1 COOPER, W. J.*; MCINTYRE, A. M.; MCGEE-MOORE, A. C.; KERN, B. S.; ALBERTSON, R. C.; Syracuse University; *wjcooper@syr.edu*

Comparative Evolution of Trophic Morphology Among the East African Cichlids of Lakes Malawi, Victoria, and Tanganyika

The explosive trophic divergences among East African Rift Lake cichlids represent some of the best known examples of adaptive radiations. These relatively young lineages have undergone morphological diversification that is equivalent to the combined diversity of multiple fish families. The remarkable nature of these events is heightened by the fact that lakes Malawi, Victoria and Tanganyika represent natural replicates of these phenomena. In addition, the ages of these lakes closely follow a logarithmic distribution (Tanganyika, 8-10 my; Malawi, 1-2 my; Victoria, 100-200 ky). These circumstances offer an ideal situation for examining chronological patterns of cichlid evolution. We performed a comparative morphometric study of cichlid heads using specimens from a large percentage of the genera that are endemic to each lake. These data were used in relative warp analyses, and all heads were represented in a shared "shape space" that permitted us to determine whether trophic convergence was accompanied by morphological convergence. We calculated the morphological diversity of all three lineages, and estimates of cranial shape diversity were plotted on a geological timeline. Non-parametric re-sampling techniques were employed in order to statistically compare the cranial shape diversity of the cichlids from each lake. Although these lineages have served as textbook examples of adaptive radiations, this study represents the first time that their trophic diversity has been quantified. Such quantification is a necessary prerequisite for a rigorous comparative study of the incredible morphological evolution that has repeatedly occurred within the East African Rift Lakes.

79.2 COPELAND, D.L.*; EARLEY, R.L.; University of Akron, University of Alabama; *dlcevo1@yahoo.com*

Fighting is metabolically costly for both winners and losers in the convict cichlid fish Amatitlania nigrofasciata

The success of individuals who engage in multiple contests over a short period may depend heavily on physiological adaptations associated with energy mobilization. We examined post-fight muscle lactate, liver glycogen and both plasma and liver glucose levels in convict cichlid fish *Amatitlania nigrofasciata*. Lactate accumulation can negatively impact skeletal muscle performance while glycogen and glucose reflect energy mobilization. Based on a body of game theoretical literature, we predicted that losers would accumulate more muscle lactate and/or mobilize carbohydrate stores faster than winners, which could ultimately lead to their submission. We staged 32 contests between size-matched males. We quantified aggression as duration and frequency of mouth wrestling between males, which constitute the most highly escalated behaviors of the cichlids fighting arsenal. We also quantified threat displays and circling behavior, and concentrations of post-fight androgens and cortisol. In both winners and losers, we found a significant, positive relationship between lactate accumulation in the caudal muscle and the frequencies of mouth wrestling and threat display, and contest duration. The slopes of these regressions were statistically indistinguishable between winners and losers. We found no evidence that status (winner, loser, control) impacted any of the physiological parameters. These results demonstrate that, of the physiological responses to fighting, metabolic costs are most pronounced. Independent of social status, intense contests elicit significant lactate production in the muscle, which could preclude fatigued fighters from engaging in, or winning, future contests.

S10.4 COPPACK, T.; Univ. of Zurich, Switzerland; *coppack@access.uzh.ch*
Springing ahead - The evolution and control of avian protandry
Migration is a critical life-history stage, ultimately determining when, and in which order, males and females arrive at the site of reproduction. In migratory organisms, the evolution of the timing of reproduction, therefore, can only be understood in light of the cues and constraints that shape the timing (and extent) of migration. Protandry, i.e. the earlier arrival of males relative to females, is a prime example of how closely the timing of migration is associated with sex-specific activities during the reproductive period. The phenomenon of protandrous migration is widespread across animal taxa, including insects and anadromous fish. Among migratory bird species, the time lag between male and female arrival covaries with characteristics that are directly subject to sexual selection. Within avian species, high-quality males tend to occupy prime territories first and reproduce earlier and more successfully than late-arriving males of lower quality. Despite the plethora of studies on sex- and condition-dependent arrival patterns in birds, the proximate mechanisms that cause males to arrive before females are still unclear. Future studies should attempt to identify the genetic and physiological bases of sex-specific migratory traits. An in-depth understanding of the causal links between animal migration and mating systems is becoming increasingly important for predicting how species and populations will respond to global environmental change.

36.4 CORCORAN, Aaron/J.; BARBER, Jesse/R.; CULLEN, Megan/A.; CONNER, William/E.*; Wake Forest University, Colorado State University; *conner@wfu.edu*
Sound Strategies: Acoustic Aposematism, Mimicry, and Sonar Jamming in the Bat-Moth Arms Race.
Moths have long engaged in an evolutionary arms race to avoid capture by bats. Tiger moths (Lepidoptera: Arctiiidae) are unique among moths in that they answer the echolocation cries of bats with high-frequency clicks. In the past we have provided evidence that many tiger moths use these sounds to advertise their unpalatability to bats and that others gain an advantage by mimicking the sound of the advertisers. We now investigate the ability of the sound-producing tiger moth *Bertholdia trigona* to jam the sonar of the FM big brown bat, *Eptesicus fuscus*. Four bats (3 nae and 1 experienced forager) were presented a sequence of 16 tethered moths including 4 sound-producing *B. trigona* and 12 control moths for each of 7 consecutive nights followed by 2 nights when silenced *B. trigona* were substituted for sound-producing *B. trigona*. We observed and recorded the interactions using high-speed infrared sensitive video cameras and an ultrasonic microphone. The results suggest that big brown bats avoid catching sound-producing *B. trigona* despite the fact that they are reasonably palatable. Our results are discussed in light of two non-mutually exclusive hypotheses about the function of the tiger moth-produced sounds.

S1.9 COREY, David P*; KARAVITAKI, Domenica; SOTOMAYOR, Marcos; Harvard Medical School; *dcorey@hms.harvard.edu*
Macro- and micro-mechanics of hair-cell transduction
The transduction channels of hair cells are located at the tips of the stereocilia that extend as a bundle from the top of each cell. A positive deflection of the bundle increases tension on tip links that extend between adjacent stereocilia; tip links convey tension to transduction channels to open them. To understand how tension opens channels, we must understand how tension depends on deflection. When the tallest stereocilia are moved, the bundle moves as a unit, indicating the presence of a strong cohesive force between adjacent stereocilia that nevertheless permits stereocilia to shear past one another. If the tip links provide cohesion, then the transduction channels in a column of stereocilia are mechanically in series with one another. If an independent mechanism exists for a sort of sliding adhesion between stereocilia, then the channels are mechanically in parallel. We have found with high resolution strobe illumination that, even in the absence of tip links and most other links, stereocilia adhere tightly to each other and separate by <10 nm even for very large deflections. Channels are thus in parallel and independent. Theories of transduction, confirmed by micromechanical measurements, propose an elastic gating spring in series with the channels. Although tip links were initially thought to be this spring, their morphology in EM and their invariant length argued that they are not extensible. Tip links are most likely composed of a parallel dimer of cadherin 23 in series with a dimer of protocadherin 15. We have used steered molecular dynamics to model the elasticity of tip-link cadherins, and find that they are unlikely to be the gating spring. In addition, we find that cadherin mutations that cause deafness in humans are likely to reduce the breaking strength of the tip link.

65.3 CORNELIUS, J.M.*; ZYLBERBERG, M.; BREUNER, C.W.; HAHN, T.P.; Univ. of California, Davis, Univ. of Montana; *cornelius@ucdavis.edu*
Stress physiology and parasite burden differ during winter and summer breeding in a north-temperate zone temporal opportunist, the red crossbill Loxia curvirostra
Physiological ecologists often explain seasonal patterns in physiology using energetic, behavioral and trade-off hypotheses. However, it is difficult to tease apart and test predictions for these hypotheses because multiple variables change seasonally. For example, changes in physiology that occur during the spring and summer are often related to seasonal breeding behavior, but it is difficult to separate the effects of breeding from other seasonal variables such as temperature or food availability. We collected 6 years of field data from a north-temperate zone opportunist, the red crossbill (*Loxia curvirostra*), to compare glucocorticoid physiology and parasite load during winter and summer breeding. North-temperate opportunists offer the unique opportunity to make within-species comparisons of breeding physiology under very different thermoregulatory challenges. We found no differences in absolute levels of testosterone, corticosterone binding globulins, or hematocrit in winter versus summer breeders. Winter breeders, however, had higher baseline corticosterone and lower stress-induced corticosterone. The relationships between these and other variables (e.g. breeding condition, body condition, and parasite load) also differ in interesting ways across breeding seasons. For example, *Haemoproteus* infection is high during summer breeding and absent during winter breeding and degree of infection does not correlate significantly with testosterone, suggesting that the immunocompetance hypothesis cannot fully explain seasonal patterns of parasite burden. We will discuss these and other breeding- stress- immune relationships in this unique comparison of winter and summer breeding physiology.

50.1 CORRIGAN, S.T.*; IRWIN, J.; Central Wash. Univ.; *corrigas@gmail.com*

Supercool social wasps: lower lethal limits to cold tolerance

Of the selective pressures that have shaped species evolutionary success or failure, the most universal abiotic factor, is probably temperature. In the higher latitudes the ability to survive cold temperatures may be the limiting factor to historical species radiation, distribution and abundance. Because insects are the most diverse fauna on earth, inhabiting the planet from pole to pole, the study of insect cold tolerance has received increased scrutiny. In temperate regions of North America, such as eastern Washington State, overwintering queens of the social wasps (Hymenoptera: Vespidae), the yellowjackets and paper wasps, must survive sustained sub-zero winter temperatures. Because freezing of intracellular fluids invariably causes damage to cell membranes, it is usually lethal to the organism. To ascertain the lethal limits to low temperature survival of vespid wasps, we measured the supercooling points (SCPs) of gynes from four species representing three genera of locally occurring social wasps. In all cases, a seasonal progression in cold hardening was observed; as fall advanced into winter, supercooling ability increased, resulting in progressively lower SCPs. Though data in some cases indicated differences between genera, we found that most local wasps in the heart of winter are able to survive at least brief exposures below -20C. Mean midwinter SCPs were as follows: *Dolichovespula maculata* , -20.1; *Vespula pensylvanica*, -22.3; *Vespula germanica*, -22.6; *Polistes dominulus*, -23.3. No wasp in our study survived freezing, even those inoculated by external ice. Our data indicate that the vespid wasps in eastern Washington State are not tolerant to freezing, and instead survive winter by the ability to supercool below temperatures that are generally experienced in hibernacula.

S2.4 COSTELLO, MJ; University of Auckland; *m.costello@auckland.ac.nz*

Progress in understanding the ecology of sea lice, copepod parasites of wild and farmed salmonids

Fish farmed in sea cages may become infested by parasites from wild fish, and in turn become point sources for parasites. Sea lice are the best studied example of this risk. They are the most significant parasite in salmon farming in Europe and the Americas, costing the aquaculture industry US$400 million a year. A recent review indicates that they are also pathogenic to some wild fish under natural conditions. Epizootics are rare in wild fish populations, but have occurred on wild fish in areas where farms have sea lice infestations, notably Europe, east and west coasts of North America, and Chile. Recent reviews and modelling studies now provide an understanding of the mechanisms of how the salmon louse, *Lepeophtheirus salmonis*, can infest wild salmonids from farm sources. Three-dimensional hydrographic models predict the distribution of the planktonic salmon lice larvae best when they include wind driven surface currents and larval behaviour. Caligus species can also cause problems on farms and transfer from farms to wild fish, and this genus occurs worldwide. The increasing evidence that lice from farms are a significant cause of mortality on nearby wild fish populations provides a challenge for the farms to control lice, but also raises conservation, economic, and political issues about how to balance aquaculture and fisheries resource management. Current and possible additional strategies to control lice are outlined.

27.4 COSTELLO, MJ*; BOXSHALL, GA; BOYKO, CB; HOEG, JT; MARKHAM, J; APPLETANS, W; University of Auckland, Natural History Museum, London, American Museum of Natural History, University of Copenhagen, Arch Cape Marine Laboratory, Flanders Marine Institute; *m.costello@auckland.ac.nz*

How can we best make authoritative biological information available online?

Following on from the presentation on Development of a sustainable authoritative online species databases, we propose an open discussion on how our community can best communicate and publish content on the internet. Several scientists currently involved as Taxonomic Editors of the World Register of Marine Species (www.marinespecies.org) will be at the Symposium on Parasitic Crustacea, namely Geoff A. Boxshall, Mark J. Costello, Christopher B. Boyko, Jens T Hoeg, and John Markham. Others may also be speaking at parallel symposia, and delegates may also know of authoritative online resources that should be linked to, that need a more permanent host institution, or that could easily be created from content at hand. In principle, experts should only have to publish the content online once, and from there it can be linked and accessed by other resources, with appropriate attribution and citation. We propose a short open forum to invite comments on the current online resources and how these can be developed to best communicate quality-assured content online.

60.11 COUGHLIN, D.J.; Widener University, Chester, PA; *djcoughlin@widener.edu*

Does urea affect the calcium binding properties of parvalbumin and thereby alter muscle relaxation in trout?

Parvalbumin (PV), a myoplasmic protein with multiple isoforms in fish muscle, is a low molecular weight protein (9-11 kD) that appears to aid in relaxation from contraction. PV binds free Ca^{2+}, which reduces the intracellular concentration of the ion and leads to muscle relaxation. The impact of PV on muscle relaxation depends on both the rate of Mg^{2+} dissociation as well as the rate of Ca^{2+} binding. Work in elasmobranchs has shown that the binding properties of some isoforms of PV are labile to physiological concentrations of urea. For instance, marine elasmobranchs can have concentrations of urea in their tissues on the order of 200-300 mM. At such concentrations, urea reportedly leads to increased binding affinity of PV for Ca^{2+} (lower Ca^{2+} K_D). We tested this hypothesis by manipulating urea content of muscle in mechanics experiments. Using rainbow trout as the experimental subject, contractile properties were measured in white, fast-twitch muscle bundles in physiological saline containing zero, 200 and 400 mM urea. The time for muscle bundles to relax from contraction decreases with increasing urea content. Further, the effect is reversible lowering urea content leads to longer muscle relaxation times. These preliminary experiments suggest urea content influences muscle relaxation, perhaps by altering the binding properties of PV, and may therefore affect swimming behavior in some fishes.

60.5 COVI, J.A.; BADER, B.A.; WASMUNDT, N.M.; CHANG, E.S.; MYKLES, D.L.*; Colorado State University, UC Davis Bodega Marine Lab; *don@lamar.colostate.edu*

Myostatin Signaling and the Regulation of a Molt-Induced Atrophy in Crustacean Claw Muscle

Molt-induced claw muscle atrophy is under the control of steroid molting hormones (ecdysteroids). The reduction of as much as 78% of the muscle mass, which facilitates withdrawal of the claws at molt (ecdysis), is achieved by the degradation of myofibrillar proteins by calpains. Only the claw muscles are responsive to the atrophy-inducing signal. Thoracic muscle, which does not respond to ecdysteroid, serves as an internal control. Moreover, there is no transformation of fiber phenotype or satellite cells. Thus, crustaceans provide an ideal model system in which the molecular mechanisms regulating protein turnover can be studied apart from those regulating fiber phenotype transformation or satellite cell proliferation. The central hypothesis is that the action of ecdysteroids is mediated by myostatin (Mstn)/Smad signaling. cDNAs encoding Mstn and Smad transcription factors were cloned from three decapod species (land crab, green crab, and lobster). Isoforms differing in the length and/or sequence of the Mstn propeptide appear to be generated by alternative splicing. The effects of two methods of molt induction on Mstn expression were determined in the land crab, *Gecarcinus lateralis*. Acute elevation of hemolymph ecdysteroids by eyestalk ablation (ESA) increases Mstn mRNA in claw muscle but not thoracic muscle. In contrast, molting induced by multiple limb autotomy decreases Mstn mRNA in both claw and thoracic muscles during premolt. These data suggest that Mstn expression is regulated by ecdysteroid hormone, but nature of the tissue response depends on the method used to induce molting. This indicates that ESA cannot be used mimic the transition from intermolt to premolt stages in intact animals. Supported by NSF (IOS-0618203).

81.3 COVI, J.A.*; MYKLES, D.L.; Colorado State Univ.; *joseph.covi@colostate.edu*

Regulation of ecdysteroidogenesis in the decapod molting gland: a new synthesis

Biochemical, physiological, and structural changes associated with molting in decapod crustaceans are orchestrated by ecdysteroids, and factors that inhibit the production of these polyhydroxylated steroids by the molting gland (Y-organ) ultimately regulate the molting cycle. The neuropeptide, molt inhibiting hormone (MIH), is the primary endocrine factor in control of ecdysteroidogenesis during intermolt. However, the signaling pathway activated by MIH remains a subject of controversy. From a broadly comparative perspective, data support the involvement of both cAMP and cGMP in MIH signaling. Differences among species in responsiveness of the Y-organ to specific pharmacological treatments offer insight into both the core and flexible components of neuropeptide signaling. Data indicate that cAMP is the primary regulator of catabolic, anabolic, and transport processes, which ultimately support the capacity for ecdysteroid production by the molting gland. While cAMP also regulates facultative ecdysteroidogenesis to some extent, cGMP appears to be the primary signaling molecule responsible for acute regulation of ecdysteroid synthesis and secretion. Little is known about the signaling mechanisms involved in the alteration of responsiveness to neuropeptides over the molt cycle. During premolt, the Y-organ becomes progressively less responsive to MIH. In the hypothetical model of MIH signaling presented, changes in MIH pulses are translated through cAMP transients to cue the alterations in gene expression responsible for decreased responsiveness. Gene expression is altered directly via cAMP-dependent kinases and indirectly though cGMP-dependent kinases and nitric oxide. Supported by NSF IBN-0342982 and ISO-075224)

96.4 COX, Robert*; STENQUIST, Derek; CALSBEEK, Ryan; Dartmouth College; *robert.m.cox@dartmouth.edu*

Testosterone stimulates growth in a lizard (Anolis sagrei) with extreme male-biased sexual size dimorphism

The brown anole (*Anolis sagrei*) exhibits extreme sexual size dimorphism (SSD) in which adult males exceed females by about 30% in snout-vent length and 140% in body mass. Recent studies show that the sex steroid testosterone can act as a bipotential regulator of SSD by stimulating growth in species with male-biased SSD and inhibiting growth in species with female-biased SSD. Thus, we predicted that testosterone should stimulate growth in *A. sagrei*. We raised *A. sagrei* lizards in captivity from hatching through adulthood to characterize the ontogeny of SSD and verify that sexual differences in growth give rise to SSD in captivity. Males and females did not differ in size at hatching, but males grew significantly faster than females throughout postnatal ontogeny to reach substantially greater adult sizes. We tested the hypothesis that testosterone stimulates growth using surgical castration and testosterone replacement in adult males. Castrated males receiving testosterone implants grew significantly faster in length and mass than castrated males receiving placebo implants. Growth rates of intact control males were intermediate. Our results support the hypothesis that testosterone acts as a bipotential regulator of sexual differences in growth that give rise to SSD.

11.1 COX, L.N.*; MARKO, P.B.; Clemson University; *lncox@clemson.edu*

Trans-Pacific phylogeography: geographic isolation and speciation in Nucella lima

Fluctuating climate during the last 2 million years (MY) repeatedly caused latitudinal shifts and fragmentation of species distributions. In the north Pacific, during cooler Pleistocene glacial periods, regional extinction of northern populations caused by widespread glaciation may have divided trans-Pacific nearshore marine taxa into isolated eastern and western populations, potentially leading to trans-Pacific speciation. *Nucella lima* is a predatory marine gastropod living in the middle to low intertidal zone and is found on both sides of the Pacific. Although reported from Vancouver Island and northern Japan, sampling in the western Pacific shows a discontinuous distribution due to the species absence from much of the eastern Russian coast. Samples from both the eastern and western North Pacific were analyzed using the mtDNA marker cytochrome oxidase I (COI). Eastern and western populations are reciprocally monophyletic, with a net nucleotide divergence of 1.32%. Based on a conservative 1% rate of divergence we estimate an east/west split no earlier than the Pleistocene; given that gene lineage splits always predate population splits, this estimate is likely an upwardly biased estimate of population splitting time. Our data therefore supports the hypothesis that glacial-interglacial cycles of the Pleistocene caused geographic isolation leading to speciation in the north Pacific.

59.3 CRAFT, J.D.*; PAUL, V.J.; SOTKA, E.E.; The College of Charleston, Smithsonian Marine Station ; *craftjd@gmail.com*

A coevolutionary arms-race between macroalgae and herbivores: are tropical herbivores more tolerant of lipophilic secondary metabolites than temperate herbivores?

In contrast to temperate seaweeds, tropical macroalgae produce a greater diversity and higher concentrations of lipophilic secondary metabolites. This geographic variation in plant chemical defenses is likely due to a higher intensity of herbivory in tropical regions relative to temperate regions, a greater feeding tolerance by tropical herbivores relative to temperate herbivores, or both. However, few studies have tested the notion that tropical marine herbivores evolved greater feeding tolerance for tropical plant defenses. Here, we test this coevolutionary prediction by assessing feeding tolerance and biochemical detoxification activity for ecologically-important urchins from tropical versus temperate regions. Non-polar extracts were prepared from ten species of taxonomically diverse, chemically rich tropical macroalgae. In a series of pairwise feeding choice assays, extract-coated and control artificial foods were offered to two tropical (*Diadema antillarum* and *Echinometra lucunter*) and two temperate (*Strongylocentrotus droebachiensis* and *Arbacia punctulata*) echinoid species. If there is a coevolutionary arms-race between tropical algae and these urchins, then tropical urchins should feed on extract-coated algae more readily than temperate urchins. To elucidate the biochemical mechanisms that underlie echinoid herbivory, the activity of enzymes involved in xenobiotic metabolism (e.g., CYP450, GST) were assayed in both tropical and temperate urchins. This study represents one of a handful of tests of a diffuse coevolutionary arms-race among coral reef herbivores and their seaweed prey, and the first known examination into the biochemical adaptations urchins utilize to tolerate secondary metabolites of tropical seaweeds. Results will be presented.

23.3 CRANDELL, KE*; HERREL, A; LOSOS, JB; SASA, M; AUTUMN, KA; Lewis & Clark College, Harvard University, Universidad de Costa Rica, San Jose; *crandell@lclark.edu*

A comparative analysis of claw and toe morphology and clinging performance in mainland and island Anolis

Over the past decades, *Anolis* lizards have become a model system for the study of adaptive radiations. While most research has focused on the *Anolis* of the Greater Antilles, mainland anoles show an equally great amount of ecological and morphological differentiation. Previous authors have demonstrated that island and mainland *Anolis* differ significantly in their toe pad structure with mainland anoles having fewer subdigital lamellae. Since clinging performance is directly related to toe pad structure, we tested the hypothesis that mainland *Anolis* can generate less adhesive force per unit toe pad area. However, as anoles have two mechanisms used for adhesion (toe pads and claws), we hypothesize that mainland *Anolis* may compensate for their decreased toe pad performance by having sharper claws. Here we compare data for clinging ability, ecology, and morphology for 8 mainland species with similar data previously published for 11 species of *Anolis* from the Greater Antilles and one mainland species. Across all species, toe pad area, claw height, and claw length are positively correlated suggesting co-evolution of components of both claws and toe-pads. Island species, however, have blunter claw tips than mainland species suggesting that the decreased number of lamellae in mainland species may be compensated for by sharper claws. Interestingly, whereas toe pad area and claw size are positively correlated to perch height, claw tip angle and perch height appear to be negatively correlated. Perch diameter, on the other hand, is negatively correlated to claw curvature suggesting that increased claw curvature may be adaptive for lizards utilizing narrow perches

36.6 CRATSLEY, C.K.*; POULIOT, A.; BASINSKY, G.; WADDINGTON, J.; GODIN, T.; Fitchburg State College; *ccratsley@fsc.edu*

Photinus ignitus flash signal patterns and preferences: evidence for selection through mate choice and Photuris predation

Photinus firefly bioluminescent courtship signals are critical for attracting and locating mates, but also serve as beacons for predatory *Photuris* fireflies. *Photinus ignitus* flash patterns are characterized by single flash pulses with long interflash intervals and female response delays. In spite of evidence for female preference for long male flash duration, females produce longer duration single-pulse flashes than males. In order to explore how mate choice and predation may select for *P. ignitus* flash patterns and preferences, we simulated firefly flash signaling in the field using Virtual Firefly Instruments. In separate experiments we simulated different *P. ignitus* courtship interactions and varied flash signaling patterns, female response delays, and female flash durations. We observed male *P. ignitus* and predatory *Photuris* flash behavior in response to these treatments. Both male *P. ignitus* and *Photuris* were significantly more active at sites with simulated signaling behavior. However, while *Photuris* activity was highest at treatments with high flash rates in the form of multiple-pulse flash patterns and short female response delays, male *P. ignitus* did not show greater activity at these treatments. Late season *P. ignitus* males did show increased flash activity in response to very long duration female flashes. Therefore, while *Photuris* predation may select for long interflash intervals and female response delays in *P. ignitus*, male preference for long duration female flashes may select for the longer flash durations observed in females.

102.5 CRAWFORD, Karen; St. Mary's College of Maryland, MD; *kcrawford@smcm.edu*

Growth factor initiated intercalary regeneration in salamanders.

Grafting a piece of mature skin over the surface of a freshly amputated amphibian limb inhibits regeneration. In striking contrast, when a more distal level blastema (the bud of tissue that forms following amputation) is grafted to a more proximal limb stump it induces intercalary regeneration from the host and a proximodistally complete limb is restored. In contrast, when a mature hand is grafted to a more proximal level stump, intercalary regeneration is inhibited. These experiments create a unique opportunity to decipher the signals responsible for normal intercalary regeneration and possibly regeneration itself. Through juxtaposition of beads charged with growth factors between a mature hand graft and more proximal level stump it may be possible to induce intercalary regeneration and by doing so, begin to identify the early molecular cues that initiate and drive intercalary regeneration in salamanders. Preliminary results employing this approach will be presented.

44.3 CRAWFORD, N.G.*; SCHNEIDER, C.J.; LOSOS, J.B.; HOEKSTRA, H.E.; Boston University, Harvard University, Harvard University; *ngcrawfo@bu.edu*

Evolution of Dewlap Pigmentation in Anoline Lizards

Anoles (genus *Anolis*) are small arboreal lizards found throughout the Caribbean and Central and northern South America. Anoles are sexually dimorphic and males have extensible gular folds known as dewlaps. Dewlaps come in a variety of hues including red, orange, blue, pink, white, and green. Dewlap colors differ among species and are thought to play a role in species recognition and also perhaps in sexual selection. Anole species on different Caribbean islands have convergently evolved dewlaps of similar colors. The genetic basis of skin pigmentation in reptiles is poorly known, but chromatographic studies have shown that pteridine pigments play a significant role. Pteridine pigments are synthesized within specialized cells, and a pathway for pteridine biosynthesis has been proposed. In this study we identify the genes involved in the pteridine biosynthetic pathway in Anolis and assay their activity in species of Anolis that have convergently evolved similar dewlap colors. This is a significant step toward understanding the genetic basis for color in reptiles and determining if convergent phenotypes result from convergent changes in the genome.

36.11 CRAWFORD, J.C.*; CHARPENTIER, M.J.E.; BOULET, M.; DREA, C.M.; Duke University, CEFE-CNRS; *jeremy.crawford@duke.edu*

Lemurs Discriminate the Scent of Conspecifics Based on Individual Heterozygosity and Pairwise Relatedness

Sexual selection theory predicts that certain traits may function as honest indicators of genetic quality, influencing intrasexual competition and mate choice. There is mounting evidence to suggest that, like visual and auditory cues, olfactory cues can signal genetic traits. Likewise, olfactory cues are increasingly implicated in kin recognition, influencing nepotism and facilitating inbreeding avoidance. In prior studies of ring-tailed lemurs (*Lemur catta*), we showed that the semiochemical profiles of scent gland secretions from males and females vary according to an individual's heterozygosity and converge between conspecifics as the genetic distance between pairs decreases. Here, we complement and extend those chemical data with behavioral evidence that lemurs detect the genetic information contained in olfactory cues. We presented 22 'recipient' lemurs (10 M; 12 F) with paired samples of scrotal or labial glandular secretions obtained from conspecific 'donors.' Donors were non-group members that differed in their heterozygosity (relative to each other) and in relatedness (relative to the recipient). We recorded recipient responses during 157 15-min trials conducted during the breeding and non-breeding seasons. Across seasons, both sexes discriminated between odorants based on the donors' genetic characteristics. These data constitute the first evidence that nonhuman primates can decipher genetic information via olfactory cues. We suggest that *L. catta* may use available olfactory cues to guide competitive or nepotistic decisions, as well as to select the best and most unrelated mates. Funded by NSF grant IOS-0719003.

S5.2 CROCKFORD, S.J.; University of Victoria, BC; *scrock@uvic.ca*

Thyroid hormones and iodine in the evolutionary history of cell-cell signalling

In vertebrates, thyroid hormones (THs, thyroxine and triiodothyronine) are critical cell signalling molecules. THs regulate and coordinate physiology within and between cells, tissues and whole organisms, in addition to controlling embryonic growth and development, via dose-dependent regulatory effects on essential genes. While invertebrates and plants do not have thyroid glands, many utilize THs for development, while others store iodine as TH precursor molecules (mono- and di-iodotyrosine, MIT and DIT) or produce similar hormones that act in analogous ways. Such common roles for THs and iodotyrosines across kingdoms suggest that a common endocrine signalling mechanism may account for coordinated evolutionary change in all multi-cellular organisms. Here I expand my earlier hypothesis for the role of THs in vertebrate evolution (Crockford 2006) by proposing a critical evolutionary role for iodine, the essential ingredient in all THs. Iodine is crucial to life for virtually all unicellular organisms (including evolutionarily-ancient cyanobacteria), in part because it acts as a powerful antioxidant that protects cells from the chemically disruptive effects of oxygen. I propose that during the evolution of early cells, the ease with which iodine reacts with simple biological compounds explains why iodine became the antioxidant of choice. Transferred within cells as a consequence of reactions at the cell wall, iodine became incorporated into basic internal biochemical reactions, including those involved in metabolism and mtDNA replication. The coupling of iodine with the amino acid tyrosine was a critical step in the evolution of complex cell-cell signalling, as MIT and DIT eventually became components of ubiquitous signalling molecules for communicating within and between cells, tissues and organs, and for coordinating whole body physiology.

96.1 CUNNINGHAM, C. B.*; CARRIER, D. R.; Universtiy of Utah, University of Utah; *c.cunningham@utah.edu*

Male-Male Competition's Influence on Primate Brain Size

Primates have evolved large brains. We hypothesized that male-male competition has helped drive the enlargement of the primate brain because competition demands extensive cognitive and physical interactions between opponents. Both the cognitive and physical aspects of physical competition should drive increases in brain size more in highly competitive primates than in less competitive primates. To address this prediction, we examined the correlation between brain size and both mass- and canine height-dimorphism, reliable indicators of male-male competition, within primates. Analyses were conducted with species and phylogenetically independent contrast (PIC) values. Consistent with the prediction, brain size was always positively correlated with mass- and canine-dimorphism using species values. Mass dimorphism was positively correlated with brain size using PIC values. Canine dimorphism was not correlated with brain size across the order. Further analysis of both indicators was done by breaking the order into the sub-groups: Strepsirhini, Haplorhini, New World Monkeys, Old World Monkeys, and Gibbons & Apes. Results were not consistent, and contained both significant positive and negative correlations between brain size and competition, using PIC values. In conclusion, brain size is weakly positively correlated with male-male competition overall, but this correlation is highly variable within specific sub-groups. This correlation is suggestive that competition has partially driven the increased brain size in primates.

87.5 CUNNINGHAM, C; SCHILLING, N; ANDERS, C; CARRIER, D*; Univ. of Utah, Salt Lake City, Friedrich-Schiller-Univ. Jena, Univ. Hospital Jena; *carrier@biology.utah.edu*

Plantigrade foot posture increases locomotor economy in walking but not in running humans.

Plantigrade foot posture, in which the heel (calcaneus) contacts the substrate during a step, is a derived character of great apes (Hominidae). We used human subjects (N=11) to test the hypothesis that the energetic cost of transport (COT, oxygen consumed to travel a given distance) is lower during walking and running with plantigrade than with digitigrade foot posture. When the subjects walked with their heels slightly elevated, COT increased by 63 + 8% (mean + SEM) above that of plantigrade walking. In contrast, at each of the four speeds we tested, there was no difference in COT when subjects ran with digitigrade versus plantigrade foot posture. Subsequent observations and experiments suggest that the greater economy of plantigrade walking results from a suite of factors. First, stride length decreased when the subjects walked with digitigrade posture, resulting in higher stride frequencies (9.0 + 1.0%) and accounting for a 15% increase in metabolism in a control experiment. Second, electromyography indicates that recruitment of the main extensor muscles of the ankle, knee, hip, and back is higher during walking with digitigrade foot posture. Third, preliminary analysis of the mechanical work done on the center of mass suggests (1) that the positive external work is approximately 11% greater during digitigrade walking, and (2) the potential to save energy via a transfer of gravitational potential and forward kinetic energy is reduced during digitigrade walking. Relative to other species, humans are exceptionally economical walkers, but not economical runners. The structure and posture of the human foot may help explain how humans are able to walk economically.

77.5 CUNNINGHAM, Gregory B*; STRAUSS, Venessa; St. John Fisher College, Southern African Foundation for the Conservation of Coastal Birds; *gcunningham@sjfc.edu*

Title: Further studies investigating the behavioral responses of African penguins (Spheniscus demersus) to olfactory stimuli.

Most of the research into seabird olfaction has focused on procellariiforms (albatrosses and petrels); these birds are responsive to food, nest and social odors. Recently, however, we demonstrated that wild and captive African penguins (*Spheniscus demersus*) could detect and orient towards a food-related odor, dimethyl sulfide (DMS). Since DMS is associated with high levels of primary productivity in the ocean, we postulated that penguins could use DMS as an indicator of regions where prey is likely to be found when diving. To continue to investigate how penguins use odors while foraging, we were interested in determining whether birds were attracted to odors of their prey. We tested African penguins at a rehabilitation centre using a Y-maze that contained the scent of blended anchovy (*Engraulis capensis*) or a blank control and found that penguins chose randomly between these two stimuli. This suggests that penguins are not attracted to the scent of their prey. Our interpretation is that since anchovies are found at depth, penguins are unlikely to encounter the scent of their prey in the air above the ocean and thus may have little experience with this scent in the wild. Additionally, similar to our findings, many procellariiforms that hunt using DMS do not recruit to experimental deployments of the scent of their prey item at sea. In a second study we tested male and female penguins with fecal odors. In this study, we found that females avoided their own scents while males did not. The implications for the use of social odors by penguins will be discussed.

18.3 CUROLE, J.P; MANAHAN, D.T.*; Univ. of Southern California; *manahan@usc.edu*

Genomic analysis of genotype-dependent responses of marine larvae to temperature change

Wide variation in the response to temperature change is a common phenomenon in many species. The focus of this study was to (i) determine if there is a genetic component to this variance, (ii) to understand the relationship between genotype and environment, and (iii) quantify the transcriptomic complexity of this phenotype. Differentially temperature-sensitive phenotypes were produced using genetically-defined larval families of the marine bivalve *Crassostrea gigas*. Larvae from reciprocal hybrid crosses showed different genotype-dependent responses to temperature. Whole-genome expression analysis of 25.5 million cDNAs from larvae identified a set of distinct transcripts that showed a significant interaction between genotype and temperature. Further analysis of these genes will lead to the identification of marker genes that could be used to predict what percent of a species' progeny is adaptive under variable environmental conditions. Such information for dispersive larval phases will greatly enhance modeling efforts to predict species distribution ranges in the changing ocean.

90.8 CURTIN, A.J.*; MACDOWELL, A.A.; SCHAIBLE, E.G.; ROTH, V.L.; Duke Univ., Advanced Light Source, Lawrence Berkeley National Lab.; *amanda.curtin@duke.edu*

Non-invasive histological comparison of bone growth patterns among fossil and extant neonatal elephantids using synchrotron radiation X-ray microtomography

How is bone growth modified in insular dwarfing? We applied X-ray microtomography as a non-invasive method for obtaining high-resolution image-"slices" of the femoral diaphyses of four neonatal elephantids: a stillborn modern African elephant (*Loxodonta africana*), one neonate of *Mammuthus columbi*, and two neonatal specimens of its close relative, the insular dwarf *M. exilis*. Scanning large objects at voxel size ~17 microns is non-standard, and required development of a method for splicing a series of images. The results compare favorably in level of detail with histological sectioning, but without the shrinkage, distortion, or loss of tissue inevitable with the latter. Transverse sections at midshaft for the two full-sized species and one of the dwarfs showed a concentric pattern of laminar bone units surrounding a medullary region containing coarse cancellous bone and cancellous trabeculae. A distinct change in tissue microstructure in the *M. columbi* and one *M. exilis* specimen marks the boundary between prenatal and postnatal periosteal bone deposition and shows that these two individuals survived birth. Laminae in the *L. africana* individual were significantly thinner and more numerous than those of either mammoth species; *M. exilis* differed from the larger mammoth in having fewer and slightly thinner laminae. Compared to *M. columbi*, *M. exilis* laminae were evidently laid down at a slower rate, even allowing for the scaling of gestation length with body size. Comparison of the full trajectory of growth in these animals is now facilitated by collaboration with P. Tafforeau, ESRF, Grenoble, through imaging of more and of fully-grown individuals.

64.1 DACOSTA, J.M.*; SHULL, H.C.; SEFC, K.M.; BALAKRISHNAN, C.N.; PAYNE, R.B.; SORENSON, M.D.; Boston University, University of Michigan; *dacostaj@bu.edu*

Recent sympatric diversification of brood parasitic indigobirds: setting an upper limit on speciation times.

Indigobirds (genus *Vidua*) are host-specific brood parasites in which host colonization and behavioral imprinting have apparently led to sympatric speciation. However, the same behavioral mechanisms that are responsible for speciation in this system can also facilitate introgression among species. Mitochondrial DNA sequences suggest that the four indigobird species in southern Africa evolved after indigobirds from West Africa colonized the region. Given the possibility of ongoing introgression, a possible alternative explanation is that a selectively advantageous West African mtDNA lineage found its way into existing indigobird populations in southern Africa and swept to fixation, thereby obscuring a more ancient origin of the southern species. To test these alternatives, we sequenced several nuclear loci and analyzed these data using coalescent methods designed to simultaneously estimate gene flow and divergence times. Data from nuclear loci were broadly consistent with mtDNA data, indicating recent divergence of western and southern indigobirds as well as relatively low genetic diversity in the south. Coalescent analyses suggest that a small fraction of the ancestral population gave rise to southern indigobirds on the order of 10^5 years ago, after which there has been little or no gene flow between regions. Thus, four morphologically distinct indigobird species in southern Africa evolved within the region sometime after 10^5 years ago, consistent with a model of sympatric speciation through host shift.

35.6 DANLEY, Patrick D; Baylor University; *patrick_danley@baylor.edu*

Aggression and the diversification of Lake Malawis rock-dwelling cichlids

Among the rock-dwelling Haplochromine cichlids of Lake Malawi, males must obtain and defend a territory to secure access to females. As a result, aggression plays a critical role in mbuna territoriality. This study examined the patterns of aggression in four sibling species within the mbuna genus Metriaclima at two locations in the southern Lake Malawi. The number of aggressive acts of two sympatric species was examined at each location. At each site, one species defends territories over bedrock and the other over cobble. The number of aggressive acts across the four species was compared. The influence of habitat type on male aggression was examined and the targets of male aggression were identified to evaluate several hypotheses concerning the evolution of male aggression. The results show that aggression quantitatively varied among species, was largely directed towards heterospecifics, and was strongly influenced by habitat type. The aggressive behavior of one sympatric species pair, Metriaclima benetos and Metriaclima zebra, was observed under controlled laboratory conditions. Laboratory results support field observations: the bedrock associated species performed more aggressive acts and aggressive acts were directed primarily at heterospecifics. The results of this study provide further evidence that behavioral evolution has contributed to the most recent speciation events among Lake Malawis cichlid fish.

37.6 DANOS, Nicole; Harvard University; *ndanos@oeb.harvard.edu*

Sensory input for routine turns in larval zebrafish

Early locomotor behavior in zebrafish is highly stereotyped. In this study, I investigate the effects of the physical environment on the development of this early locomotor behavior. Specifically, I seek to determine which aspects of normal behaviors are controlled by sensory input and which by the hydrodynamic environment. Specifically, if fish are raised in an altered environment, one of higher viscosity, do they still perform the same behaviors? If so, do they still perform them in the same manner? What aspects of turning remain unchanged despite having raised the fish in a novel environment? Such aspects are likely independent of mechanical sensory input and are instead under tight sensory neural control. Moreover the sensory input for these turning variables is unlikely to be mechanical. Conversely, what aspects of turning scale with viscosity, suggesting less active neural control of the magnitude of such variables? To address these questions, zebrafish were raised in high viscosity (5, 10 or 15cP) until 5 days post fertilization. Five fish from each viscosity treatment were then filmed at 1000 fps performing at least three routine turns in the medium that they were raised in. The following turn characteristics were unaffected by viscosity and did not require any learning on behalf of the larvae since the fish never swam in normal viscosity water: maximum turn angle (º) and absolute duration (ms) of stage 2. The proportion of a turn spent in stage 1 also remained constant in all viscosity treatments, despite the absence of a strong correlation between viscosity and total turn duration. Maximum angular velocity decreased with viscosity only in 5 and 10cP; at 15cP it was indistinguishable from angular velocity in water. This experimental system allows for the distinction between hydrodynamic and neural control of normal behaviors such as routine turns and suggests that routine turns are largely under neural rather than hydrodynamic control.

92.6 DAS, S.*; HOPKINS, P.M.; DURICA, D.S.; University of Oklahoma; *sunetra.das-1@ou.edu*

Expression of ecdysteroid responsive genes in response to hormonal induction and RNAi mediated gene silencing in Uca pugilator

The ecdysteroids, steroid hormones of arthropods, regulate growth, reproduction and limb regeneration in crustaceans by regulating gene expression. We have taken two different approaches to study ecdysteroid responsive genes in *Uca pugilator*. One approach involved examining *EcR*, the ecdysteroid receptor gene, and *E75*, a related nuclear receptor gene, whose transcriptional activity in insect systems increase as a direct result of hormone induction. To test whether endogenous crustacean ecdysteroids affect these candidate genes, newly hatched synchronously growing larvae were incubated in various concentrations of ecdysteroids (ecdysone, 20-hydroxy-ecdysone or ponasterone A) for 3 hours. RT-PCR results indicated a 2 to 5 fold increase in *UpEcR* ($p=0.03$) and *UpE75* ($p=0.001$) transcript abundance when incubated with ponasterone A, but not with the other two hormones, indicating that these two genes are primary response genes to ponasterone A. A second approach involved RNAi mediated knockdown of either *UpEcR*, or its heterodimer partner in the functional ecdysteroid receptor complex, *UpRXR*, during limb regeneration. For these experiments, RNAi injections were performed on day 1 and 4 following autotomy (limb loss), where a 207nl volume of dsRNA (420-840ng) was applied directly below the autotomy membrane in proximity to the developing blastema. RT-PCR results showed that injection of dsRXR leads to a 2 fold decrease of *UpRXR* transcripts in day 6 blastemas ($p=0.04$); dsEcR injection, however, did not show a significant decrease, with high variability between animals. To standardize blastemal samplings, injected limb buds from crabs with comparable levels of circulating ecdysteroids are currently being tested for receptor knockdown, and changes in growth rate and morphology.

S5.8 DAVIDSON, Brad*; SWEENEY, Sarah; ZHEN, Yisong; RAGKOUSI, Katerina; Univ. of Arizona; *bjd18@email.arizona.edu*

Exploring the role of cell fate specification in chordate heart evolution.

Chordate heart evolution appears to involve a gradual increase in complexity; from the simple peristaltic tubes of basal chordates to the four-chambered hearts of amniotes. To better understand this process, we study heart development in the basal chordate *Ciona intestinalis*. We have previously shown that Fibroblast Growth Factor (FGF) signaling plays a crucial role in *Ciona* heart specification. Targeted manipulations of this specification event increase heart cell progenitor number. Surprisingly, this increase in progenitor cells can result in the emergence of a novel, functional two-compartment heart phenotype. To better understand this intriguing result, we are analyzing two interlinked roles for FGF in *Ciona* heart specification; regulation of cell polarity and gene expression. Our data indicates that FGF initially regulates cell polarity thereby refining the transcriptional response of cells to subsequent FGF signaling. This dual role for FGF may provide a robust yet flexible mechanism for cell fate specification.

9.7 DAVIS, J.E.*; FOLTZ, S.L.; QI, X.; LEI, F.; WINGFIELD, J.C.; Radford University , University of California, Davis, Qinghai University, Chinese Academy of Sciences, Institute of Zoology; *jasdavis@gmail.com*

Hormones, Habitats and Habits up on the Roof: Stress Modulation across Species and Life History Stages in the Passerines of the Tibetan Plateau

At an average elevation over 3000 meters, the Tibetan Plateau is a uniquely harsh environment in which resident passerines deal with the challenges of low oxygen, low precipitation, low temperatures, and limited food sources. In addition, winter migration from the plateau is relatively uncommon in native passerines, as moving sufficiently far south to escape low winter temperatures requires birds to traverse the formidable barrier of the Himalayas. A recent increase in the human population on the plateau has resulted in heavy grazing of the grasslands, massive expansion of urban centers, increased pollution and disturbance of native habitats. However, such habitat modification also provides additional sources of food and novel locations for refuge and nesting, encouraging both invasion by non-native species and the expansion of native species into new, urban, niches. Both native and invasive birds exhibit a range of behavioral and ecological adaptations that may facilitate survival on the plateau, including modulation of reproductive timing, sociality, modulation of the adrencortical response to stress, aggression, and flexibility to make use of the "human habitat." Here we present initial results of comparative analysis of hypothalamo-pituitary-adrenal activity in endemic and invasive passerine species from January through August of 2008.

10.8 DAVIS, JS*; NICOLAY, CW; Ohio University, Univesity of North Carolina, Asheville; *jillian_davis.chiroptera@yahoo.com*

Biomechanical and Functional Analysis of the Jaws of Vampire Bats (Chiroptera: Phyllostomidae)

The three species of vampire bats (Phyllostomidae: Desmodontinae) are the only mammals that subsist on a diet consisting almost exclusively of blood. Due to the demands of obtaining their unusual diet, these bats are characterized by a highly specialized cranial morphology. Among other unique characteristics is a protruding jaw which extends beyond the anterior tips of the extremely large upper central incisors. When the jaw is closed, the upper incisors project into bony pits in a mandibular shelf behind the lower incisors. In spite of these apparent dietary and morphological similarities, preliminary data, including linear measurements from osteological specimens, scanning electron microscopy, and microCT analysis, demonstrate differences in fusion of the two dentary bones at the mandibular symphysis. The symphyses of the common vampire bat, *Desmodus rotundus*, and the white winged vampire bat, *Diaemus youngi*, remain unfused, whereas the hairy-legged vampire bat, *Diphylla ecaudata*, fuses its symphysis completely during development. Initial results suggest that *Desmodus rotundus* has a larger symphyseal area relative to its mandible than does *Diphylla ecaudata*. The volume and orientation of the mandibular pits are being quantified using high resolution microCT scanning to determine the relationship between fusion of the mandibular symphysis and the relative volume and orientation of the bony pits.

10.7 DAWSON, M.M.*; METZGER, K.A.; BAIER, D.B.; BRAINERD, E.L.; Brown University, Touro University College of Medicine; *megan_dawson@brown.edu*

Kinematics of the Quadrate Bone During Feeding in Mallard Ducks

The avian quadrate is complex in both its shape and kinematics, making it a difficult bone to describe and understand functionally. Because the quadrate plays a central role in feeding mechanics, particularly in the elevation of the upper bill, understanding its kinematics and interaction with other bones is important for more general analysis of feeding function. It has been hypothesized that the movement of the quadrate is transferred primarily through the pterygoid and palatine bones to the upper bill. Despite being key to upper bill movement, previous studies have not been able to adequately describe the movements of the quadrate. It has been suggested that the quadrate swings anteriorly and medially about its articulation with the braincase during upper bill elevation, but has not been demonstrated *in vivo*. Here, we use X-ray Reconstruction of Moving Morphology (XROMM) to study the movements of the quadrate and their effects on articulating bones during filter feeding in mallard ducks, *Anas platyrhynchos*. Rather than swinging in a single plane, the quadrate rotates about several axes during a bill elevation cycle. To describe this complex motion, we use a combination of axes defined by anatomical landmarks and helical axes. We found, as expected, that quadrate movement correlates with upper bill elevation. During upper bill elevation, the quadrate rotates anteriorly at the quadrate-braincase joint about a mediolateral axis and medially about a rostrocaudal axis. These rotations act to produce anterior and medial movement of the articulation between the quadrate and pterygoid. In addition, the quadrate rotates clockwise (viewed from above) about a dorsoventral axis during upper bill elevation, contributing to the medial and anterior movement.

S7.12 DEAN, MN*; YOUSSEFPOUR, H; EARTHMAN, J; GORB, S; SUMMERS, AP; UC Irvine, UCI, Max Planck Inst; *mdean@uci.edu*

Micro-mechanics and material properties of the tessellated skeleton of cartilaginous fishes

The natural history of sharks seems paradoxical: their long lives and swimming styles demand cyclic loading cycles on cartilaginous skeletons that cannot repair. Fatigue damage is proportional to loading cycle number and strain energy per cycle: shark skeletons should be irreparably fatigue damaged. To avoid this damage, structures can be either overbuilt (the excess safety factor decreases strain energy) or have properties to help dissipate strain energy. We have no evidence that cartilaginous skeletal elements have a larger safety factor than bony ones. We show, however, that elasmobranch skeletons are inherently fatigue-resistant; this is a function of the type of calcification of the tissue. The uncalcified hyaline-like cartilage core of each element is tessellated by a bark of abutting mineralized tiles (tesserae), adjoined by a fibrous phase. Indentation tests show that the mineralized tissue behaves nearly elastically and is more than two orders of magnitude stiffer than the uncalcified layer, which is highly viscoelastic. Using percussion testing, we show that tessellated cartilage is comparatively high in damping capacity and stiffness, a combination of cartilage- and bone-like mechanical behaviors. The damping capacity of tessellated cartilage (damping coefficient = 0.085) equals that of uncalcified cartilage, 50% greater than spongy bone (0.0552) and an order of magnitude greater than compact bone (0.085). However, the stiffness of tessellated cartilage approaches that of trabecular bone. A Reuss isostress model of a composite beam in bending shows tiling the surface of a gel shifts the strain energy into a less damaging loading regime by disproportionately loading the tissues compressive side. In this way, the tiled and calcified design of elasmobranch cartilage inherently imparts fatigue-resistance in a skeleton that cannot remodel.

S6.10 DEARING, M. D.*; MAGNANOU, E.; MALENKE, J.; SKOPEC, M. S.; University of Utah, CNRS - UniversitP et M Curie, Weber State; *denise.dearing@utah.edu*

Functional genomics of mammalian herbivores

Mammalian herbivores with a narrow diet breadth, i.e., specialists, are predicted to utilize different hepatic biotransformation enzymes to process plant secondary compounds (PSC) compared to generalist herbivores. The large number of biotransformation enzymes (200-300) has limited the ability to comprehensively address this hypothesis. Genomic techniques offer unprecedented opportunities to address such hypotheses on biotransformation systems. In two separate experiments, we used microarrays designed for laboratory rats to investigate hepatic biotransformation of PSC in woodrat herbivores (*Neotoma*). First, we compared the expression profiles of biotransformation genes of specialist (*N. stephensi*) to generalist (*N. albigula*) woodrats fed juniper (*Juniperus osteosperma*) and control diets. Second, we examined biotransformation expression profiles in populations of *N. lepida* to identify gene candidates that permit populations in the Mojave desert to ingest greater quantities of the toxic shrub, creosote (*Larrea tridentata*) compared with populations outside of the Mojave. Crosshybridization of woodrat samples to rat arrays (70%) exceeded that for other crosshybridization studies. The number of biotransformation enzymes with adequate hybridization was 224. In the specialist and generalist comparison, we found large, dose dependent differences in gene expression. We found limited support for the hypothesis that specialists utilize Phase 1 enzymes to a greater extent than Phase 2. In our study examining the ability of *N. lepida* to feed on creosote, we found several gene candidates that may permit creosote feeding including Cytochrome P450 2B, catechol-O-methyl transferase and superoxide dismutase. We are sequencing the woodrat liver transcriptome and developing functional in vitro assays to test biotransformation rates of the gene candidates against particular PSC.

17.1 DEBAN, S.M.; Univ. South Florida; *sdeban@cas.usf.edu*

Low thermal dependence of elastically-powered movement in salamanders

Biological springs in musculoskeletal systems provide a range of benefits to organisms including energy recovery, power amplification, improved force control, and expanded functional range of muscles. To test the hypothesis that, in addition, elastic recoil mechanisms extend the thermal range over which rapid, powerful movements can be performed in ectotherms, ballistic tongue projection was examined in plethodontid salamanders. *Hydromantes platycephalus* were imaged at 3-6 kHz feeding over a range of body temperatures and inverse dynamics analysis was performed on ballistic, elastically-powered tongue projection, and on non-ballistic, non-elastic (i.e. muscle-powered) tongue retraction. Temperature had no significant effect on projection distance or projection dynamics but strongly influenced retraction dynamics. Q_{10} values over 5-20C were lower for dynamic parameters of elastic tongue projection than for those of non-elastic tongue retraction: peak velocity (1.2 for projection vs 1.4 for retraction), peak acceleration (1.2 vs 2.4), peak power (1.3 vs 3.5). These results reveal that tongue projection is less thermally dependent than retraction, and is consistent with the hypothesis that this lower thermal dependence may be due to the reliance of tongue projection on the elastic recoil of collagen fibers whose elastic properties are relatively thermally independent. Decoupling of the dynamics of muscle contraction, which generally have strong thermal dependence, from the dynamics of movement may be a general mechanism by which ectotherms can maintain high performance of predatory and escape behaviors at low temperatures.

63.4 DEMAINTENON, Marta; Univ. of Hawaii, Hilo; *demainte@hawaii.edu*

Body size within species groups; do snail taxa have a specific size?

Variation in body size within animal taxa involves anatomical differences, which may take the form of differences in cell numbers, cell size, and/ or variation in overall anatomy. Evolutionary decrease in body size is a factor that has been associated in many animal groups with the origination of novel body plans, leading to origination of higher taxa. Columbellids, a diverse group of small marine snails, have been shown to vary in adult size, from about 1mg to 200mg, and internal anatomy. The objective of this project was to investigate whether species level clades of columbellid gastropods vary in anatomical size, and if so how? Closely related species should be similar in overall anatomy, and so if they vary in body size should do so via cell sizes or numbers. Ongoing research on the systematic relationships of columbellids will be used to determine clades for comparison.

16.1 DERRICKSON, EM*; MARINELLI, K; Loyola College; *ederrickson@loyola.edu*

Compensatory morphological plasticity 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 examined the effect of dietary protein on gut morphology in lactating mice, which have substantial need for nitrogen to support themselves and their dependent young. Mice were maintained on isocaloric diets of 10 or 20% protein during gestation and lactation, and sacrificed at 14 or 21 days of lactation. Data were collected on food consumption, fecal production, gut transit and organ characters. The small intestine significantly increased in length, mass and thickness during the lactation period. In addition, the small intestine significantly increased in thickness (>25%) and mass (>30%) on the low protein diet. Although researchers have shown that mice can modify their guts in response to energetic needs, this study demonstrates that mice also exhibit plasticity in response to decreased nitrogen availability. The modifications of the small intestine during lactation and on low protein diets may reflect a broader strategy by mice to increase assimilation of dietary protein by increasing the surface area for absorption. Organs not involved in protein absorption responded differently; a low protein diet was associated with a smaller cecum, heart, liver and kidney. This indicates that lactating mice also may respond to a low protein diet by breaking down tissue in their body to support the demands of lactation. Further study is needed to determine if intestinal plasticity in response to nitrogen is found primarily in opportunistically breeding omnivorous mice, or if this is a more general strategy.

55.2 DESROCHERS, D.W.*; MCWILLIAMS, S.R.; SILBERNAGLE, M.D.; REED, J.M.; Tufts University, Univ. of Rhode Island, Coastal Institute in Kingston, U.S. Fish & Wildlife Service; *DavidW.DesRochers@gmail.com*

Do energy and nutritional value of food influence Hawaiian Moorhen (Gallinula chloropus sandvicensis) abundance?

Traditional species-habitat use models typically are based on relationships between species abundance and specific habitat or landscape-level features. Modeling abundance as related to other biotic or abiotic phenomena such as competition or energy has been done to a lesser extent in birds, and typically focuses on wintering migrants with a very narrow diet. Here we report on an investigation of the relationship between abundance of the endangered Hawaiian Moorhen (*Gallinula chloropus sandvicensis*) and gross energy and nutritional content of the food that moorhen most commonly consume. Specifically, I investigate how moorhen abundance relates to kcal/ha, and percents fat, protein, carbohydrate, and fiber concentrations of food plants for 30 sites on Oahu. This information provides a potentially important way to investigate the patterns of a species' distribution. Additionally, this study provides important information for waterbird managers in Hawaii for whom habitat improvement is a major goal for delisting Hawaiian Moorhen from the U.S. Endangered Species list.

25.7 DEVRIES, M.S.; Univ. of California, Berkeley; *msdevries@berkeley.edu*

Stable isotope analysis: a quantitative approach to linking diet and morphological specialization in mantis shrimp

Many animals have specialized feeding structures used to consume specific prey types. Mantis shrimp provide an excellent system to study the relationship between morphological and diet specialization, because their raptorial appendages capture a wide range of prey items and exhibit tremendous morphological diversity. Currently, knowledge of mantis shrimp morphology far exceeds that of diet. Stable isotope analysis (SIA) has made it possible to quantify diet specialization across mantis shrimp taxa. Specifically, stable isotope mixing models determine the percentage of prey types in a predators diet in order to estimate diet specialization with a standard diversity index that applies to any taxonomic group. One potential difficulty with SIA is the variation in stable isotope composition among habitats. My goal was to determine the effects of habitat variation on isotopic analyses of diet in *Neogonodactylus bredini*, a species with hammer-like appendages thought to be specialized for smashing hard-shelled prey. Animals were collected from seagrass and rock habitats along with potential prey items (clams, crabs, hermit crabs, fish, and snails). Mixing model analyses of diet were then run on each group of animals from the two habitats. The mixing model analysis of *N. bredini* from the rock habitat revealed mean (SD) percentages of 652% fish, 138% clams, 128% crabs, 54% hermit crabs, and 43% snails, while the analysis of *N. bredini* from seagrass failed to converge on a plausible solution. These analyses suggest that *N. bredini* feeds primarily in the rock habitat where it consumes both hard- and soft-bodied prey. Thus, while *N. bredini* appears to be specialized for breaking hard-shelled prey, it actually consumes a wider diversity of prey than what is currently documented in the literature.

S9.3 DHABHAR, F.S.; Stanford University, Stanford, CA.; *dhabhar@gmail.com*

A Hassle A Day May Keep The Pathogens Away: The Fight-Or-Flight Stress Response And The Augmentation of Immune Function

Although stress has a deservedly bad reputation, it is important to appreciate that a psycho-physiological stress response is one of nature's fundamental survival mechanisms. Without a fight or flight stress response, a lion has no chance of catching a gazelle, just as the gazelle has no chance of escape. Therefore, we initially hypothesized that just as the stress response prepares the cardiovascular, musculoskeletal and neuroendocrine systems for fight or flight, under certain conditions, stress may also prepare the immune system for challenges (e.g. wounding or infection) that may be imposed by a stressor (e.g. predator or surgical procedure). Studies showed that short duration stressors induce a large-scale redistribution of immune cells within the body and that immune function is significantly enhanced in organs like the skin to which leukocytes traffic during acute stress. Subsequent studies identified additional mechanisms involving dendritic cell, neutrophil, macrophage, and lymphocyte trafficking, maturation, and function through which acute stressors enhance innate as well as adaptive immunity. In contrast, chronic stress dysregulates immune responses by altering the cytokine balance in favor of Type 2 cytokine-driven responses and accelerating immunosenescence, and suppresses immunity by decreasing numbers, trafficking, and function of protective immune cells while increasing regulatory/suppressor T cells. The overall goal of our research is to identify mechanisms through which natural psycho-physiological mediators may be harnessed to regulate in vivo immune function, and to use this knowledge to clinically modulate immune responses to confer maximum benefit for the patient.

S8.2 DI PALMA, Federica*; SWOFFORD, Ross; GRABHERR, Manfred; MAUCELI, Evan; PIRUN, Mono; LANDER, Eric S.; LINDBLAD-TOH, Kerstin; Broad Institute of Harvard and MIT, Broad Institute of Harvard and MIT, Genome Biology, Broad Institute of Harvard and MIT, Genome Biology ; *fdipalma@broad.mit.edu*

Sequencing the genome of non-traditional model organisms.

The Broad Institute has been given the responsibility to sequence the complete genome of several terrestrial and aquatic vertebrates. As genome sequence information in vertebrate species increases, comparative genomics provides investigators with the power to study the key molecular mechanisms responsible for specific adaptations. The Caribbean anole lizard, the threespine stickleback, and the African Cichlids represent classic examples of adaptive radiations, and evolutionary divergence due to natural selection. The availability of complete genome sequences for these species will reveal valuable information on the size, structure and content of their genome, including their functional landscape of coding and non-coding regulatory sequences; it will allow the further development of genomic tools to facilitate: the comparison between genomes, the understanding how variation shapes the genome, and the relationship between normal developmental processes and disease. Here we give specific examples of how Broad genome sequencing projects leverage the science in these non-traditional model species, facilitating the study of comparative genomics and evolution.

100.4 DIAMOND, S.E.*; KINGSOLVER, J.G.; University of North Carolina, Chapel Hill; *sdiamond@email.unc.edu*

Does diet quality alter the temperature-size rule?

How does variation in diet quality and temperature interact to affect survival, size and development time in herbivores? We conducted laboratory experiments with the tobacco hornworm, *Manduca sexta*, that were reared on typical (tobacco) and novel (devil's claw) host plants at three constant temperatures (20, 25, and 30 C). Both field and domesticated laboratory populations of *M. sexta* were considered. Preliminary analyses suggest that survival on tobacco was relatively high (> 80%) at all temperatures for both populations; in contrast, survival on devil's claw declined strongly with decreasing temperature, particularly in the laboratory population. Pupal mass and development rate were greater on tobacco than on devil's claw at all temperatures. Pupal mass declines with increased rearing temperature for both populations reared on tobacco, in agreement with the temperature-size rule. However, preliminary results suggest that this pattern is obscured or reversed on devil's claw. We discuss how diet quality may alter the associations among temperature, body size and development time in herbivorous insects.

61.4 DICK, M.H.; GORDON, D.P.; LIDGARD, S.*; MAWATARI, S.F.; Hokkaido Univ., Sapporo, Japan, National Institute of Water and Atmospheric Research, Wellington, New Zealand, Field Museum, Chicago; *slidgard@fieldmuseum.org*

Parallel evolution of key innovations in a phylum of modular animals

Analysis of convergent structures is emerging as a powerful tool to address how complex evolutionary novelties arise. Yet clear examples of convergence in key innovations, those correlated with extensive species radiations, are rare. In cheilostome bryozoans, a major group of colonial animals, the costal shield and ascus were key innovations correlated with an explosive radiation beginning in the Cretaceous about 80 my ago; these innovations are integral to a major evolutionary trend for increased frontal protection of zooids. Here we establish the independent origin of costal shield and ascus in a bryozoan lineage less than 12 my ago. A COI molecular phylogeny and the fossil record indicate that the evolutionary trajectories in the Cretaceous radiation and the Neogene lineage are remarkably parallel, apparently shaped both by predation as a continuous, diffuse selective force and by a functional constraint. Facilitated by the overt modularity of bryozoan phenotypes, our analysis demonstrates how complex structures can rapidly originate through stepwise morphological transitions involving the novel integration of modular elements.

14.1 DICKENS, M.J.*; MEDDLE, S.L.; ROMERO, L.M.; Tufts University, University of Edinburgh; *molly.dickens@tufts.edu*

Mineralocorticoid and glucocorticoid receptor expression in brains of translocated chukar, Alectoris chukar

Translocation has become an increasingly important tool in the rescue of declining animal species. Unfortunately, translocations have a surprisingly low rate of success and although stress is often blamed for translocation failure, very few studies have made this direct link between chronic stress and unsuccessful translocations. This study follows up on prior experiments, which found alterations to the stress response and hypothalamic-pituitary adrenal (HPA) axis following translocation. Here, we investigate changes in corticosterone binding receptors in the avian brain. Using simulated translocation procedures with a model species, chukar (Alectoris chukar), we investigated how the components of translocation alter expression of mineralocorticoid (MR) and glucocorticoid receptors (GR) in the Hippocampus (HP) and well as GR in the paraventricular nucleus (PVN). Brains were collected from four groups either upon the first capture of the individual (Pre-Capture) or upon recapture of the following groups: 1) captured and released (Trap/Release); 2) captured, held in captivity and released to home territory (Captivity/Return); and 3) captured, held in captivity and released to unfamiliar territory (Captivity/Translocate). We ran in situ hybridization on 15 micron sections to determine relative expression of MR and GR in the regions of interest. We hypothesize that if the procedures cause chronic stress then we will see increasing disruption of MR and GR expression with the additional translocation components.

51.2 DICKINSON, B. T.*; SWARTZ, S. M.; BATTEN, B. A.; Oregon State University; *dickinsb@onid.orst.edu*

A Mathematical Model of the Detection of Unsteady Flow Separation by Hairs on a Bat Wing

Many animals use hair-like structures to detect flow fields. Bats fly at Reynolds numbers where flow is unsteady, so they must be able to detect and react to changes in flow across the wings to maintain control. Studies have shown that bats have arrays of small (0.1 to 4.0 mm) hairs distributed across the dorsal and ventral wing membrane surfaces. These are hypothesized to detect flow fields, enabling the bat to adjust its wing shape and kinematics to control flight stability. In this work, we created a mathematical model of hairs in a fluid to test their sensitivities to different flow regimes. We sought to determine whether hairs would be able to detect separation of flow, which should occur in unsteady flow regimes, and would have important aerodynamic consequences for flight. Our simulations show that hair sensor arrays are sensitive to characteristic features of unsteady flow separation, including the formation, presence and span of reversed flow on the wing. These results are consistent with the hypothesis that bats use hair cell arrays to detect and control unsteady air flows over the wing during flight.

39.2 DICKSON, Juleen*; MAIA, Anabela; DOMENICI, Paolo; University of Rhode Island, CNR-IAMC; *jdickson@mail.uri.edu*

Three dimensional excape response of white spotted ratfish, Hydrolagus colliei.

Escape responses are vital to the survival of prey during predator-prey interactions. This study documented the kinematics of the escape responses of white spotted ratfish, *Hydrolagus colliei* (Chimaeriformes). Three *H. colliei* (345-460 mm TL) were trawled off the coast of San Juan Island, WA and housed in flow-through aquaria at the University of Washington, Friday Harbor Laboratories. Escape responses were elicited with a forceful tap on the caudal region and recorded using a high speed camera at 250 fps. The video sequences were digitized for both lateral and dorsal views. Escape responses generally included a large vertical excursion which corresponded to 77% of the horizontal displacement. Large vertical excursions in escape locomotion is relatively unusual in fish, although they have been observed in *Carnegiella strigata* and *Xenomystus nigri*. The potential advantages of this type of response may lie in eluding predators that have little vertical maneuverability. The average latency time to response was about 200 ms, which is higher than the latency values commonly observed in teleosts (10-50 ms). This was unexpected, since ratfish are the only chondrichthyans whose adults are known to have Mauthner cells. The average head turning rate during stage 1 (initial formation of C-shape) was 517.16 deg.s^{-1} (mean+SEM), which is in line with results on other fishes. Maximum acceleration was 116$\pm$31 m s^{-2} and maximum speed was 8.52$\pm$1.15 BL s^{-1}. Pectoral fin analyses indicate that right and left fin abduction are not simultaneous, but rather alternate over time. Maximum pectoral fin velocities were usually during stage 1. Overall, locomotor performance appears to be higher than that observed in previously studied chondrichthyan species.

23.5 DIRKS, JH*; CLEMENTE, CJ; FEDERLE, W; University of Cambridge; *jhd32@cam.ac.uk*

Smart foot secretion - insects dont slip!

Many insects are able to cling to surfaces using adhesive organs on their feet. Adhesion is mediated by thin films of fluid secretion, which help to compensate surface roughness and give rise to capillary and viscous forces. Even though a continuous fluid film between the pad and the surface is expected to lubricate and cause sliding, the shear forces of insect pads strongly exceed adhesive forces, and pads can even produce considerable static friction on smooth substrates. This suggests that the fluid secretion itself plays a role in the resistance against shear.

Interference microscopy revealed that the secretion is not a simple fluid but a water-in-oil emulsion. It is known that many emulsions show non-Newtonian properties and only begin to flow above a certain yield point. We therefore hypothesized that the insects two-phasic adhesive secretion is a mechanism to prevent sliding.

To test this idea, we used water-absorbing polymeric substrates that selectively reduce the volume of the hydrophilic component in the emulsion, thus changing the emulsion's phase ratio. Single-leg force measurements of stick insects (*C. morosus*) on more or less absorbing substrates made of the same material demonstrated that pads produced significantly higher friction and shear stress when more droplets of the watery component were present in the adhesive fluid.

Our results suggest that the two-phasic nature of insect pad secretion is an adaptation for combining capillary adhesion with resistance against sliding. An emulsion-based artificial adhesive may also provide an interesting alternative to many conventional adhesives.

53.1 DLUGOSZ, EM*; CHAPPELL, MA; MEEK, TH; SZAFRANSKA, P; ZUB, K; KONARZEWSKI, M; JONES, JH; BICUDO, E; GARLAND, T, Jr.; University of California, Riverside, Mammal Research Institute, Polish Academy of Sciences, Mammal Research Institute, Polish Academy of Sciences; University of Bialystok, Poland, University of California, Davis, University of Sao Paolo, Brazil; *edlug001@ucr.edu*

Phylogenetic Analysis of Mammalian Maximal Oxygen Consumption

We compiled data from the literature on maximum oxygen consumption during forced exercise (VO_2max), and also included new measurements on ~20 species of small mammals tested in enclosed running wheel respirometers, and on two large rodents, agoutis and capybaras, tested on treadmills. We used both conventional and phylogenetically informed statistics to analyze if VO_2max varied in relation to domestication or measurement method. We used ln likelihood ratio tests and the Akaike Information Criterion (AIC) to compare candidate models. We found no evidence for systematic differences between wheel- versus treadmill-elicited VO_2max in small mammals or between domesticated and wild animals. Considering all 73 "species" (including subspecies or species populations within species), both $\log_{10}$ body mass and residual $\log_{10}$ VO_2max showed highly significant phylogenetic signal ($P<0.001$). Conventional (non-phylogenetic) analysis indicated an allometric scaling exponent of 0.857 (95% confidence interval 0.823-0.890). The best-fitting model, which separated nine clades and allowed transformation of the phylogenetic branch lengths under an Ornstein-Uhlenbeck model of residual variation, yielded a lower slope ($0.747<0.810<0.873$). NSF IOB-0543429

37.1 DORGAN, Kelly M*; ARWADE, Sanjay R; JUMARS, Peter A; University of California, Berkeley, University of Massachusetts, Amherst, University of Maine; *kelly.dorgan@berkeley.edu*

Worms as wedges: Effects of sediment mechanics on burrowing behavior

Marine muds are elastic solids through which animals move by propagating a crack-shaped burrow. Fracture mechanics depend on material stiffness as well as fracture toughness, so we prepared a range of transparent gels that varied in stiffness and fracture toughness to assess the dependence of burrowing behavior on these material properties. When the polychaete *Nereis virens* elongated its burrow, it altered its body shape and behavior across these gels in a manner consistent with predictions based on theory of stable, wedge-driven crack propagation. For wedge-driven fracture, the ratio of fracture toughness to stiffness of a material is more important than the absolute values; more work is required to crack a tough material, but a wedge does more work in displacing a stiff material. In materials with higher fracture toughnesses, worms everted their pharynges to become thicker and blunter wedges, as theory predicted. In stiff materials with low toughness, worms moved their heads from side to side to extend the crack edges laterally, relieving elastic forces in the sediment compressing them and allowing them to maintain body shape more easily. We introduce a dimensionless wedge number to characterize the relative importance of work required to fracture the sediment material and extend the burrow and work to maintain body shape against the elastic restoring force of the material. The mechanism of burrowing by crack propagation is utilized across a range of material properties found in natural muds, and variation in these properties strongly influences burrowing behaviors.

72.5 DORNBURG, A*; SIDLAUSKAS, BL; SORENSON, L; SANTINI, F; ALFARO, ME; Yale University, National Evolutionary Synthesis Center, Virginia Institute of Marine Science, Univ. of California, Los Angeles; *alex.dornburg@yale.edu*

Morphological and Mechanical Patterns of Evolution in Triggerfish Fins

Balistiform swimming is an unusual form of locomotion involving undulations of the dorsal and anal fins. Triggerfish have been used to study the fluid dynamics of this locomotion strategy, yet little is known about the evolution of triggerfish fin morphology. In this study we quantify fin shapes using a combined landmark/sliding semilandmark approach and also calculate aspect ratio as a functional property of fin shape for 25 triggerfish species. We test several hypotheses of morphological and mechanical evolution using a balistid phylogeny with divergence times estimated under an uncorrelated rates model in conjunction with several fossil calibrations: (1) Are multiple morphologies producing the same mechanical output and what is the distribution of these morphologies in the morphospace?; and (2) What model of evolution best fits the pattern of shape change observed across the triggerfish tree? Morphological and mechanical disparity through time plots reveal balistids to have separated into disparate regions of the morpho and mechanospace early in their history. Information theory based model selection recovers equal support for either a constrained Ornstein-Uhlenbeck or an evolutionary burst model of fin evolution for the balistids. Our results also indicate a correlation in the evolution of dorsal and anal fin shape, suggesting a potential functional or developmental constraint imposed by the coupling of these fins during locomotion.

22.3 DOROBA, C.K.*; SEARS, K.E.; University of Illinois; *carolyn.doroba@gmail.com*

The highly divergent developmental pathways of marsupial fore- and hind limbs: Evidence from the AER

Marsupials give birth after short gestations to neonates that must immediately crawl to the teat using only their precociously developed forelimbs (FL). As their hind limbs (HL) play no role in the crawl, they are relatively undeveloped at birth. We hypothesize that these differential selective pressures on the marsupial FL and HL resulted in the divergence of their developmental pathways. As a first step in testing this hypothesis, we examined apical ectodermal ridge (AER) development in marsupials. The AER manifests as an epithelial ridge along the dorsoventral boundary (DVB) of the embryonic limb and is a primary signaling center for limb outgrowth. All amniotes (e.g., reptiles, birds, mammals) possess a well-defined AER, with the exception of two groups with greatly reduced limbs, whales and snakes. Using scanning election microscopy, we compared the AER of the Mus musculus (mouse) and Monodelphis domestica (possum) FL and HL at comparable stages. The possum FL AER is greatly reduced and characterized by seemingly random clumps of epithelial cells along the DVB, although the DVB appears to be intact. The possum HL AER is well defined and comparable to that of mouse limbs. These results suggest that the development of the marsupial FL and HL are more divergent than in any known mammal in which both limbs are present. We also hypothesize that differences in expression of one or more gene families with a role in AER formation (e.g., *Wnt*'s, *Fgf*'s, and *Bmp*'s) are responsible for the relative reduction of the marsupial FL AER. Gross *Fgf8* expression in the possum FL is similar to that in the possum HL and mouse limbs. We are currently testing for differences in *Fgf8* expression at the cellular level, and for differences in expression of *Wnt3* and *Bmp2/4*.

46.1 DORSEY, J. P.*; GEORGE, M.; ANDERSON, S.; SWANSON, B. O.; Gonzaga University; *jdorsey@gonzaga.edu*

Effects of heavy metal pollution on fish feeding and escape performance

Environmental pollutants, such as heavy metals, can target animal tissues and affect behavior. These behavioral changes can alter specific ecological relationships between the affected animal and organisms at other trophic levels. It has been shown that the interactions between bluegill sunfish and snails change dramatically in the presence of Cd, Zn, and Pb. Here we examine the effects of heavy metals in sunfish, and predict that Cd, Zn, and Pb should decrease performance in ecologically important, nervous system-dependent activities, such as escape responses and suction-feeding. We obtained two sets of pumpkinseed sunfish, the first from a relatively clean (reference) lake. Half of these fish were fed snails exposed to Cd, Zn, and Pb, while the other half were fed clean snails, for a total of fifteen days. The other set consisted of two groups, one from several polluted lakes, and another from reference lakes. Fast starts were recorded with a high-speed video camera and image sequences were digitized. Duration of each stage, along with maximum acceleration and velocity, were calculated. Feeding behavior was recorded with a high-speed video camera as well. Several landmarks were digitized in order to measure gape distance, hyoid depression, and maximum jaw protrusion. No statistical differences in performance were observed between the two groups of snail-fed fish. However, in almost all cases, fish from clean lakes demonstrated higher performancecompleted behaviors in less time with higher peak valuesthan did fish from polluted lakes. The differences in performance between fish in clean and polluted lakes suggest that long term or developmental exposure to heavy metals alters performance in ecologically significant behaviors, and may explain ecological changes in the presence of these pollutants.

76.6 DUBANSKY, Benjamin D.*; GALVEZ, Fernando; Louisiana State University, Baton Rouge; *bduban1@lsu.edu*

The physiological costs of fish gill remodeling following infection by freshwater mussel larvae.

Larval freshwater mussels (glochida) are obligate ectoparasites, infecting the gill epithelium of host fish. Following attachment, glochidia are fully encapsulated by the surrounding host epithelium, where they develop for a period of days to months. Studies in our laboratory are investigating the process of fish gill remodeling during this ectoparasitic infection of freshwater mussel glochidia. The physiological mechanisms associated with this process are poorly understood. Likewise, little is known on how alterations in host physiology influence the success of glochidial attachment and subsequent metamorphoses. This presentation will describe results from laboratory infections of bluegill sunfish (Lepomis macrochirus) with the glochidia from the paper pondshell (Utterbackia imbecilis.) Glochidial infection has been shown to elicit a significant impairment of ionoregulatory balance and other hematological effects in infected bluegill. Current work is utilizing whole-animal and cell physiological approaches to assess the effects of glochidial infection on host fish, and ascertaining how alterations in host physiology, such as hormone supplementation, influence the process of fish gill remodeling following glochidial attachment.

S7.7 DUDEK, DM*; GOSLINE, JM; MICHAL, CA; DEPEW, TA; ELVIN, C; KIM, M; LYONS, R; DUMSDAY, G; Univ. of British Columbia, CSIRO, Brisbane, CSIRO, Clayton; *dudek@zoology.ubc.ca*

Dynamic Mechanical Properties of Synthetic Resilin

As a nearly ideal elastic protein, resilin simplifies the function, construction, and maintenance of structures that contain it (e.g. the cicada tymbal mechanism oscillating at 4 kHz), by allowing for a system without lubrication, friction, or abrasion of loaded parts with low heat production. It can be strained to more than three times its rest length, and suffers neither from creep or stress relaxation during long term static tests. Previously, we showed that >99% pure resilin from dragonflies acts on its rubber plateau below 200 Hz, and returns more than 95% of the energy input each cycle even at 1000 Hz. This is in stark contrast to the large energy dissipation seen at high frequency in the locust pre-alar arm, which is composed of only 76% resilin. Here we use dynamic mechanical analysis to show that synthetic resilin from both fruit flies and mosquitoes is highly elastic and able to return more than 90% of the energy input each cycle even at 100 Hz, making it one of the most resilient synthetic rubbers known. 13C NMR spectra show the amino acid backbone of the crosslinked protein to be highly mobile and confirm the absence of an ordered tertiary structure for this protein. The peptide sequences vary considerably between these two insect resilins, resulting in the mosquito sample being significantly less resilient and molecularly mobile than the fruit fly. The ability to study pure samples of isolated recombinant resilin from multiple species allows us to use the natural experiment of evolution to understand the effects of peptide sequence on the properties and structure of elastomeric proteins in general.

S4.4 DUDLEY, R.*; YANOVIAK, S.P.; Univ. of California, Berkeley, Univ. of Arkansas, Little Rock; *wings@berkeley.edu*

Arthropod Aloft: The Origins and Functional Diversification of Insect Flight

The evolution of wings in the late Paleozoic was the essential innovation underlying subsequent hexapod radiations in the terrestrial biosphere. Although the insect analog of Archaeopteryx has yet to be unearthed, recent demonstrations of directed aerial descent in arboreal arthropods have suggested new evolutionary trajectories for the origins and functional utility of protowings. Phylogenetic studies of ancestrally wingless hexapods indicate that aerodynamic control and maneuverability precede the origin of wings proper. A major feature of subsequent pterygote evolution has been historical change in body size; most of modern insect diversity is associated with body lengths less than 5 mm. Repeated bouts of miniaturization have been enabled by acquisition of asynchronous flight muscle and concomitantly elevated wingbeat frequencies during flight. Ordinal-level patterns of wing transformation for non-aerodynamic purposes have similarly been enabled by the high flapping frequencies of the remaining wing pair, an effect most clearly evidenced by the elytra of Coleoptera and the halteres of Diptera. Major features of insect morphological evolution thus derive indirectly from biomechanical adaptations of the flight apparatus.

47.2 DUFFY, TA*; PICHA, ME; WON, ET; BORSKI, RJ; CONOVER, DO; Stony Brook University, North Carolina State University, North Carolina State University; *taduffy@ic.sunysb.edu*

Early ontogenetic aromatase expression in two locally adapted populations of Atlantic silverside (Menidia menidia) with different forms of sex determination

Aromatase cytochrome P450 (cyp450arom) is an important enzymatic mediator of sex determination in teleosts with genetic sex determination (GSD) and is likely to play a role in fish with temperature-dependent sex determination (TSD). We compared the ontogeny of aromatase expression in a population of Atlantic silversides (*Menidia menidia*) from South Carolina (SC) that exhibits TSD and a second from Nova Scotia, Canada (NS) that exhibits GSD. Embryos and 6mm larvae were sampled from 21C treatments, and 8-21mm larvae were reared under feminizing (15C) and masculinizing (28C) temperatures. We measured whole-body Cyp450arom expression in embryos and 6mm larvae (prior to the window of sex determination) and aromatase expression in the trunk (head removed) of larvae at 8, 15 and 21mm TL, bracketing the window of sex determination. No differences in Cyp450arom were detected between populations at the egg and 6mm stage, but expression increased in both populations from 8-21mm. Individual fish from NS exhibited the highest overall expression at both temperatures and showed evidence of male-female differences in expression in 15 and 21mm fish. Fish from SC displayed low levels of expression at 28C with increased expression in some 15 and 21mm individuals at 15C. Tissue distribution of aromatase indicated Cyp450arom was increased substantially in the ovaries relative to other tissues. These results indicate that cyp450arom expression is heightened in some fish, presumably females, during sex determination. Expression levels between populations and temperatures may indicate that the role Cyp450arom differs between fish with TSD and GSD.

88.2 DUMONT, E.R*; GROSSE, I.R.; SLATER, G.J; Univ. of Massachusetts, Amherst, Univ. of California, Los Angeles; *bdumont@bio.umass.edu*

Comparing the performance of finite element models of biological structures

There has been a rapid increase in the use of finite element analysis to investigate mechanical function in living and extinct organisms. This brings to the fore two critical questions about how such comparative analyses can and should be conducted: 1) what metrics are appropriate for assessing the performance of biological structures using finite element analysis? and, 2) how can performance be compared such that the effects of size and shape are disentangled? With respect to performance, we argue that for force-transmitting structures, minimization of elastically stored strain energy is a reasonable optimality criterion. We show that volumetric average strain energy density (a measure of work expended by the organism in deforming the structure) is a robust metric for comparing mechanical efficiency. Results of finite element analyses can be interpreted with confidence when model input parameters (muscle forces, detailed material properties) and/or output parameters (reaction forces, strains) are well-documented by studies of living animals. However, many interesting questions require comparisons of species for which these input and validation data are difficult or impossible to acquire. In these cases, the performance of structures that differ in shape can be compared if variation in size is controlled. We offer a theoretical framework and empirical data demonstrating that scaling finite element models to equal total force to total surface area ratios removes the effects of model size and permits comparisons based solely on shape. Thus, while finite element analyses of biological structures should be validated experimentally whenever possible, the *relative* performance of un-validated models can be compared if they have been scaled properly.

54.8 DUNKIN, R.C.*; DAVIDSON, E.; ROBERTS, K.; HURLEY, W.; WILLIAMS, T.M.; U.C. Santa Cruz, Dolphin Conservation Center, Dolphin Conservation Center; *dunkin@biology.ucsc.edu*

Longitudinal Measurements of Caloric Intake and Body Condition in Atlantic Bottlenose Dolphins (T. truncatus) Across Three Thermal Environments

Water temperature has long been considered important in driving seasonal variation in body condition and caloric intake in cetaceans but this hypothesis has not been tested. In this study, body condition (body mass and blubber thickness) and daily caloric intake were examined longitudinally in Atlantic bottlenose dolphins housed in three thermal regimes: uniform warm (UW) (25.5 +/- 1.2 °C) (n=10), variable cold (VC) (16.8 +/- 2.0 °C) (n=10), and uniform moderate (UM) (19.8 +/- 0.2 °C) (n=2). UW animals had significantly lower mean body mass ($p<0.0001$, $F=89.34$) and blubber thickness ($p<0.0001$, $F=39.25$) compared to VC animals and there was no correlation between body mass ($p=0.16$, $r^2=0.23$) or blubber thickness ($p=0.22$, $r^2=0.14$) with water temperature. In contrast, VC animals had higher body mass and blubber thickness compared to UW animals and these factors were negatively correlated with water temperature ($p=0.01$, $r^2=0.5$; $p=0.004$, $r^2=0.73$ respectively). Mean daily caloric intake was not significantly different between UW and VC groups but was 35% lower in the UM group. Despite apparent water temperature-driven trends in body condition, animals in all thermal regimes had similar mean percent annual variability in body mass (UW=10.5, VC=11.28, UM=11.6%) and blubber thickness (UW=30.0, VC=30.4, UM=18.0%), suggesting water temperature may not be the primary driver of seasonal changes in body condition in these animals. Further investigation of animals in the uniform moderate group found that testosterone concentration was significantly correlated with body mass, indicating the potential importance of endocrine cues in driving seasonal body condition changes.

9.2 DURANT, Sarah E*; HEPP, Gary R; MOORE, Ignacio T; HOPKINS, Brittney C; HOPKINS, William A; Virginia Tech, Blacksburg, Auburn Univ, Auburn; *sdurant@vt.edu*

Slight changes in incubation temperature affect early growth and stress endocrinology in wood duck (Aix sponsa) ducklings

Although the effects of incubation temperature on phenotype of avian hatchlings are poorly understood, recent research suggests that subtle changes in incubation conditions can influence hatchling characteristics including body size and condition. We explored the effects of incubation temperature on hatching success, survival to 9-d post hatch, growth, and the hypothalamo-pituitary-adrenal (HPA) axis in wood duck (*Aix sponsa*) ducklings. Wild wood duck eggs were experimentally incubated at temperatures that encompass the range of temperatures of naturally-incubated wood duck nests (35.0, 35.9, and 37.0C). Survival and growth were monitored in ducklings fed *ad lib* for 9-d post hatch. In addition, baseline and stress-induced plasma corticosterone concentrations were measured in 2- and 9-d old wood ducklings. Hatching success and post hatch survival was greatest in ducks incubated at the intermediate temperature. Ducklings incubated at both 35.9 and 37.0C had 43% higher growth rates than ducklings incubated at 35.0C. In addition, ducklings incubated at the lowest temperature had higher baseline (17-50%) and stress-induced (32-84%) corticosterone concentrations than ducklings incubated at 35.9 and 37.0C at 2- and 9-d post hatch. We also found a significant negative correlation between body size and plasma corticosterone concentrations (baseline and stress-induced) in 9-d old ducklings. To our knowledge, this is the first study to demonstrate that thermal conditions during embryonic development can influence the HPA axis of young birds. Our results demonstrate that subtle changes (<1.0C) in the incubation environment can have important consequences for physiological traits important to fitness.

80.4 EARLEY, RL*; CAMPBELL, JM; HSU, Y; University of Alabama, California State University Fresno, National Taiwan Normal University; *rlearley@bama.ua.edu*

Consistent behavioral and life history variation within clones of the killifish Kryptolebias marmoratus

For decades, a popular debate has raged regarding the relative contributions of genetic inheritance and environment to phenotypic variation. Some invertebrate/plant systems have provided insights into this question but there are far fewer vertebrates in which the impact of the environment on complex social behaviors can be investigated independent of genetic variation. The mangrove killifish, *Kryptolebias marmoratus* is a unique exception because it exists naturally as a self-fertilizing simultaneous hermaphrodite and, in many cases, completely homozygous parents produce offspring genetically identical to themselves. We examined variation in life history traits, aggressive behavior, and endocrine profiles both within and among six killifish clones. We also determined whether individuals exhibit consistent behavioral and endocrine variation over a time span of up to one year. Individual killifish showed highly repeatable aggressive responses to mirror image stimulation, and significant consistency in pre- and post-fight androgen (but not corticosteroid) concentrations. Further, there was significant variation in aggressive and endocrine responsiveness among individuals within a clone and among clones. We also found that suites of life history traits (e.g., time of maturation, fecundity) covary with one another, and with both behavior and endocrine measures. These covariation patterns suggest that some clones invest considerably in competition while others invest heavily in reproduction. We interpret our preliminary findings as indicative that the environment might play a central role in mediating phenotypic variation in the killifish. In addition, these initial results will serve as a springboard for more rigorous experimental approaches to the question of what governs the phenotype in this novel organism.

36.10 EITING, T.P.*; DUMONT, E.R.; University of Massachusetts Amherst; *tpeiting@bio.umass.edu*

A comparative analysis of olfactory communication in bats

Many studies have explored the importance of olfaction in food detection and acquisition in bats. While several comparative studies of fruit- and nectar-eating bats have examined the link between foraging ecology and olfaction, investigations into patterns of olfactory communication among bats have been rare. A few species of bats employ olfaction in communication, but a complete understanding of bat olfaction remains elusive. This study tests the hypotheses that bats employ olfaction for both roostmate recognition and species identification. Relative olfactory bulb volume was used as a measure of olfactory ability, colony size was chosen as a proxy for roostmate recognition, and the number of sympatric bat species was taken as a proxy for species identification. After testing for phylogenetic effects, independent contrasts were used to test for correlated changes in relative olfactory bulb volume and both colony size and number of sympatric species. Results demonstrate that animal-eating bats living in large colonies have relatively large olfactory bulbs, while animal-eaters that live in high degrees of sympatry do not. Among plant-eating bats, the pattern is reversed: those that live in large colonies do not have relatively large olfactory bulbs, while plant-eaters that live in greater sympatry have larger-than-expected olfactory bulbs. These results imply that animal- and plant-eating bats rely, in part, on olfaction to mediate social communication. Olfactory communication apparently mediates different social functions in bats that have different foraging ecologies.

74.1 ELLERS, O*; YOSHIMURA, K; MOTOKAWA, T; JOHNSON, A.S.; Bowdoin College, Maine, Tokyo Institute of Technology; *olafellers@suscom-maine.net*

An inverted pendulum model for underwater walking

The inverted pendulum is a common model for terrestrial locomotion but a corresponding model for underwater walking has not been explicitly enunciated. We present an underwater version of the Froude number that is modified to account for buoyancy, acceleration reaction and drag. We use standard damped oscillator theory to model the motion of underwater pendulums and, via the inverted pendulum, to model underwater walking. An underwater pendulum's frequency is strongly affected by its density relative to the fluid density and somewhat influenced by the added mass coefficient. Higher frequencies result from shorter strings, lower added mass and higher bob densities. Drag tends to damp motion and slightly decreases frequency with increasing drag. The damping effect of drag is greater for smaller diameter bobs, and damping is slightly increased by increasing added mass. Reasonable values of drag coefficient and added mass can produce damping that is large enough that nearly all of the swing amplitude is lost each cycle (critical damping). This model should apply to many underwater walkers such as bipedal octopuses, crabs and sea urchins. The urchin *Diadema setosum* moves rapidly, speed-walking on its spines when alarmed. We tested the pendulum-like characteristics of this urchin by swinging it with and without spines to measure the added mass and damping due to drag. Both the added mass and high drag damping of this urchin mean that with spines, this urchin is nearly critically damped. Thus, walking rapidly must be energetically costly and therefore reasonable only for escape locomotion. We will further develop the inverted pendulum model and apply it to filmed walking kinematics.

32.1 ELLIOTT, Glen RD*; LEYS, Sally P; University of Alberta; *gelliott@ualberta.ca*

Evidence for chemical signalling systems (Glutamate, GABA and Nitric Oxide) involved in coordinated body contractions of Ephydatia muelleri.

Sponges are benthic suspension feeders that are considered to lack a tissue level of organization, sensory cells and coordinated behaviour. Recent molecular and physiological studies suggest that the Porifera have cell signalling systems similar to those found in higher metazoans. Unfortunately, few model systems exist in the Porifera that enable functional experiments to be undertaken to examine their physiology. The demonstration of coordinated contractions of canals that function to expel waste water in *Ephydatia muelleri* prompted us to examine the physiology of these contractile canals. It is hypothesized that sponges are able to coordinate or modulate contractions by the use amino acids (Glutamate or GABA) or short-lived gases (Nitric Oxide). Using a combination of digital time-lapse microscopy, HPLC, immunocytochemistry, and pharmacological manipulations provides a description of signalling systems in the freshwater sponge. HPLC analysis of sponge tissue for free amino acids identified pools of glutamate, glutamine, and GABA used to maintain a metabotropic receptor signalling system. Application of glutamate induces contractions in a dose dependent manner and application of GABA induces rapid twitches of the choanosome. Nitric oxide induces the contraction of the osculum and nitric oxide synthase has been localized in mesenchyme cells of the apical pinacoderm, choanocytes and in cells surrounding excurrent canals and osculum, which is corroborated by using a cGMP assay indicating that the Nitric oxide system is functional. We propose that *Ephydatia muelleri* has chemical signalling systems to coordinate (Glutamate, GABA) or to locally modulate contractions (Nitric oxide).

60.2 ENG, CM*; HIGHAM, TE; BIEWENER, AA; Harvard Univ., Cambridge, MA, Clemson Univ., Clemson, SC; *cmeng@fas.harvard.edu*

Muscle fiber length operating ranges reflect disparate functions between muscles

Animals move in complex environments that place constantly shifting demands on the locomotor system. To accommodate these demands, hindlimb muscles may be functionally integrated or disparate. For example, the lateral gastrocnemius (LG) and medial gastrocnemius (MG) in the guinea fowl are both synergists (in ankle extension) and antagonists (in knee flexion and extension, respectively). There are many factors that may be modulated to facilitate changes in demand (e.g. force-velocity properties, fiber type recruitment). Furthermore, a muscle may modulate the fiber lengths over which it operates, and hence, active force, a relationship described by the muscle-specific length-tension (L-T) curve. We measured the L-T properties of the LG and MG of helmeted guinea fowl (*Numida meleagris*) and examined how different demands affected the operating range of each muscle relative to its L-T curve. Sonomicrometry crystals were used to measure fiber length during walking and running on level and incline. Following *in vivo* experiments, the muscles were isolated in an *in situ* preparation and stimulated at incremental lengths to construct a muscle-specific L-T curve. Both LG and MG operate at lengths shorter than optimal (determined *in situ*) during all training conditions. The range of fiber strain increased for the LG on the incline, but not with speed. However, the LG operated closer to optimal length as speed increased, indicating a greater capacity for active force generation. There was no change in the operating range in MG across training conditions. These results demonstrate: 1) there are multiple ways in which a muscles operating range can be modulated, and 2) LG may be more important than MG in increasing hindlimb work as running speed increases.

94.1 ENGEL, S.*; HYDE , T.; WOLF , B. O.; Univ. of New Mexico, Albuquerque; *sengel@unm.edu*

Is avian migration in the American Southwest timed to the bloom of columnar cacti?

During spring time in the Sonoran Desert, columnar cacti like saguaro produce an abundance of nectar- and pollen-rich flowers, the seasonal timing of which is very predictable and mainly dependent on spring temperature. Flowering thus occurs in a wave, starting out in Northern Mexico and moving north into Arizona. Since the geographic range of saguaro overlaps widely with the migration routes of many bird species we hypothesize that cactus nectar may be an important food source during spring migration, and that migration may actually be timed to follow the wave of cactus bloom. We took advantage of the fact that cactus nectar has an isotopic CAM value (^{13}C=12.8 ‰ VPDB) which is very distinct from other (C3) resources available at this time of the year (^{13}C=24.9 ‰ VPDB). We collected samples of breath and blood from 37 bird species (Warblers, Flycatchers, Finches, Orioles, and other) captured in Southern Arizona during migration from late April to end of June. This time period encompassed the local cactus bloom, starting early May and peaking in late May. Since carbon has very different turn-over rates in breath, plasma and red blood cells, we can determine the relative importance of cactus nectar as feeding resource for a time frame from very recently (breath) to several weeks ago (red blood cells). This allows us to model the temporal utilization of this short-lived but super-abundant food resource and to infer the degree to which migration is timed to columnar cactus bloom.

18.1 ESTES, Anne M.*; PIERSON, Elizabeth A.; University of Arizona; *amestes@u.arizona.edu*

Genome size of bacteria in a variable endosymbiotic environment

A strong correlation exists between the degree of environmental variability and genome size in prokaryotes. Free-living bacteria such as *Escherichia coli* must survive periods of desiccation, starvation, UV damage and be able to use a variety of nutrients. A relatively large genome is thought to be necessary for free-living bacteria to survive fluctuating external environments. In contrast, intracellular endosymbiotic bacteria of insects are found in a specific and relatively constant host environment. These endosymbiotic bacteria have extremely small genomes as compared to free-living relatives. The tephritid olive fly, *Bacterocera oleae*, provides a variable environment to its endosymbiont, *Candidatus* Erwinia dacicola and other microbes associating with the fly. *Ca.* E.dacicola resides in an evagination off the digestive system in both the larval and adult stages. As the host switches from feeding on olives as larvae to feeding on nectar as adults, the bacteria encounter a different set of nutrients. Additionally, the bacteria are intracellular in the larval midgut and extracellular in the adult foregut. To survive these host developmental transitions, the olive fly endosymbionts may have a relatively high degree of phenotypic plasticity. Pulse Field Gel Electrophoresis was conducted on the olive fly symbionts and several free-living relatives to determine if the genome size is similar to free-living relatives or reduced as in other endosymbionts.

73.3 EVANGELISTA, Dennis J.; Univ. of California, Berkeley; *devangel@berkeley.edu*

Up, up, and away! The jump of the amphipod Apohyale pugettensis

Kinematics of an intertidal amphipod (*Apohyale pugettensis*) jumping in air were obtained with high speed video and analyzed for jump distance, energy and power requirements. *A. pugettensis* launched itself with a muzzle velocity of 100 body lengths/s, tumbling at 2000 rpm. Takeoff accelerations reached 221 m/s^2, approximately 23 Gs. Takeoff was accomplished with a rapid abdominal extension at extremely high specic power output (1100 W/kg), suggesting that an elastic storage mechanism is likely present. A mathematical model of the ground-contact phase of launch, applicable to other jumping organisms that use abdominal extension, is described. Anatomical studies suggest several possible storage mechanisms and triggers.

S7.4 EWOLDT, R.H.*; HOSOI, A.E.; MCKINLEY, G.H.; MIT, Cambridge, MA; *ewoldt@mit.edu*

Nonlinear viscoelastic biomaterials: meaningful characterization and engineering inspiration

Nonlinear mechanical properties play an important role in numerous biological functions. For example, the strain-stiffening of artery walls enables stability to inflation over a range of pressures (Shadwick, J. Exp. Biol. 1999), and the dramatic viscous shear-thinning of gastropod pedal mucus enables the wall-climbing abilities of adhesive locomotion (Denny, Nature 1980). Purely elastic and purely viscous nonlinearities are amenable to standard characterization techniques. However, biomaterials are often viscoelastic, exhibiting both elastic and viscous nonlinear responses simultaneously, requiring more advanced characterization techniques. Here we discuss a new framework for describing and understanding such nonlinear viscoelastic behavior, outlining new material measures and clearly defining commonly used but previously ambiguous language such as strain-stiffening/softening and shear-thickening/thinning. This framework enables a meaningful physical interpretation of nonlinear viscoelastic material responses which before could only be described mathematically. Interest in soft materials is increasing within the engineering field, for example with the use of complex fluids and smart materials for mimicking natural systems. The wall-climbing ability of gastropods has motivated our pursuit of an engineered system which imitates native pedal mucus. Furthermore, soft-bodied animals give inspiration for soft robots which can actively control their shape and/or mechanical properties. A better understanding of complex viscoelastic biomaterials will help the engineering community integrate soft solids and complex fluids into the working components of devices.

87.6 FEITL, KE*; STROTHER, JA; VAN TRUMP, WJ; MCHENRY, MJ; Univ. of California, Irvine; *kfeitl@uci.edu*

Larval fish sense predators by detecting rapid water flow

The ability to sense water flow plays a role in a variety of behaviors in adult fish. However, the function of this sensory system in earlier life history stages is not clear. We tested whether the flow-sensing lateral line system facilitates predator detection in larval zebrafish (*Danio rerio*). We constructed a flow tank that generates a well characterized and highly repeatable impulsive flow stimulus that closely approximates the accelerations generated during suction feeding. This stimulus elicited an escape response in larvae, but this response ceased when larvae were treated with an antibiotic that ablates lateral line hair cells. As hair cells regenerated over the course of 72 hours, flow sensitivity and behavioral responsiveness returned. These findings suggest the lateral line system mediates the escape behavior of larval fish in response to fish predators.

91.2 FENN, A.M.*; FLORANT, G.L.; ZERVANOS, S; Colorado State University, Penn State University; *amfenn@simla.colostate.edu*

Genetics vs. Environment: Variance in Torpor Patterns of Woodchucks along Latitudinal Gradients

Little is known about characteristics of torpor during hibernation at different latitudes. Woodchucks (*Marmota monax*) (WC), exhibit a variety of torpor patterns and have a population range from south-eastern United States to northern Alaska. To determine whether latitudinal gradient plays a role in torpor pattern characteristics, WC were obtained from 3 locales along a northern to southern gradient (Maine (WCM) (Latitude 43°42'N), Pennsylvania (WCP) (Latitude 40°22'N), and South Carolina (WCS) (Latitude 34°40'N)) and placed in a common room in Colorado (CO) (Latitude 40°45'N). Marmots (*Marmota flaviventris*) from CO were used as a reference out-group. WC were maintained in constant darkness at an ambient temperature (Ta) of 5° C. Body mass, body temperature (Tb) and food intake were recorded in all animals; during winter hibernation food was removed. We hypothesized that torpor characteristics would be similar among WC in the lab suggesting environmental conditions have a greater impact on torpor patterns than genetics. In the lab, WCM spent the most time at low Tb (2743.5 hrs) while WCS spent the least amount of time (1995 hrs). Time spent euthermic, number of torpor bouts, minimum and mean Tb and torpor bout length did not vary between populations. In comparison with field WC time in torpor, time euthermic, torpor bout length, and minimum and mean Tb appeared to differ with WC in the lab. Our data suggests that some traits such as date of final arousal and number of torpor bouts are more genetically fixed while traits such as minimum and mean Tb, torpor and euthermic bout length, and time euthermic vary with environment. These data support our hypothesis that the majority of torpor characteristics vary with environment suggesting high phenotypic plasticity.

105.1 FERNANDEZ, Maria Jose*; DUDLEY, Robert ; Univ. of California, Berkeley; *mjose@berkeley.edu*

Elevational variation in flight mechanics and energetics of the giant Andean hummingbird

Hummingbirds are unique in their ability to sustain hovering, one of the most energetically demanding forms of locomotion. The giant hummingbird (*Patagona gigas*) weighs on average 20 g, twice as much as the second-largest hummingbird, making it an outlier in the hummingbird body size distribution. Despite the challenges of supporting its large body weight, *P. gigas* also inhabits a broad altitudinal range from sea level to 3,800 m in South America. At high elevations, the lower air density relative to sea level will reduce lift production, and mechanical power output must increase. At the same time, the lower partial pressure of oxygen may constrain metabolic power production. Thus, the occurrence of *P. gigas* at a wide range of altitudes provides an excellent natural experiment, and the opportunity to assess biomechanical and energetic responses of this bird to natural hypobaric conditions. The objectives of this study are to determine how *P. gigas* modulates kinematic and energetic parameters at high elevation in order to cope with enhanced energetic demands. Contrary to previous studies with small hummingbirds, we found that the giant hummingbird significantly increases both wing stroke amplitude and wingbeat frequency under hypobaria. Also, oxygen consumption during hovering increases significantly from sea level to 3,800 m.

38.3 FERRY-GRAHAM, LA*; SUMMERS, AP; DEAN, M; GROGAN, E; Moss Landing Marine Labs; *lfgraham@mlml.calstate.edu*

Under pressure: Ventilatory and suction feeding mechanics of ratfishes (Chimaeroidea)

Holocephalans possess a fused upper jaw and a non-suspensory hyoid. These features, along with robust tooth plates, are thought to be associated with a durophagous foraging habit that arose coincident with the evolution of this group. However, extant holocephalans (Chimaeroidea) tend to show a trend towards reduction of the tooth plates and may rely on suction to capture prey. This implies that suction is being generated in a mechanical system where the upper jaw cannot protrude and the hyoid cannot depress, posing serious limitations on suction generation as we have come to understand it (based upon studies of elasmobranchs and actinopterygians). As a first attempt at understanding if, and how, suction is generated within chimaeroids, we measured intra-oral pressures in *Hydrolagus colliei* and *Callorhynchus callorhynchus* during ventilation and prey capture. Pressure transducers were implanted in the orobranchial and parabranchial cavities, and pressure was recorded during several modes of respiration, ranging from active pumping with paired fin movement to quiescent ventilation, and during prey capture. Comparison of the patterns of pressure fluctuations allowed us to produce a general model of flow, which has several periods of reversal, and the associated kinematics of ventilation for the two species. In contrast to the two-pump (i.e, suction-pressure) models prevalent in elasmobranchs and actinopterygians, a single pump appeared to dominate in chimaeroids. We postulate that during ventilation, water is drawn into the orobranchial cavity using a very low-pressure suction pump, on the order of 100-1000 Pa. Casts of the orobranchial cavities indicate that the chamber expands only a small fraction (~20%) due to the shape and orientation of the branchial arches. Despite this, water and prey were clearly observed being drawn into the open mouth during feeding events.

18.4 FIELDS, P.A.*; TOMANEK, L.; ZUZOW, M.J.; CLAUSEN, R.C.; Franklin and Marshall College, Cal Poly San Luis Obispo; *peter.fields@fandm.edu*

A proteomic analysis of temperature acclimation and heat stress in blue mussel (Mytilus) congeners

The blue mussel *Mytilus galloprovincialis* (M.g.) is invasive along the southern California coast, and has displaced the native *M. trossulus* (M.t.) there. Physiological and biochemical evidence suggest that M.g. may out-compete M.t. due to relative warm adaptation. Here, we use a proteomics approach to examine the cellular responses of gill from the two species to acclimation temperature (7 or 13C) followed by acute heat shock (HS; 32C). Using two-dimensional electrophoresis, in-gel digestion and mass spectrometry, we have found that the two species respond to acclimation and to HS differently. We identified a series of HS protein (HSP) 70 isoforms that are up-regulated significantly (ANOVA; $p < 0.05$) in M.g. after HS, whether acclimated to 7 or 13C. The same isoforms are up-regulated after HS in M.t. acclimated to 7C, but they are not up-regulated after HS in M.t. acclimated to 13C. In acclimated animals that did not experience HS, M.t. acclimated to 13C have higher levels of HSP70s than do M.g. acclimated to 13C. Levels are similar in M.g. acclimated to 7 or 13C, and M.t. acclimated to 7C. We have also identified four HSP24 isoforms in both species, two of which are expressed in a pattern similar to that of HSP70s. The other two HSP24s, while showing up-regulation after HS in M.g. acclimated to 13C, show no response in M.t. to HS at either acclimation temperature. These results suggest that M.g. produces a more robust HS response than M.t. after acclimation to 13C, and that the response of M.t. to acclimation at 7C is in some ways similar to the response of M.g. at 13C. Currently, we are using the expression profiles of HSP70 and HSP24 isoforms in the two species to search for other proteins that also are up-regulated in response to acclimation or HS.

91.5 FILL, J.F.*; KLUG, P.; SANDERCOCK, B.K.; University of Massachusetts Amherst, Kansas State University; *jfill@student.umass.edu*

The Influence of Habitat Variation on Snake Body Temperature and Behavior on Konza Prairie

An understanding of how snake behavior is influenced by tallgrass prairie management (burning and grazing) is critical in understanding how these animals will respond to the anthropogenic changes to the ecosystem, and how this may affect their predatory relationship with grassland birds. My objective was to investigate the influence of burning and grazing on snake behavior. To do this I looked at the relationship between snake body temperature and habitat structure resulting from experimental grazing and burning treatments on Konza Prairie. I radiotracked yellow-bellied racers (Coluber constrictor) and Great Plains ratsnakes (Pantherophis emoryi) on Konza Prairie from June to August, recording body temperature and both watershed (treatment type) and habitat at each location. ANOVA results showed that body temperature differed significantly between species ($P<0.0001$) and within each species it differed among snakes located in grassland, edge, forest, and shrubby draws (ratsnake: $P=0.02$ and racer: $P=0.0036$). Contrary to the expected habitat associations of racers with grassland and ratsnakes with edge (based on preferred body temperature of the species), I found racers using shrubby draws more often in less frequently burned areas while ratsnakes exhibited no outstanding trend. Based on the correlation between body and litter temperatures in the racer ($r2=0.48$) and between body and under-rock temperatures in the ratsnake ($r2=0.50$), I conclude that behavioral use of habitat in the racer is more strongly affected by management due to alteration of substrate by burning. While differences in use of macrohabitats may also be a result of foraging strategy, availability of macrohabitat, or predator avoidance, these results represent a reaction to alteration of the landscape that may have important implications for biodiversity conservation.

52.1 FINGERUT, J*; SCHAMEL, L; FAUGNO, A; MESTRINARO, M; HABDAS, P; Saint Joseph's University; *jfingeru@sju.edu*

Silk filaments facilitate larval dispersal through freshwater stream pools

For species that use ambient flow to facilitate dispersal, the heterogeneous nature of the lotic environment can have serious fitness consequences. For non-swimming larvae such as those of the black fly *Simulium tribulatum*, the presence of large regions of slow flow (pools) may impede downstream movement and act as a sink, limiting population size and spatial distributions. Extended time spent in pool habitat increases predation and greatly reduces feeding opportunities. *S. tribulatum* may, however, use silk threads, already known to aid settlement in riffles, to increase their chances of successfully transiting pools by reducing fall velocity and/or increasing the chance of resuspension after deposition. In this study we employ video analysis to determine the fall velocity of larvae both with and without naturally produced silk threads. In addition we measure the drag forces exerted on larvae both with and without silk threads under simulated pool-bed flow conditions using scale models. We find that the presence of silk caused a significant reduction in fall velocity ranging from ~50% for the smallest neonates (0.6mm) to ~20% for the largest (7mm) late-instar larvae. In addition, analysis of the scale models revealed that the presence of silk threads should significantly increase the drag force exerted on larvae already settled to the bed. This drag should increase the chance that larvae are resuspended from the bed, allowing them to continue their downstream transport. The combined effect should be to increase the chances for all larvae to successfully transit unsuitable pool habitat. However, the success rate should be much greater for the youngest/smallest larvae and may be important in determining the spatial and demographic distributions of larval populations.

S6.2 FINK-GREMMELS, J; Utrecht University, Utrecht, The Netherlands; *J.Fink@uu.nl*

Genetic links? Comparing metabolizing enzymes and efflux transporters in domestic animals

Domestication of large herbivorous mammals has turned a significant part of the world into monocultures of selected monocotyledonous plant species. The basis for selection of these plant species was their nutritional value and the absence of toxic secondary plant metabolites. Several of these secondary plant metabolites, however, fulfill an important role in the mammalian organism as determinants of the gastro-intestinal flora, as natural inducers of protective efflux transporters (ABC transporters) and detoxifying enzymes. Efflux transporters and biotransformation enzymes are highly conserved and expressed in virtually all prokaryotic and eukaryotic organisms. They are closely linked to essential physiological functions including for example the inactivation of endogenous signaling molecules such as hormones and neurotransmitters, thereby fulfilling an indispensable role in the homeostasis. At the same time they are an essential part of the innate defense system against exposure to toxic substances. Both systems reflect species-specific adaptive traits and dietary preferences in the given habitat, resulting in unexpected differences in the expression pattern of transporters and enzymes in apparently related animal species, such as for example the suborder ruminants. Various lines of evidence suggest that in the absence of challenge exerted by diverse secondary plant metabolites in herbivores reduces the competence to cope with accidental exposures to natural toxins, environmental pollutants and even therapeutic agents. At the same time the strategic use of plant extracts or formulations is increasingly recognized as a therapeutic principle to regain homeostasis and to improve the overall resistance of animals to environmental challenges.

39.4 FISH, Frank E*; LEGAC, Paul; WILLIAMS, Terrie M; WEI, Tim; West Chester Univ., Rensselaer Polytechnic Institute , Univ. of California, Santa Cruz; *ffish@wcupa.edu*

Exceptional force generation is behind dolphins swimming prowess

It has been a longstanding impression both within as well as outside of the scientific community that dolphins are effortless swimmers. This assertion has been promoted by what has been called Grays Paradox, where dolphins are not supposed to be able to swim fast with the available muscle mass, without the benefit of special drag reducing mechanisms. Previous uses of computational hydrodynamic models and gliding experiments have indicated that dolphins can produce high thrust (=drag), but these tests have relied on various assumptions. The thrust produced by two actively swimming bottlenose dolphins (*Tursiops truncatus*) was directly measured using Digital Particle Image Velocimetry (DPIV). For dolphins swimming in a large outdoor pool, the DPIV method used illuminated microbubbles that were generated in a narrow sheet from a finely porous hose and a compressed air source. The movement of the bubbles was tracked with a high-speed video camera. Dolphins were trained to swim steadily at 0.7 to 3.4 m/s or by fast starts within the bubble sheet oriented along the dorso-ventral midline of the animal. The wake of the dolphin was visualized as the microbubbles were displaced due to the action of the propulsive flukes and jet flow. The oscillations of the dolphin flukes were shown to generate strong vortices in the wake. Thrust production was measured from the vortex strength through the Kutta-Joukowski theorem of aerodynamics. The dolphins generated up to 425 N during steady swimming and up to 1468 N during fast starts. The results of this study demonstrated that dolphins produce more than enough thrust to propel themselves without reliance on special drag reduction mechanisms.

39.3 FLAMMANG, B.E.*; LAUDER, G.V.; Museum of Comparative Zoology, Harvard University; *bflammang@oeb.harvard.edu*

Caudal fin shape modulation and control during acceleration, braking, and backing maneuvers in bluegill sunfish, Lepomis macrochirus

Evolutionary patterns of intrinsic caudal musculature show that control of the dorsal lobe of the tail evolved first, followed by the ability to control the ventral lobe. This progression of increasing differentiation of musculature suggests specialization of caudal muscle roles. Fine control of fin elements is likely responsible for the range of fin conformations observed during different maneuvering behaviors. The kinematics of the caudal fin and the motor activity of the intrinsic caudal musculature during kick and glide, braking, and backing maneuvers, are examined and compared to our previous work on the caudal fin during steady swimming. Kick and glide maneuvers consisted of large amplitude, rapid lateral excursion of the tail fin, followed by forward movement of the fish with the caudal fin rays adducted and in line with the body to reduce surface area. Just prior to the kick, the flexors dorsalis and ventralis, hypochordal longitudinalis, infracarinalis, and supracarinalis showed strong activity. When braking, the dorsal and ventral lobes of the tail moved in opposite directions, forming an S-shape, accompanied by strong activity in the interradialis muscles. During backing up, the ventral lobe initiated a dorsally-directed wave along the distal edge of the caudal fin. Relative timing of the intrinsic caudal muscles varied among maneuvers and their activation was independent of the activity of the red muscle of the axial myomeres in the caudal region. There was no coupling of muscle activity duration and electromyographic burst intensity in the intrinsic caudal muscles during maneuvers as was observed in previous work on steady swimming.

54.3 FLETCHER, Q.E.*; SELMAN, C.; SPEAKMAN, J.R.; LEEUWENBURGH, C.; HUMPHRIES, M.M.; McGill University, University of Aberdeen, University of Florida; *quinn.fletcher2@mail.mcgill.ca*

Metabolically mediated oxidative stress and in a free-ranging mammal

Cumulative physiological damage is the underlying cause of senescence and it results because of the allocation trade-off between reproduction and somatic maintenance. Levels of metabolic expenditure are one possible measure of allocation to reproduction that may mediate this trade-off. In mammals, high levels of metabolic expenditure are necessary to wean offspring, but an unavoidable by-product of aerobic metabolism is the generation of reactive oxygen species which may lead to oxidative stress. The accumulation of oxidative stress is widely believed to mediate the rate of physiological aging. Here, we examine the effect of metabolic expenditure on levels of oxidative stress accumulated during reproduction. Research was conducted on a natural population of red squirrels in Yukon, Canada. Levels of oxidative stress were determined from plasma samples paired with measures of field metabolic rate. Overall, levels of oxidative stress were higher in lactating as compared to nonbreeding females, and there was a positive relationship between field metabolic rate and oxidative stress. In conclusion, our results suggest that metabolic expenditure may be the underlying mediator of the trade-off between reproductive output and the somatic damage that underlies aging.

9.5 FOKIDIS, H. Bobby*; DEVICHE, Pierre; Arizona State University; *bfokidis@asu.edu*

Sources of variation in the hypothalamic-pituitary-adrenal axis of urban and desert birds.

Glucocorticoids (GCs) are the end products of an endocrine system called the hypothalamic-pituitary-adrenal (HPA) axis, which is activated in all vertebrates in response to stressful stimuli. The secretion of GCs has been the subject of substantial research in free-living animals. This research has shown that average plasma GC levels often differ across populations of conspecific individuals, but we know little regarding how this difference arises. We measured plasma corticosterone (CORT), the primary avian GC, in adult male Curve-billed Thrashers, *Toxostoma curvirostre*, belonging to an urban and a desert population, 30 minutes after an injection of corticotropin-releasing factor (CRF), arginine vasotocin (AVT), or adrenocorticotropin hormone (ACTH). Administration of AVT or ACTH increased plasma CORT, and urban thrashers showed a greater acute response to these hormones than desert birds. In contrast, CRF treatment had no influence on plasma CORT in either population. Population differences in resistance to negative feedback of GC on the brain and pituitary gland were assessed by comparing plasma CORT before and 30 minutes after an injection of the synthetic GC dexamethasone (DEX). DEX administration decreased plasma CORT to the same extent in urban and desert thrashers. These data suggest that urban thrashers have a higher pituitary and adrenal gland sensitivity to AVT and ACTH, respectively, than desert birds. This difference in turn indicates an overall increase in HPA axis activity, possibly associated with repeated activation of this axis, in birds dealing with urban environment-associated stressors.

S6.11 FOLEY, William J.*; MORAN, Gavin F.; KESZEI, Andras; KULHEIM, Carsten; Australian National University; *william.foley@anu.edu.au*

Chemicogenomics of plants

Many studies have documented variation in the profile and concentration of plant secondary metabolites (PSMs). Ecologists assume that much of this variation is environmentally determined and best described by carbon-nutrient balance hypotheses. Genetic influences can be estimated through detection of family level variance in traits in common garden experiments. Although concentrations of many PSMs with defined effects on herbivores have been shown to be strongly heritable, there has been little attempt to identify specific gene variants and quantify the degree to which they are under selective pressure. Careful analysis of phenotypes can provide information on the nature of the genetic structure of PSMs. Particular care must be taken in the measurement of chemical phenotypes and this is more difficult than anticipated. Large numbers of phenotypes from the whole range of the population need to be measured using techniques such as near-infrared spectroscopy. Candidate genes for PSMs can be identified by homology from better-characterized systems such as *Arabidopsis* and *Populus*. Common variants (most usually single nucleotide polymorphisms (SNPs)) must be identified and characterized. This can be done by functional expression and transformation of the plant or by association (linkage disequilibrium) mapping. Association mapping requires a specific population of unrelated individuals, many candidate genes, and SNP genotyping in addition to phenotyping. However, once a suitable population has been established, it can be re-used as more candidate genes and traits become available. The use of these approaches to identify important gene variants associated with herbivore defence in *Eucalyptus* will be discussed as well the more general problem of identifying the influence of gene variants in pharmacological studies with wild herbivores.

65.2 FOLTZ, S.L.*; DAVIS, J.E.; LEI, F.; WINGFIELD, J.C.; Univ. of California, Davis, Radford University, Chinese Academy of Sciences, Institute of Zoology; *sarahlfoltz@gmail.com*

Hormone Levels in Laying and Non-Laying Female Eurasian Tree Sparrows on the Tibetan Plateau

Onset of breeding is energetically demanding, requiring precise modulation of multiple hormones, both before and after laying. Previous studies have shown that female birds also deposit hormones in their eggs that then influence development of the embryo. Such maternal effects may be particularly important in harsh and unpredictable environments such as the Tibetan Plateau, where sudden storms and extreme temperature fluctuations may interrupt the breeding season. The Eurasian tree sparrow (*Passer montanus*), is a resident of the Tibetan Plateau in towns and settlements. It is multiple-brooded, and to maximize breeding success across the entire season it must cope with unpredictable weather and unreliable food sources. Late season breeding is particularly risky due to the possibility of early snow storms shortening the breeding season. To determine potential mechanisms of coping with this severe environment, we measured corticosterone and testosterone levels of individual birds and eggs,comparing females with and without developing eggs. Additionally, we compared the hormone levels in yolks of developing eggs relative to each other and to the mother.

33.4 FOX, Jessica L.*; DANIEL, Thomas L.; University of Washington; *jessfox@u.washington.edu*

Estimation of information transfer rates in highly precise sensory afferents

To coordinate their motion, animals rely on sensory systems to acquire, process, and transmit necessary information from the environment. Dipteran insects use specialized structures known as halteres to detect forces that occur as a result of body motions during flight. The primary afferents extending from haltere mechanoreceptors respond to stimuli with extremely high timing precision, suggesting that they are capable of transmitting information at high rates (Fox and Daniel 2008). Given this high degree of precision, we sought to directly measure the mutual information between a stimulus and the resulting spike train. We recorded the activity of more than 30 haltere primary afferent cells while mechanically stimulating the haltere with band-limited Gaussian white noise. In doing so, we directly measure the rate of information transfer. We found that many haltere primary afferent cells are able to transmit information at a rate of at least 60 bits per second and up to 133 bits per second, significantly higher than the rate found in many visual systems. Additionally, we used the measured jitter in response to repeated sine waves (n = 15 cells) to estimate the bit rate as a function of frequency, allowing us to create a neural tuning curve in the common currency of bits per second. By using this modality-independent metric of neural encoding, we can assess the sensory conduction of haltere primary afferents in the context of other information-processing systems.

11.6 FOX, A.M.*; SCHREY, A.W.; MCCOY, E.D.; MUSHINSKY, H.R.; University of South Florida; *amfox@mail.usf.edu*

Genetic relatedness in the fossorial sand skink, Plestiodon reynoldsi, in the scrub of central Florida

Understanding the reproductive behavior of secretive species is an important aspect when conducting studies for conservation and management. In order to make decisions related to management it is beneficial to know the proportion of individuals contributing to the gene pool, as well as the patterns of dispersal. The sand skink, *Plestiodon reynoldsi*, is a fossorial lizard, currently listed as threatened throughout its range along the scrub habitat of the central ridges in Florida. Genetic differentiation has been found among distinct geographic samples across the range of the sand skink, but there is information lacking regarding its mating system and fine-scale dispersal patterns. The goal of this study is to investigate parentage, reproductive success, and genetic relatedness among sand skinks sampled within a single scrub location near Davenport, Florida. Four sites (less than 2 km apart), consisting of multiple transects of pitfall arrays, were used to sample the Davenport location for sand skinks (N > 500). Parentage analysis will be performed among all individuals sampled and estimates of relatedness will be calculated for each site using multiple microsatellite loci. Significant genetic differentiation exists among the four sites, suggesting a lack of gene flow. Low rates of dispersal or the existence of neighborhoods of closely related individuals could be reasons for the apparent lack of gene flow. Characterizing these fine scale genetic properties of a local scrub habitat will provide needed information for conservation efforts, especially if detectable family structure exists.

61.1 FRAIRE-ZAMORA, JJ*; CARDULLO, RA; University of California, Riverside; *jfrai001@student.ucr.edu*

Molecular differences between male and hermaphrodite sperm in the nematode Caenorhabditis elegans

Reproductive strategies in nematode species comprise gonochoristic, hermaphroditic, and parthenogenetic forms. In *C. elegans*, hermaphrodites produce sperm in their last larval stage and then switch to the production of eggs allowing for self-fertilization. Hermaphrodites can also mate with males to produce cross progeny. While both sexes produce sperm they do so in different organs, the hermaphrodite in the oviduct and the male in the testis. A signaling pathway that involves proteins of the SPE group triggers sperm motility. This group of proteins is responsible for the extension of a pseudopod that renders the spermatozoa motile and thus enables fertilization. Motility activation is initiated by ovulation in hermaphrodites and by contact with the female oviduct in males.However, little is known about the potential molecular and physiological differences between spermatozoa of males and hermaphrodites. In this work we present differences in protein patterns between sperm from males and hermaphrodite worms. Sperm cells were fractionated using differential centrifugation and their protein patterns were compared using gel electrophoresis coupled to immunoblotting and Mass Spectrometry. Preliminary results will be discussed. The SICB-GIAR 2007 award supported this work.

44.2 FRANK, H.K.*; MAHLER, D.L.; REVELL, L.J.; LOSOS, J.B.; Harvard University, Cambridge, MA; *hkfrank@fas.harvard.edu*

Adaptive Radiation in Toepad Characteristics in Mainland and Caribbean Anolis Communities

Caribbean *Anolis* lizards are a model system for the study of evolutionary divergence and adaptive radiation as species on the different islands of the Greater Antilles living in similar habitats have converged onto similar morphologies. Toepads, which bear lamellae that allow lizards to adhere to complex surfaces, are crucial in allowing lizards to inhabit different niches. In the Caribbean, toepad width and lamella number show distinct evolutionary patterns that correlate with ecological characteristics. However, comparatively little is known about mainland *Anolis* species despite the fact that these animals comprise over half of the total radiation of the genus. Based on previously published data, we hypothesized that mainland species will show significantly less adaptive divergence (higher phylogenetic signal) than Caribbean species. We calculate phylogenetic signal (Blomberg's K) based on measurements of lamella number and toepad width taken from scans of the fore and hindfeet of over 2,131 individuals from 203 species of *Anolis*. Preliminary results based on a subset of the data support previous findings and indicate extensive adaptive divergence of toepad structure in the Caribbean ($K < 1$), but suggest toepad evolution in mainland species is significantly more correlated with phylogenetic relationships ($K_{mainland} > K_{Caribbean}$). Further studies exploring the ecological and functional differences between mainland and Caribbean anoles that may drive the observed differences are needed.

19.2 FRANSSEN, RA*; COPPOLA, DM; Randolph-Macon College; *adamfranssen@rmc.edu*

The Effects of Naris Occlusion on Cilia Development and Protein Expression

In the olfactory system, much of what is known about the role of neural activity in development comes from studies using unilateral naris occlusion (UNO) as a method of sensory deprivation. Although deprivation by this technique is not absolute, UNO produces a variety of effects in the ipsilateral olfactory bulb, including a reduction in bulb volume and number of interneurons. However, recent work in *Mus musculus* suggests that in addition to these apparent losses of function, there is actually an increase in the production of proteins involved in olfactory transduction on the occluded side relative to controls. Further, electrophysiological responses to odors appear to be greater on the occluded side of the nasal cavity. These surprising differences have been interpreted as being a compensatory response by olfactory sensory neurons to the new odor environment. Conversely, the differences between occluded and non-occluded sides may be a result of increased wear on non-occluded cilia versus the relative protection of cilia on the occluded side. To test our hypotheses, we created an antibody specific to one of the over 1,000 olfactory receptor proteins found in olfactory cilia. We studied the effects of UNO on cilia development and protein expression for occluded, non-occluded, and normal nares using immunocytochemistry; results will be discussed.

19.6 FRANSSEN, C.L.*; KARSNER, S.; TU, E.; HYER, M.M.; LAMBERT, K.G.; Randolph-Macon College; *catherinefranssen@rmc.edu*

Neuroplasticity Following Paternal Experience in Two Congeneric Species

Both the behavioral and hormonal experiences of pregnancy, birth, and lactation have been shown to significantly alter and enhance the maternal brain, a situation which improves the survival chances of both the mother and her offspring. Neurobiological enhancements in the hippocampus include, but are not limited to, increases in long-term potentiation and dendritic spine density. Little is known, however, about the neurobiological implications of paternal care. Roughly 6% of mammalian species exhibit male parental care, generally in environments with particularly challenging ecological profiles. In this study we explore behavioral and neurobiological consequences of paternal experience in the monogamous, bi-parental California mouse (Peromyscus californicus) and the polygamous, non-paternal congeneric Deer mouse (Peromyscus maniculatus). Specifically, neuroplasticity was evaluated -using nestin immunoreactivity (an intermediate filament indicative of cellular growth in the brain)- in the hippocampus of adult males of each species with variable paternal experiences (males with families, pup-exposed virgins, and virgins with no pup exposure). Preliminary results for P.californicus indicate a non-significant trend: the full paternal males had 150% more cells than the virgin males with no pup exposure and 60% more cells than the virgin males with pup-exposure. These results suggest that the parental experience changes the paternal brain in a similar pattern previously observed in maternal animals.

26.9 FREAMAT, Mihael*; SOWER, Stacia A.; University of New Hampshire, Durham, University of New Hampshire Durham; *sasower@cisunix.unh.edu*

EVOLUTION OF GLYCOPROTEIN HORMONE/GLYCOPROTEIN HORMONE RECEPTOR SYSTEMS IN VERTEBRATES FROM A SEA LAMPREY PERSPECTIVE

The endocrine control of the gonadal and thyroid physiology in vertebrates depends ultimately on the interaction between the pituitary glycoprotein hormones (GpH) and their cognate receptors (GpH-R). Both ligands and receptors are closely related proteins, with similar overall structural organization. Subtle differences between their structures result in a high degree of selectivity in the activating interactions hormone/receptor which ensures a minimal cross interaction between these pathways in later evolved vertebrates. This selectivity however was found to be less stringent in earlier evolved vertebrates. Investigation of the GpH/GpH-R system in the sea lamprey resulted in identification of one GpH and of two GpH-R homologs. We present the structural and functional properties of these molecules and their implications for understanding of the origins of pituitary-gonadal/thyroid axes, of the mechanisms of functional divergence of related receptors and evolution of complex chemical signaling networks. Supported by NSF IBN-0421923 and NH AES Hatch #332.

S9.8 FRENCH, S.S.*; MOORE, M.C.; DEMAS, G.E.; Indiana University, Arizona State University; *sufrench@indiana.edu*

Ecoimmunology: The Organism in Context

A major challenge in integrative biology is understanding the mechanisms by which organisms regulate trade-offs among various functions competing for limiting resources. Key among these competing processes is the production of offspring and health maintenance, and optimizing both appears to be difficult. The hormonal, behavioral, and energetic changes that occur during a reproductive bought can greatly influence an organisms immune system and likewise investing in immunological defenses can impair reproductive function. However, all of these interactions are greatly dependent upon context. Here we take a comparative look at interactions between the reproductive and immune systems, including current immunological approaches and how similar studies can reveal vastly disparate results. Specifically, studies in reptiles and mammals will be presented, investigating the effects of food availability, fat reserves, explicit reproductive state, and exogenous leptin treatment on different innate and humoral immunological responses. The combined results of these studies emphasize the importance of individual resource balance and environmental resource availability on the occurrence of life-history trade-offs and the efficiency of physiological processes in general. Therefore, nothing in ecoimmunology seems to make sense except in the context of an organisms environment.

S7.2 FUDGE, D.S.*; BERIAULT, D.; SZEWCIW, L.; MCCUAIG, J.; RUSSELL, D.; LANE, E.B.; VOGL, A.W.; University of Guelph, University of Dundee, University of British Columbia; *dfudge@uoguelph.ca*

From Soft Cells to Hard Keratins - The Many Lives of Intermediate Filaments

Intermediate filaments (IFs) are a diverse group of 10 nm cytoskeletal filaments that occur in most animal cells and impart mechanical integrity to the cells and nuclei in which they are found. They are especially abundant in epithelial cells, and they make up the fibrous fraction of the non-living materials known as alpha-keratins that occur in amniotes. Recent work on IF mechanics has overturned the notion that IFs in cells have the same mechanical properties as IFs in hard alpha-keratins such as wool. These studies have demonstrated that IFs as they occur in living cells are far more compliant and extensible than IFs in alpha-keratins. In this talk I will discuss the range of mechanical properties exhibited by IF-reinforced materials and the ways that they are suited to their use in life. Using a variety of illustrative examples, I will also discuss some of the mechanisms whereby the mechanical properties of IFs can be modified for particular mechanical functions. Examples will include work we have done on the biomechanics of human keratinocytes, hagfish slime, wool, and whale baleen. At the end of the talk I will provide some insights into the evolution of IF-based materials and the roles they may have played in the history of life on Earth.

7.3 GANNON, D.P.*; BERENS, E.J.; CAMILLERI, S.A.; GANNON, J.G.; BRUEGGEN, M.K.; BARLEYCORN, A.B.; PALUBOK, V.I.; KIRKPATRICK, G.J.; WELLS, R.S.; Bowdoin College, Mote Marine Laboratory, University of Missouri-Columbia, Chicago Zoological Society; *dgannon@bowdoin.edu*

Effects of Karenia brevis Harmful Algal Blooms on Nearshore Fish Communities in Southwest Florida

Blooms of the toxic alga, *Karenia brevis*, cause massive fish kills on Florida's Gulf Coast. The ecological effects of *K. brevis* on nearshore fish communities are poorly known. We surveyed fishes in five habitats of Sarasota Bay and the adjacent Gulf of Mexico during four summers using a purse seine. We collected synoptic data on *K. brevis* cell densities, temperature, salinity, dissolved oxygen, and turbidity. Catch per unit effort and species richness were significantly lower in all habitats during blooms. Shannon-Weaver diversity indices were significantly lower in four of five habitats during blooms. Classification and regression tree analysis showed significant negative relationships between *K. brevis* density and non-clupeid CPUE, and between *K. brevis* density and species richness. Canonical correspondence analysis indicated that *K. brevis* affected fish community structure. Most trophic guilds were negatively associated with *K. brevis* density, whereas the guild including clupeids was positively associated. We concluded that red tides caused the observed changes in fish abundance and community structure. Harmful algal blooms occur throughout the world and may play an important, yet little-understood, role in regulating fish communities.

26.6 GARB, J.E.*; HAYASHI, C.Y.; ZINSMAIER, K.E.; University of Arizona, University of California, Riverside; *garb@email.arizona.edu*

Comparative transcriptome profiling provides novel insights into the evolutionary genetics of black widow spider venom.

Animal venoms are complex mixtures of toxins having diverse physiological activities, which can often evolve rapidly in response to selection imposed by predators or prey. Spiders are among the largest group of animals defined by venom production, yet the diversity and evolution of spider toxins have to date received little attention. We conducted a comparative analysis of venom proteins synthesized by the black widow spider (*Latrodectus hesperus*) and two closely related species using a variety of molecular techniques. From these three species, we constructed and screened venom gland cDNA libraries and performed genomic PCR and 3' RACE to examine the expression, genetic organization and phylogeny of putative toxin families. In addition, we compared substitution rates of toxin genes with those of mitochondrial and nuclear housekeeping genes to detect instances of rapid evolution. Our results have implications for understanding the evolution of vertebrate toxicity in black widow spiders as well as for identifying novel toxins with potential pharmaceutical applications.

77.2 GARDINER, J.M.*; ATEMA, J.; HUETER, R.E.; MOTTA, P.J.; University of South Florida, Boston University Marine Program, Mote Marine Laboratory; *jmgardin@mail.usf.edu*

Internarial timing differences steer sharks

Sharks are hypothesized to orient to odors by performing bilateral comparisons between the nares and turning towards the highest concentration. However, odor dispersal fields result from fluid mixing and show chaotic intermittency with great temporal and spatial variance. The time-averaged concentration converges too slowly to be useful to determine a gradient, but an animal may get directional information from the pattern of the timing of the slopes of the concentration peaks. We fitted smooth dogfish, *Mustelus canis* with headsets to deliver odor to the two inflow nares, connected to programmable syringe pumps to precisely control the timing of odor delivery. The nares were presented with 0.5ml of squid rinse of identical concentration with the timing varied such that one naris received the pulse ahead of the other with 0.1, 0.2, 0.5 and 1s delays. To determine the contribution of concentration to odor patch orientation, both nares were simultaneously stimulated, one with full strength squid rinse, the other with a 100 fold dilution. Finally, the nares were stimulated with these concentration differences but with a 0.5s delay such that the weaker odor was received before the stronger odor. Animals displayed turns, defined as a 30 degree change in heading pre vs post-stimulation, towards the side receiving the first odor pulse, regardless of concentration differences. Simultaneous pulses of different concentrations resulted in turns towards either side with equal frequency. These results suggest that the temporal pattern of odor patches presents the most salient information for orientation and that the decision to turn is made within 0.5 seconds so subsequent, stronger pulses do not affect these behaviors. Using timing differences for steering is an essential component of the eddy chemotaxis hypothesis.

53.3 GEBCZYNSKI, Andrzej K*; KONARZEWSKI, Marek; Institute of Biology, University of Bialystok; *andgebcz@uwb.edu.pl*

Cross-test of the aerobic capacity model of the evolution of endothermy

Bennett and Ruben's aerobic capacity model proposed that the high basal metabolic rates (BMR) underlying endothermy evolved as a correlated response to selection favoring the capacity for high and sustained high activity and hence high levels of oxygen consumption (V_{O2}). However, the original formulation of the model left unclear if the postulated selection affected short-term maxima (V_{O2max}) or activity (and V_{O2}) sustained over extended periods. Subsequently, most studies testing the model have focused on short-term V_{O2max}, usually elicited by forced running. To cross-test the model we subjected laboratory mice to two independent artificial selection experiments, in which we selected on (1) V_{O2max} elicited by swimming (V_{O2swim}) and (2) body mass-corrected BMR. Experiment (1) resulted not only in significant between-line differences in V_{O2swim}, but also in the V_{O2max} elicited by forced treadmill running (V_{O2run}) and exercise endurance as indicated by the duration of running (t_{run}) and the distance (s_{run}) run to exhaustion. However, this selective regime did not generate any between-line differences in BMR. In contrast, experiment (2) resulted in substantial between-line differences in BMR but did not produce differences V_{O2run}, t_{run} or s_{run}. On the other hand, high BMR was significantly associated with high food consumption and high levels of voluntary activity. Our results indicate a genetic correlation between voluntary activity and BMR rather than between BMR and V_{O2max} and suggest that the high BMR of endotherms evolved as a by-product of selection for long-term energy expenditures, rather than short-term V_{O2max}.

101.4 GEHMAN, AM; Western Washington University; *alyssamina@gmail.com*

Maternal diet and juvenile quality in the sea star Leptasterias aequalis

Nutritional provisioning that passes from a mother to her offspring can produce maternal carryover effects. Manipulating the amount of food available to a maternal organism is one way to manipulate maternal investment ability, and thereby test maternal carryover. I collected brooding adult *Leptasterias aequalis* from three beaches with varying prey communities in the northern Puget Sound. When broods were released, I measured size and survival of the juveniles under starvation conditions. I then assigned the maternal sea stars to different feeding treatments and controlled their diets for a full year until they spawned again. I measured size and growth of juveniles released from these second broods. Juvenile *L. aequalis* from the initial broods showed surprising resistance to starvation, with 80% survival after 6 months, and some juveniles living a full year with no food. Juvenile survival over time varied significantly among the beaches. Juvenile size also varied significantly among mothers from the three study beaches, even when differences in female size by beach were accounted for. Maternal feeding treatments had no effect on the size of juveniles in the second broods. The patterns in juvenile size mirrored those I saw in the first year, regardless of feeding treatment. The beach that a female came from had a stronger effect on juvenile quality than a year of diet treatment. When looking at multiple generations of carryover in *L. aequalis*, it seems that genetics, and possibly full female feeding history, have a greater effect on juvenile quality than a single year of maternal feeding.

17.2 GEORGE, N.T.*; DANIEL, T.L.; Univ. of Washington, Seattle; *ntgeorge@u.washington.edu*

Temperature gradients in the dorsolongitudinal flight muscles of Manduca sexta may yield functional gradients.

During muscle contraction, heat is produced as chemical energy is converted into mechanical work. Many large insects with active flight muscles use this byproduct to elevate flight muscle temperature, thereby achieving higher mechanical power output during flight. Contractile heat production paired with convective and radiative heat loss necessarily lead to a temperature gradient, but the functional consequences of such a gradient remain unknown. Because force generation of muscle depends on temperature, subunits experiencing lower temperatures could function differently than those at higher temperatures. This is particularly relevant to the flight musculature of *Manduca sexta*. The dominant flight muscles (dorsolongitudinal muscles: DLMs) are divided into five subunits, each separately innervated. We measured two important aspects of temperature dynamics in the DLMs during tethered flight: (1) using a hypodermic thermocouple probe, we showed that there is a strong temperature gradient in the dorso-ventral direction, with a mean difference of 8.8C (a max of 10C; n = 7) across 5 mm, (2) using standard electromyography, we showed that the 5 subunits of the DLMs are activated nearly simultaneously (max time difference = 2 ms, 5% of cycle time; n = 3). Therefore, the muscle bundles do not appear to employ a spatial offset in timing to correct for the thermal gradient that they generate. Taken together, the observation of simultaneous activation and a strong thermal gradient suggest that the dorsal-most subunits may function differently from warmer, more ventrally located units.

38.5 GEORGI, Justin A; Midwestern University, Glendale, AZ; *jgeorg@midwestern.edu*

Semicircular Canal Morphology as Evidence of Sensory Adaptation to Locomotor Environment in Amniotes

The vestibular system is a critical component of the neural control of locomotion in vertebrates. Integrated in the cerebellum with visual and proprioceptive inputs, the signals from the semicircular ducts provide vital information about rotational movement relative to the environment, and drive stabilization reflexes.

The semicircular ducts leave distinct canals through the bones of the posterior braincase which preserve some of the morphologies that determine the system's functional parameters. Therefore, because the semicircular ducts have morphologies that determine the functional response of the system, and because some of these morphologies can be determined via the semicircular canals, it has been previously hypothesized that semicircular canal morphology can be used to link an organisms locomotion with semicircular duct biomechanics.

To test the underlying assumption of this hypothesis, adaptive change in biophysical parameters, the semicircular canals of a broad array of amniotes were examined. Within the semicircular canals of carnivoran mammals, turtles, varanids, and crocodilians there is, despite marked phylogenetic differences in shape, a consistent pattern of shape change that correlates with terrestrial, semi-aquatic, or aquatic locomotor behavior. This pattern is strongest in the anterior semicircular canal where the common crus and the peak of the canal adjacent to the common crus become shorter the more aquatic the animals behavior. This change in anterior semicircular canal shape is strongly tied to factors of limb morphology that correlate with locomotion and not with factors of skull morphology, supporting the hypothesis that this is adaptive change of the biomechanics of the semicircular canal system.

68.1 GIBB, A*; PACE, C; FERRY-GRAHAM, L; ARENA, A; PORTER WOLFE, H; Northern Arizona University, Moss Landing Marine Laboratory, University of South Florida; *alice.gibb@nau.edu*

Is there functional convergence among ray-finned fishes with a crocodilian-like morphology? Feeding behavior of the small piscivore Belonesox belizanus

The pike killifish *Belonesox belizanus* (Cyprinodontiformes: Poeciliidae) is an extremely small piscivore with highly-elongate anterior jaws, a reduced ligamentous connection between the upper and lower jaws, and numerous unicuspid teeth. Due to its superficial similarity with crocodilians, we term these cranial modifications a "crocodilian" morphology. We quantify the strike and prey-capture behavior of *Belonesox* and compare these parameters with published data for other ray-finned fishes (Actinopterygii) that also feed on fish-prey and possess this crocodilian morphology, including *Lepisosteus* (gar), *Strongylura* (needlefish), and *Sphyraena* (barracuda). *Belonesox* show convergence in aspects of the strike and prey-capture behavior with other piscivores; for example, many (but not all) of these piscivores use an S-start to produce a rapid forward attack on the prey. However, each piscivore employs a distinct combination of axial and cranial movements to lunge toward fish-prey and entrap them within the jaws. Thus, we concur with previous researchers that morphological convergence does not dictate functional convergence in prey capture behavior. However, based upon the literature, we posit that the crocodilian morphology may provide specific performance advantages for physically entrapping and handling large fish-prey; unfortunately, these hypothesized advantages remain to be tested in a phylogenetic context. Finally, the presence of very small juvenile fishes (the offspring of other livebearers) in the same habitat as *Belonesox* may allow this species to exploit fish as their primary prey items immediately after birth, thus allowing them to become some of the smallest known vertebrate piscivores.

16.4 GIBBS, V.K.*; HOFER, S.C.; LAWRENCE, A.L.; LAWRENCE, J.M.; WATTS, S.A.; Univ. of Alabama at Birmingham, Texas A&M System, Univ. of South Florida; *vkgibbs@uab.edu*

The sea urchin gut: size and nutrient storage are affected by temperature

While numerous studies have investigated the various roles of the sea urchin gonad (nutrient storage and gamete production), very few have considered the role(s) of the gut. An annual cycle for gut size has been reported for *Lytechinus variegatus* from the Northern Gulf of Mexico, where size was inversely related to field temperature. In this study, adult *L. variegatus* (ca. 40 mm diameter) were exposed to one of three temperatures indicative of average field temperatures of winter, spring/fall, or summer (16, 22, or 28C, respectively). Individuals (n= 24 per treatment) were maintained in recirculating aquaria and fed a formulated diet *ad libitum* for 8 weeks. Gut (stomach and intestine) dry weight was inversely related to temperature (0.35 +/- 0.01, 0.26 +/- 0.01, and 0.17 +/- 0.01 g/individual for 16, 22, and 28°C, $P<0.05$). Concentration of carbohydrates (71 +/- 4, 57 +/- 4, and 53 +/- 4mg/g) and lipids (344 +/- 12, 250 +/- 15, 189 +/- 7 mg/g for 16, 22, and 28°C, respectively) were highest for individuals held at 16°C. Protein concentration, however, was directly related to temperature and was highest at 28°C (295 +/- 7, 345 +/- 7, 373 +/- 5mg/g, for 16, 22, and 28°C, respectively). These data suggest temperature will modify the size and function of the gut. At low temperatures, storage of nutrients (primarily lipid and to a lesser extent, carbohydrate) occur concomitantly with digestion. However, the nutrient storage function of the gut is greatly reduced when individuals are held at warmer temperatures despite ingesting similar amounts of feed as compared to individuals held at low temperature. This study was supported in part by the Mississippi-Alabama Sea Grant Consortium and Texas Sea Grant.

68.4 GIDMARK, NJ*; STAAB, KL; HERNANDEZ, JP; BRAINERD, EL; Brown University, George Washington University; *nicholas_gidmark@brown.edu*

XROMM analysis of 3D skeletal movement during premaxillary protrusion in common carp

Multiple mechanisms have evolved in fishes for premaxillary protrusion, each resulting in suction, gape, and/or speed benefits during feeding. A novel, midline sesamoid bone, the kinethmoid, is present in cypriniform fishes and is highly mobile during jaw protrusion. The kinethmoid is suspended in a ligamentous sling between the neurocranium and the premaxilla, and is also ligamentously attached to the maxillae and palatines. Historically, jaw movements have been characterized by either speculations from dead specimens or by using external landmarks of live specimens. We used X-ray Reconstruction of Moving Morphology (XROMM) to visualize and measure 3D bone kinematics during oral jaw protrusion in common carp, *Cyprinus carpio*. Using biplanar x-ray video and laser-scanned bone data in a digital animation framework, XROMM produces accurate (0.1 mm) 3D animations of bone models, and can be used to explore movements and extract quantitative kinematic data. XROMM analysis of common carp collecting food from the bottom of an aquarium shows that the kinethmoid rotates in the sagittal plane, with the dorsal end rotating anteriorly, effecting premaxillary protrusion. Kinethmoid rotation is driven by the maxillae rotating slightly about their long axes, translating ventrally, and rotating in a parasagittal plane. The movements of the maxillae are caused in part by lower jaw rotation, and are consistent with previously hypothesized action of the A1 beta muscle. Lower jaw and maxillary rotation occurs prior to ventral translation of the maxilla and rotation of the kinethmoid. Protrusion of the premaxilla occurs over the entire duration, and is followed by lateral buccal expansion. This is the first description of cypriniform jaw bone kinematics in 3D space.

67.1 GIGNAC, P. M.*; ERICKSON, G. M.; Florida State University; *pgignac@bio.fsu.edu*

Biomechanical modeling of bite-force generation in the America alligator (Alligator mississippiensis) throughout ontogeny

The American alligator, *Alligator mississippiensis*, shows up to 5000-fold increases in mass during development. A substantial resource shift to increasingly larger and more durable prey items accompanies this change. To capture and subjugate these food resources this taxon utilizes absolutely high bite forces that have recently been shown to increase with positive allometry during development. Allometry of the cranial skeleton and jaw adductor musculature has been posited as the cause of such patterning. Nevertheless, the links between anatomical form and force generation have not been empirically tested. To address the cause of positively allometric bite forces in this taxon, we dissected a growth series of wild-caught *A. mississippiensis* and developed a mathematical model of bite-force generation based on ontogenetic changes to its feeding functional morphology. Muscle length, mass, pennation angle, and origin-insertion points for all six jaw adductors were considered. The model was tested against experimentally measured bite forces for an additional growth series of wild *A. mississippiensis*. The results show that bite force can be accurately predicted across the full size range of *A. mississippiensis* and that both mass increases and average attachment distance from the jaw joint of several of the jaw adductor muscles together contribute to the positive allometry of bite force in this taxon.

1.9 GILLAM, EH*; MCCRACKEN, GF; WESTBROOK, JK; JENSEN, ML; BALSLEY, BB; University of Regina, SK Canada, University of Tennessee, Knoxville, USDA, Agricultural Research Service, College Station, TX, CIRES, University of Colorado, Boulder; *gillam2e@uregina.ca*

Bats Aloft: Variation in Echolocation Call structure at High Altitudes

Bats alter their echolocation calls in response to changes in ecological and behavioral conditions, but little is known about how they adjust their call structure in response to changes in altitude. This study examines altitudinal variation in the echolocation calls of Brazilian free-tailed bats, *Tadarida brasiliensis*, a species known to fly at altitudes above 1000 m. From 50.2 hrs of recordings, we analyzed 113 high-quality echolocation call sequences (1,049 calls) recorded from 0 to 862 m above ground level. Bats flying near the ground (0-30 m) used shorter, higher frequency calls compared to bats recorded at higher altitudes, an effect likely due to the greater levels of echo-producing clutter (i.e. vegetation, buildings) found near the ground. When ground-level recordings are excluded, bats continue to shift towards the use of longer duration, lower frequency calls with increasing altitude. We propose that the observed high-altitude changes in call structure are a response to increasing acoustic attenuation rates, and/or decreasing insect densities at higher altitudes.

100.8 GINTOF, C.M.*; KONOW, N.Z.; ROSS, C.F.; SANFORD, C.P.; Hofstra University; *cginto1@gmail.com*

Variability of prey processing in teleost fishes with a comparison to amniotes

Sensorimotor control mechanisms governing prey-processing muscle activity in teleosts is understudied. Examining variability in underlying motor-patterns across a broad phylogenetic sample may improve our understanding of the evolution and complexity of vertebrate sensorimotor control. We examined two questions: is muscle-activity during prey-processing in fishes 1) behaviorally stereotypic or cyclic and 2) exhibiting a conserved level of variation? We recorded EMG from the adductor mandibulae (AM) in *Amia, Esox,* three osteoglossomorphs and four salmonids to quantify chewing duration and variation, which also was examined in raking, a novel behavior in the two latter groups. Distinct chewing occurred in behavioral trains among all taxa, a pattern that at least superficially resembles cyclic chewing in amniotes. Moreover, fish chewing cyclicity (variability in AM onset-onset duration) fell within the range seen in amniotes. Raking occurred more infrequently than chewing and rarely in trains. Stereotypy (variability in AM onset-offset duration) of chewing and raking was compared among basal and derived taxa and between basal (*Amia* and osteoglossomorphs) and derived lineages (*Esox* and salmonids). While chewing and raking stereotypy and chewing cyclicity were conserved among salmonids, variability existed in osteoglossomorphs. Our results support other evidence that prey-processing in basal teleosts may be neurally pre-programmed and rigorously controlled by central pattern generators. Work funded by NSF IOB#0444891, DBI#0420440.

54.10 GIRGUIS, PR*; NYHOLM, SV; ROBIDART, JA; GIRGUIS, ; GIRGUIS, ; GIRGUIS, ; GIRGUIS, ; GIRGUIS, ; GIRGUIS, ; GIRGUIS, ; GIRGUIS, ; Harvard University, University of Connecticut; *pgirguis@oeb.harvard.edu*

From metabolite flux to gene expression and proteomics: insights into the molecular mechanisms underlying primary productivity in hydrothermal vent tubeworms

Deep-sea hydrothermal vents host highly productive ecosystems. Many of these communities are dominated by vestimentiferan tubeworms, which house endosymbiotic chemoautotrophic bacteria that provide the hosts with their primary nutritional needs. Carbon fixation rates by these symbioses are also among the highest recorded. Despite the breadth of physiological and biochemical research on these associations, the underlying molecular mechanisms that regulate host and symbiont metabolite flux, and carbon fixation are largely unknown. Here we present metabolite flux, transcriptomics and proteomics data from shipboard high-pressure respirometry experiments, in which we maintained Ridgeia piscesae and Riftia pachyptila tubeworms at conditions comparable to those in situ. Our transcriptomic proteomic libraries have extremely high representation of genes and proteins involved in cellular processing and cell-cell signal transduction, as well as high representation of genes involved in metabolite exchange and acid-base regulation. These data represent the first concomitant metabolite flux rates and gene/protein expression studies of a chemoautotrophic symbiosis during net autotrophy. Together they allow us to develop a robust model of vestimentiferan tubeworm host and symbiont metabolism and growth, which suggests that cell cycle regulation may play a significant role in maintaining physiological poise during high productivity.

92.4 GLAZER, L.*; SHECHTER, A.; BERMAN, A.; WEIL, S.; AFLALO, E.D.; YUDKOVSKI, Y.; TOM, M.; SAGI, A.; Ben-Gurion University of the Negev, 4Israel Oceanographic and Limnological Research; *sagia@bgu.ac.il*

A Novel Molt-related Protein with a Possible Role in the Formation of Crayfish Calcium Storage Deposits

During premolt, the crayfish *Cherax quadricarinatus* transports and stores calcium in a pair of transient deposits termed gastroliths. Gastroliths, formed in a cavity between the cardiac stomach wall and the columnar gastrolith epithelial tissue, are composed of chitinous organic matrix with associated proteins, and of amorphous calcium carbonate. Initiation of premolt and gastrolith formation is achieved by administration of the molting hormone ecdysone. In search for molt-related proteins involved in gastrolith formation we have isolated several novel proteins, termed gastrolith proteins (GAP), from the extracellular matrix of the gastrolith, and fully sequenced their transcripts. The deduced protein of a gene called *GAP 10* has a molecular weight of 10kDa, is glycine-rich and has an acidic pI. It contains two predicted features; signal sequence and phosphorylation sites. *GAP 10*, was found to be highly up-regulated during premolt vs. intermolt in a multigenic search for expression patterns of gastrolith forming tissue specifically expressed genes, conducted using a *C.quadricarinatus* cDNA microarray chip. The chip was assembled from a gastrolith forming tissue cDNA suppression-subtractive hybridization (SSH) library and three additional SSH libraries of other tissues, all from ecdysone-induced premolt individuals. Due to its prominent up-regulation, *GAP 10* was chosen as a target for functional genomic investigation, for the elucidation of its role in gastrolith formation.

76.5 GLENNON, K.L.*; HILL, E.A. ; DONALDSON, J; CHURCH, S.A.; George Washington University; *kglennon@gwu.edu*

Evaluating ecological and morphological differences between the endangered Roan Mountain bluet and its common congener, Houstonia purpurea

The taxonomic status of the federally endangered Roan Mountain Bluet (*Houstonia purpurea* var. *montana*) has been controversial for many years. Currently, it is a variety of the common species *Houstonia purpurea*. The Roan Mountain bluet is undergoing review for continuation of its endangered species status; therefore, it is important to use a variety of data to fully resolve this taxonomic conflict. We evaluated multiple morphological and environmental characteristics of both the Roan Mountain bluet and its congener *Houstonia purpurea*. We hypothesize that if these two taxa are unique from one another, they will occupy unique habitats and have significant differences in morphological traits. Alternatively if these are not unique taxa we expect there will be a gradient of both morphological and environmental traits. Preliminary results suggest that these two lineages are indeed distinct from one another based on the seven traits we measured. However, there do appear to be morphological intermediates present in 2 populations. These results support the continued protection of the endangered Roan Mountain bluet as well as its distinction from *H. purpurea*.

S9.10 GODBOUT, JP; The Ohio State University, Columbus; *godbout.2@osu.edu*

Neuroinflammation and behavioral deficits in the aged: Is microglial hyperactivity to blame?

The bi-directional communication between the immune system and the CNS is necessary for mounting the appropriate immunological and behavioral responses to immune stimulation. Microglia, CNS innate immune cells, play an integral role in propagating inflammatory signals that are initiated at the periphery. Activation of peripheral innate immune cells elicits the secretion of inflammatory cytokines that use several distinct pathways to relay this signal to the CNS. This communication, in turn, induces microglia to produce the same cytokines, which target neuronal substrates and elicit a sickness behavior syndrome that is normally adaptive. In the elderly, however, systemic infection is associated with an increased frequency of behavioral and cognitive complications. We hypothesize that excessive cytokine production by microglia underlie these deficits. In support of this premise, we demonstrate that stimulation of the peripheral immune system in aged BALB/c mice causes exaggerated neuroinflammation that is paralleled by prolonged sickness and depressive-like behaviors. Moreover, our findings indicate that microglia become primed during normal aging with increased surface expression of MHC class II. Furthermore, minocycline, a purported microglia inhibitor, attenuates lipopolysaccharide (LPS)-induced exaggerated neuroinflammation and prolonged behavioral deficits in aged mice. Finally, peripheral LPS injection in aged mice causes exaggerated interleukin (IL)-1beta induction in primed (MHC II+) microglia. Taken together, these findings provide novel evidence that age-associated priming of microglia could play a pathophysiological role in the increased prevalence of neurobehavioral complications observed in the elderly.

47.1 GOLINSKI, A.*; KUBICKA, L.; KRATOCHVIL, L.; JOHN-ALDER, H.; Rutgers Univ., New Brunswick, Charles Univ., Prague ; *golinski@aesop.rutgers.edu*

Hormonal regulation of sexual dimorphisms in Lichtenfelderi's gecko (Goniurosaurus lichtenfelderi): expanding the comparative story of eublepharid lizards

Eyelid geckos (Eublepharidae) have a well-defined phylogeny and exhibit sexual dimorphisms in head and body size, combativeness, and pre-cloacal pore structure, yet these traits have become evolutionary dissociated. Thus, this family provides a model to study proximate mechanisms and evolution of sexual dimorphisms. A number of processes may cause phenotypic differences between the sexes. However, the correlated expression of sex-specific morphological and behavioral traits suggests coordination by a common hormonal mechanism. Previous work on other lizards has shown that these traits are testosterone (T) dependent. Here, we report studies on *G. lichtenfelderi*, which has genetic sex determination in common with *Coleonyx elegans* but mates seasonally in common with *Eublepharis macularius*. Our experiments included 3 groups of males (intact control, surgically castrated, castrated with T replacement) and 2 groups of females (intact control, T supplemented). Testosterone stimulated aggressive behavior and the activity of precloacal pores in males. Male sexual behavior was not affected by castration or T replacement, but T treatment induced male-typical courtship in females. Growth rate and head width were not affected by treatment in these adult lizards over a 10-week period, but the size of hemipenes was increased in males and even in T-treated females. Our experiments demonstrate that regulation of sexual dimorphisms in several morphological and behavioral traits is conserved in eyelid geckos, yet reveal some interesting differences among species. Supported by Czech Science Foundation No. 206/06/P282 (LK) and CESRI Program (AG).

1.2 GOLUB, J.L.*; FOSTER, S.A.; Clark University; *jgolub@clarku.edu*

dietary cue allow embryonic threespine stickleback (Gasterosteus aculeatus) to learn potential predators.

A variety of chemical cues exist in the environment at any give time, and an ability to use these cues to assess predation risk can greatly enhance survival. Aquatic predators produce dietary olfactory cues, which inform potential prey of their predators diet. These therefore can be learned as a predator avoidance cue. Species that have undergone rapid proliferation into new environments are exposed to novel predator regimes, and should therefore rely on learned recognition of predatory dietary cues rather than innate recognition. This logic should also extend to embryonic individuals. Being sedentary, embryos are at high risk of predation, and many of their predators continue to threaten them once they hatch. Thus, embryonic individuals in widespread species should also rely on learning to avoid predation, increasing their post-hatching survival. Threespine stickleback, a species that has rapidly radiated into novel environments, has consequently been exposed to a variety of novel predator regimes. Their embryos are exposed to the dietary cues of a wide variety of predators and might benefit greatly from learned recognition of those cues. Embryonic stickleback from a variety of marine and freshwater populations were exposed to dietary cues of novel (goldfish, *Carassius auratus*) and native (prickly sculpin, *Cottus asper*) predators to determine if they can learn these predator cues, and respond with enhanced antipredator behavior after hatching. Fry showed a stronger response to both natural and novel predators if, as embryos, they had been exposed to the cues of predators fed an embryo diet. Controls showed no change in response. Thus, stickleback embryos are able to learn to recognize natural and novel predators and respond accordingly after hatching.

95.1 GOMEZ-MESTRE, I.*; TOUCHON, J.C.; SACCOCCIO, V.L.; WARKENTIN, K.M.; Donana Biological Station, CSIC, Spain; Dept. of Biology, Boston University, Dept. of Biology, Boston University; *igmestre@ebd.csic.es*

Quantitative genetic analyses of risk-induced hatching reveal limits to plasticity of inducible defenses

Inducible defenses are paradigmatic examples of adaptive phenotypic plasticity that often mediate ecological interactions. We have studied the heritable basis of hatching plasticity in two amphibian species using quantitative genetic analyses. Amphibian embryos are exposed to many hazards, and risk-induced alterations of hatching timing are effective inducible defenses against predators and pathogens in several species. First, we analyzed genetic variation in hatching acceleration of embryos of the American toad (*Bufo americanus*) in response to the presence of pathogenic water mold. We collected adult toads from vernal pools in Lynn Woods (MA, USA) and followed a nested breeding design (North Carolina I) to obtain a series of paternal halfsibs and maternal fullsibs. We observed low levels of additive genetic variance but a significant non-additive component of plasticity in hatching timing. Second, we analyzed genetic variation in hatching acceleration of embryos of the red-eyed treefrog (*Agalychnis callidryas*) in response to simulated predator attacks. Using a breeding colony of wild-caught frogs from Limon (Costa Rica), we used a partial diallel breeding design to obtain a series of maternal and paternal halfsibs, and obtained broadly similar results to the preceding study. Both studies indicate a clear pattern of reduced genetic variation for the induced defensive phenotype early hatching than for uninduced, spontaneous hatching. This pattern contradicts most other studies on induced defenses and may be common for plasticity in the timing of ontogenetic switch points, where development imposes asymmetric limits to plasticity.

S1.10 GOODMAN, M. B.; Stanford University; *mbgoodman@stanford.edu*

Mechano-electrical Transduction Channels in Two Classes of C. elegans Mechanoreceptor Neurons

The ability to detect touch is conserved from echinoderms to humans. It relies on specialized mechanoreceptor neurons that vary in their sensitivity and association with accessory structures. Despite its importance and conservation across taxa, very little is known about how touch works. We seek to improve understanding by studying the nematode *C. elegans*, a simple animal that has only 30 mechanoreceptor neurons. Our work focuses on two classes of mechanoreceptor neurons: the 6 non-ciliated touch receptor neurons (TRNs) that detect touch applied to the body wall and the paired ciliated ASH neurons that detect noxious mechanical stimuli applied to the nose. Genetic analysis has revealed ion channel genes needed for TRN and ASH function. To learn the precise cellular function of such channel proteins and to investigate their gating mechanisms, we combine genetic dissection with in vivo electrophysiology and biomechanical analysis. The picture emerging from our work is that touch activates similar ion channels in the nonciliated TRNs and the ciliated ASH neurons. Challenges for the future include understanding the basis for differences in sensitivity and the biophysics of channel gating.

S1.11 GOPFERT, M. C.; Univ. of Gottingen, Germany;
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Auditory transduction in Drosophila

Hearing is a multi-step process that starts with the conversion of acoustic energy into mechanical vibrations (stimulus reception), the funnelling of these vibrations to dedicated mechanosensory cells and molecules (coupling), the transformation of the vibrations into electrical currents (mechano-electrical transduction), and the subsequent conversion of these currents into spike-trains that are forwarded to the CNS (encoding). We report that the molecular mechanism that brings about mechano-electrical transduction governs the macroscopic performance of a whole ear. In Drosophila, hearing is mediated by ca. 500 primary mechanosensory neurons that connect to an external sound receiver formed by the distal part of the antenna. We found that this antennal sound receiver displays all the mechanical key characteristics that have been reported for the sensory hair bundles of vertebrate hair cells, including signatures of transducer gating, transducer adaptation, and active amplification. We further found that, with minor modifications, a transduction model as proposed for vertebrate hair cells explains all these hair-bundle-like properties of the flys sound receiver as well as properties of electrical compound responses in the auditory afferent nerve. As judged from our analysis, hearing in Drosophila relies on directly gated, fully adapting transduction channels, whereby the interplay between these channels and associated adaptation motors actively shapes auditory system performance. Knocking down putative transduction molecules in the fly's auditory mechanosensory cells is shown to profoundly alter the mechanical properties of the ear.

S4.3 GORB, Stanislav N.; Zoological Institute, Department of Zoology: Functional Morphology and Biomechanics, University of Kiel, Kiel, Germany;
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Convergent evolution of hairy attachment devices

Most recent data on biological hairy attachment systems demonstrated their excellent adhesion and high reliability of contact. In contrast to smooth systems (tree frogs, grasshoppers), some hairy systems (geckos, spiders) seem to operate because of dry adhesion, because they do not produce supplementary fluids in the contact area. Interestingly, hairy systems appeared several times in animal evolution and at least three times independently even within insect evolution. This fact may indicate that such surfaces must have an advantage for adhesion enhancement in biological systems and also in artificial surfaces with similar geometries. The physical background of this effect was theoretically discussed in several recent publications. Comparison of the wide variety of animal groups revealed that the size of single contacting points gets smaller and their density increases as the body mass increases. This general trend is theoretically explained by applying the JKR theory, according to which splitting up the contact into finer sub-contacts increases adhesion. The effective elastic moduli of the fiber arrays and spatula-like terminal elements are very small, which is of fundamental importance for adhesion on rough substrata. It is predicted that an additional advantage of patterned surfaces is the reliability of contact on various surface profiles and the increased tolerance of defects at individual contacts. In a real situation, failure of some microcontacts due to dust particles or to mechanical damage of single seta would minimally influence adhesion. In the case of a solitary contact, even slight damage of the contact due to the presence of dirt or surface irregularities will immediately lead to contact breakage similar to the crack propagation in bulk material.

S7.6 GORB, Stanislav N.; Zoological Institute, Department of Zoology: Functional Morphology and Biomechanics, University of Kiel, Kiel, Germany;
s.gorb@mf.mpg.de

Materials for reversible adhesion: from biological systems to wall-climbing robots

Many insects and some larger animals can easily climb vertical walls or even walk on the ceiling. These features require a method to attach the feet reversibly but strongly to a surface which can be smooth or rough, hydrophilic or hydrophobic, clean or containing contaminants. During the last decade we have studied the complex features of reversible adhesion in biological systems and investigated which concepts could act as an inspiration for the development of artificial reversible adhesive systems. These general rules will be discussed in the present lecture. Comparison of a wide variety of animal groups revealed that the size of single contacting points gets smaller and their density increases as the body mass of the animal group increases. An additional advantage of patterned surfaces is the reliability of contact on various surface profiles and the increased tolerance to defects at individual contacts. Spatula-shaped tips of the setae are responsible for the proper contact formation with the substrate due to the low bending stiffness of the plates without or with a minimum of a normal load. We demonstrate here how the functional principles found in biological attachment devices aided in the development of reversible adhesive systems for numerous industrial applications.

S3.10 GOYMANN, Wolfgang; Max-Planck-Institut fuer Ornithologie;
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Hormones, sex roles, and performance

Testosterone is a key hormone related to reproductive aggression in male birds and some experimental evidence suggests that additional testosterone may increase performance of reproduction-related traits in free-living male song sparrows, white-crowned sparrows and dark-eyed juncos, i.e. testosterone-treated birds enlarged their territories or gained extra-pair fertilizations. On the other hand, testosterone decreased paternal care in these species, indicating a potential trade-off between the performance of different traits related to reproduction. External testosterone has been demonstrated to activate or increase behavioral traits such as song and aggression in females of bird species in which females normally do not show such behaviours. Hence, one may naively expect that in sex-role reversed species in which females sing and defend territories or mates such behaviors may be controlled by testosterone as well. Evidence for this is, however, limited. Because high levels of testosterone may interfere with the reproductive physiology of females, other mechanisms may have evolved to hormonally control sex-role reversal. In this talk I will look at hormonal factors that may promote resource-defense aggression in sex-role reversed female birds and that may promote female or male parental care and reproductive success.

82.4 GRABOWSKY, Gail*; KAHAKUI, Donna K.; ECKART, Lani; Chaminade University, U.S. Environmental Protection Agency, Kai Makana (NGO); *ggrabows@chaminade.edu*

Service-Learning and Values-Based Discussions Enhance Science Education and Student Engagement

It has been our experience in Hawaii that biology and environmental science courses more successfully achieve our course and Environmental Studies Program learning outcomes when we incorporate hands-on service-learning experiences in which the students actively apply biology/environmental science skills and knowledge to help ameliorate real-world environmental issues. Students also enjoy science courses with a service-learning component in the community more than courses without such a component. This greater success in achieving learning outcomes and course satisfaction when incorporating real-world service efforts into the curriculum is attributed to (1) the educational benefits of applying knowledge and skills learned in the classroom and laboratory in the real-world, as well as (2) a greater level of engagement by our students because they feel their scientific efforts are benefitting the environment. Our students are very ethnically and culturally diverse. Many come from places where strong ecological ethics and traditional wisdom are intact/somewhat intact. For these students the science curriculum is perhaps most successfully delivered when discussions of ecological ethics and the value of nature are allowed to occur along side the dominant scientific components of the courses both in the classroom and in the field. It may be possible that the inclusion of hands-on service-learning and values-based discussions into science classrooms anywhere could help improve student engagement and the overall achievement of science education goals.

78.3 GRAY, Emilie M*; ROCCA, Kyle AC; BESANSKY, Nora J; Univ. of Notre Dame; *djemilie@gmail.com*

Chromosomal inversion effects on aridity tolerance in the mosquito Anopheles gambiae

The malaria vector *Anopheles gambiae* is endowed with a large number of chromosomal inversions, apparently allowing the species to inhabit a wide variety of habitats. Inversion frequencies vary both geographically and seasonally, yet the phenotypic nuances resulting from this mosaic of genotypes are unknown. This ecological flexibility is exemplified by the 2La inversion, whose frequency co-varies with aridity. We have selected two colonies of *A. gambiae* differing in only the 2La inversion in order to characterize distinguishing traits of the inversion. This paper presents our findings regarding the inversions effect on adult aridity tolerance. An accompanying paper (Rocca, Gray and Besansky) explores larval thermotolerance. We established that carriers of the 2La inversion resist desiccation longer than their standard conspecifics. In teneral adults this difference is due to variation in water loss rate (WLR) whereas at later ages it is due to variation in desiccation tolerance (DT). We analyzed mass, water, lipid, trehalose and glycogen content and found only trehalose to differ, being higher in 2La than in 2L+. We also tested the effect of dry season acclimation (8 adult days at lower humidity and higher temperature) on desiccation resistance and found that both colonies increased resistance by reducing their WLR. The amplitude of change, however, was similar in both populations. In conclusion, our results suggest that 2La enhances aridity tolerance by acting on DT and WLR. The first is possibly associated with higher trehalose levels. The second may be linked to variations in cuticular characteristics; interestingly many cuticular protein genes have been identified within the 2La inversion. Possible modes of action of the inversion on the phenotype will be discussed.

29.6 GREIVES, Timothy J*; KRIEGSFELD, Lance J; DEMAS, Gregory E; Department of Biology and Center for Integrative Study of Animal Behavior, Indiana University, Bloomington, 47405, USA, Department of Psychology and Helen Wills Neuroscience Institute, University of California, Berkeley, 94720, USA. ; *tjgreive@indiana.edu*

A springtime KiSS?: Uncovering a role for the neuropeptide kisspeptin in seasonal reproduction

Most non-tropical animals exhibit seasonal bouts of reproduction, and photoperiod acts as the main environmental cue regulating the timing of breeding. The integration of photoperiod cues ensures offspring are born during favorable environmental conditions. The precise mechanisms by which photoperiodic information are integrated to directly regulate the reproductive neuroendocrine axis has, however, remained less well specified. The neuropeptide kisspeptin has recently been identified as a potent positive regulator of reproductive function and is associated with the onset of puberty in laboratory mammals and humans. We investigated the role of kisspeptin in regulating seasonal changes in reproduction in the photoperiodic Siberian hamsters (*Phodopus sungorus*). The reproductive neuroendocrine axis of Siberian hamsters is tightly regulated by changes in photoperiod; hamsters held in summer-like long-days maintain fully functional gonads, while animals held winter-like short-days regress their gonads and are reproductively quiescent. To begin to uncover the role of kisspeptin in seasonal reproduction, hamsters were subjected to hormonal and photoperiod manipulations; hamsters were housed either in summer-like long days (L:D 16:8) or winter-like short days (L:D 8:16). The effects of hormonal and photoperiod manipulation on the kisspeptin system and the effects of kisspeptin on the reproductive neuroendocrine axis in reproductive and non-reproductive hamsters will be presented. Further, the potential role of kisspeptin as a key modulator of seasonal reproductive activity will be discussed.

S1.2 GRIDI-PAPP, M.*; FENG, A.S.; SHEN, J.-X.; YU, Z.-L.; ROSOWSKI, J.J.; NARINS, P.M.; Univ. of California, Los Angeles, University of Illinois, Urbana, Chinese Academy of Sciences, Beijing, Chinese Academy of Sciences, Beijing, Harvard Medical School, Boston; *mgpapp@ucla.edu*

High frequency hearing and behavioral tuning of the ear in frogs

The upper frequency limit of anuran communication has been recently raised from 5-8 kHz to 34 kHz by studies on the Chinese concave-eared torrent frog (*Odorrana tormota*, Ranidae). Here we report on the mechanics of high frequency hearing and ear tuning in this species. The eardrums exhibit a broad response to acoustic stimulation with peak vibration velocity at 7 kHz, and high frequencies are transmitted across the stapes. *Odorrana tormota* can actively close its Eustachian tubes (ETs), falsifying the common belief that ETs in amphibians stay permanently open. The frogs close their ETs by contracting the submaxillary and petrohyoid muscles, which cause pivoting of the anterior hyoid horn over its attachment to the skull. Eustachian tube closure shifts the acoustic sensitivity of the middle ear, producing up to 20 dB gain above 10 kHz and up to 26 dB attenuation below 10 kHz. Such shift is the effect of reducing the volume of the air cavity behind the eardrum. When the ET closes, the connection between the middle ear and the large buccal volume is lost and the compliance of the middle ear cavity is reduced, stiffening the eardrum. Behavioral monitoring in the field has confirmed ET closure during the phonatory phase of each call and during swallowing. Several non-exclusive potential roles for ET closure are being examined, including: protection of the inner ear from intense sound or high air pressure during calling; reduction of acoustic masking of conspecific calls by stream noise or self-generated vocalizations; and protection of the thin eardrums from injury by life prey in the mouth.

54.4 GRIM, Jeffrey/M*; CROCKETT, Elizabeth/L; KRISKA, Tamas; HYNDMAN, Kelly/A; ALBERT, Girotti/W; Ohio University and MDI Biological Laboratory, Medical College of Wisconsin, Medical College of Georgia and MDI Biological Laboratory, Medical College of Wisconsin; *grimj@ohio.edu*

Protection of elevated membrane PUFA contents by GPx4 in marine vertebrates

Reactive oxygen species (ROS) are formed during aerobic metabolism. Animals depend on a suite of defense for protection against ROS-induced damage. Among antioxidant enzymes catalase (CAT) eliminates H_2O_2, a primary ROS, while glutathione peroxidase-4 (GPx4) detoxifies lipid hydroperoxides produced during lipid peroxidation. We hypothesize that basal marine vertebrates have high levels of both CAT and GPx4 in order to protect elevated and highly oxidizable PUFA contents of biological membranes. We compared CAT and GPx4 activities in livers of six basal vertebrate species (hagfish, lamprey, spiny dogfish shark, two teleost fishes, and newt) with the mouse. Most marine animals had greater GPx4 activity compared to mouse. Highest activities ($p < 0.0001$) were found in hagfish and killifish being 3 and 5 fold, respectively, relative to mouse. GPx4 protein levels were greatest in dogfish (3.5-fold) and killifish (4.5-fold) relative to mouse ($p < 0.002$). CAT activity was most robust in newt (mean 6-fold increase) compared with other groups ($p < 0.0001$). Contrary to our expectation that marine vertebrates would show enhanced activities of both CAT and GPx4, a weak negative trend was present between these antioxidant enzymes, although it failed to reach significance ($p = 0.06$). These data indicate that livers of basal marine vertebrates possess particularly high activities of GPx4, which should facilitate their capacity to protect PUFA in biological membranes. Supported by MDIBLs NIEHS Center for Membrane Toxicity Studies (P30 ES003828-20) and Stan and Judy Fund, and and OU SEA Award (SEA-08-39).

S4.1 GRIMALDI, D.; American Museum of Natural History, New York; *grimaldi@amnh.org*

Main Episodes in Insect Evolution and the Importance of Stem Groups

Stem groups are paraphyletic grades of basal or extinct species possessing some but not all of the specialized features of their crown group. Probably every feature of all species has evolved through a series of steps, and so stem groups possess nascent transformation of one or more features. Examples of stem groups are taken from four main episodes in the 400-million-year history of insects, each representing major adaptive features of hexapods that have contributed to their evolutionary and/or ecological success: 1. the hexapod colonization of land; 2. the origin of flight; 3. holometabolous development; 4. and advanced sociality (eusociality). The evidence for a Crustacean ancestry of hexapods provides novel views on the transition to land, but an undisputed sister group to hexapods remains elusive. Perhaps the single largest problem of insect evolution regards the origins of wings, which appeared suddenly and in full form in the Late Carboniferous, as an Early Carboniferous record is essentially lacking for insects. Holometaboly apparently evolved in the Permian, when the stem groups to modern holometabolous orders first appeared. Sociality appeared last, in the Cretaceous, and independently in four lineages. Implications of stem groups are discussed regarding evolutionary interpretations.

12.4 GRIZANTE, MB*; KOHLSDORF, T; University of Sao Paulo, FFCLRP; *tiana@usp.br*

Evolution of phalangeal formula in gymnophthalmid lizards: patterns of character states and inferences about developmental processes.

Limb reduction occurred repeatedly along Tetrapod evolution, and lizards in particular are one of the best models for studying the evolution of limblessness because intermediate forms are abundant and range from pentadactyl to entirely limbless. Recent studies suggest reversals in digit loss during the evolution of specific clades, but detailed investigation of the patterns of phalangeal formula evolution and possible developmental mechanisms underlying such morphological transitions is still urgently needed. Here we investigate in gymnophthalmid lizards if the patterns of limb reduction are common to the front and hind limbs, analyzing limb reduction in a phylogenetic context and inferring about possible developmental mechanisms related to digit loss in the group. Phalangeal formula and presence of limb bones and articulations were assessed from x-rays obtained from fixed specimens of microteiids available at the Museum of Zoology of the University of S Paulo. All analyses were performed based on a molecular phylogeny available for Gymnophthalmidae. Most tetradactyl species lack digit I, and lineages where one of the limbs is reduced usually retain the girdle, limb bones and even phalanges in the other limb. Moreover, digit loss seems to be decoupled between hand and foot in microteiids: some clades present major reduction in the hindlimb, while in others loss occurs mostly in the forelimb, and there is even one species that lacks different digits in the forelimb (d. I) and the hindlimb (d. V). The large plasticity of character states for phalangeal formula observed in Gymnophthalmidae likely lays on molecular mechanisms of developmental genes.

71.1 GROGAN, E.D.*; LUND, R; Saint Joseph's University, Carnegie Museum; *egrogan@sju.edu*

Heads, Jaws, and Feeding: In Search of the Basal Chondrichthyan Condition.

Chondrichthyans, represented today by sharks, skates, rays, and chimaeras, are gnathostomes with an evolutionary history spanning 400-500 million years. They are often invoked to exemplify the primitive jawed vertebrate condition by virtue of their cartilaginous skeleton, a neurocranium presenting as a continuous unit, and in the forms of jaw and jaw suspension that they exhibit. Yet, new observations and discoveries of Paleozoic chondrichthyans reveal much greater variation in chondrocranial design, suspensorial design, and feeding mechanisms than previously acknowledged. The data suggest that most Carboniferous chondrichthyans were operculate and characterized by jaws suspended directly from the cranium, without the intervention of the hyoid arch. This autodiastylic condition has previously been proposed as the condition from which all other chondrichthyan suspensorial states may arise. With regard to chondrocranial design, Devonian and Carboniferous finds have confirmed early forms with a partial to complete intracranial fissure. A more basal condition is suggested by taxa from the Bear Gulch Limestone of Montana (Serpuhkovian, Namurian E2b) which provide evidence of a neurocranium in three parts, generated by an intracranial joint and a complete oticooccipital fissure. Despite some variation within these forms, features of the suspensorium and feeding mechanism of these taxa reveal a premandibular component to the feeding mechanism in chondrichthyans. Taken collectively, the anatomical details of these forms reveal that early chondrichthyans exhibited features previously attributed only to other gnathostomes. This provides insight into the basal chondrichthyan condition and, so, a better resolution of the relationship of chondrichthyans to other gnathostomes

18.2 GUERRERO-FERREIRA, Ricardo*; GORMAN, Clayton; NISHIGUCHI, Michele; New Mexico State University; *ricardo@nmsu.edu*

Variation in gene expression profiles among bacterial symbionts from squids of the family Loliginidae (Mollusca: Cephalopoda)

Luminescent bacteria in the family Vibrionaceae (Bacteria:Gamma-Proteobacteria) are commonly found in complex, bilobed light organs of squids in the families Sepiolidae and Loliginidae. These organs are of similar morphology in both families of squids, but species of bacteria inhabiting each host are different. Previous research provided evidence of a non species-specific association between sepiolid and loliginid squids and Vibrionaceae bacteria including the pathogenic bacterium *Vibrio harveyi*. This suggests that specificity for the *Vibrio* genus exists, but may be influenced by additional factors besides host species. We investigated differences in gene expression profiles between bacteria grown in their free-living state (seawater) or their symbiotic state (light organ) in an effort to establish which genes are co-opted for metabolic functions required for symbiosis in *Vibrio harveyi*. Genes that are exclusively expressed in the loliginid light organs encode for proteins such as cell wall-associated hydrolases, outer membrane, putative transporters (YaaJ, gamma-glutamyltransferease and transglycosylase C) and transcriptional regulators of the LysR family. Comparison of gene expression profiles between symbiotic and free-living states will provide a better understanding of the factors that are responsible for specificity, establishment, and maintenance of the association. Combining data from this study with similar studies on sepiolid symbionts will also illustrate whether bacteria are selecting for a generalist evolutionary path for host colonization, and if those mechanisms are similar amongst two different families of host squids.

24.1 GUNDERSON, J.A.*; SANTHANAKRISHNAN, A; MILLER, L.A.; Univ. of North Carolina, Chapel Hill; *jengun@email.unc.edu*

Fluid Flow in Physical Models of the Endothelial Surface Layer

The purpose of this study is to investigate fluid flow in physical models of the endothelial surface layer by comparing both Newtonian and non-Newtonian fluids. Newtonian fluids are characterized by a linear relationship between applied shear stress and resultant strain. Newtonian fluids are conventionally used to study biological fluid flows, but this constitutes an approximation as blood is non-Newtonian. The endothelial surface layer covers the luminal side of the endothelial cells and protrudes into the blood flow. This layer consists of the glycocalyx (proteoglycans, glycoproteins and glycolipids) and attached plasma proteins. Changes in the shear stress imposed by the blood flow are sensed by the cell and these have been proposed to be important to trigger biochemical cascades within the cell. To understand the effect of varying morphology of the endothelial surface layer on the flow field, dynamically scaled physical models were used in this study. These models consist of rows of rigid two-dimensional cylinders with varying height, cylinder array length and number density. Quantitative measurements of the differences in Newtonian and non-Newtonian flow over a range of Reynolds numbers are obtained using particle image velocimetry (PIV). Based on comparisons of these fluid properties and the experimental data, we are able to obtain a better understanding of how non-Newtonian properties might alter flow patterns and the resulting shear stress and pressure gradients.

73.1 GUTMANN, A.K.*; BERTRAM, J.E.A.; RUINA, A.; University of Calgary, Cornell University; *annegutmann@gmail.com*

Metabolic Cost of Human Hopping: Linking Mechanics and Physiology of Locomotion

One of the central questions in biomechanics is "Why do people and animals move the way they do?" People and animals bodies have many degrees of freedom and, thus, are capable of a wide variety of movements. But, in general, people and animals choose to execute common tasks especially repetitive tasks such as locomotion in certain predictable ways. For example, people could choose to use an asymmetrical, limping gait to move from place to place, but most choose to walk using symmetrical steps. And, on a more subtle level, people are capable of using a wide variety of step length-step frequency combinations when walking, but mostly use a preferred step length-step frequency pair. Why is this the case? We hypothesize that humans use movement patterns that consume the minimal amount of energy necessary to accomplish a specific task and that energy minimization results in consistent movement patterns. However, this leaves open questions such as, "What is the task?" and "How does cost control motion?" In this study we use human hopping (similar to the kind done when jumping rope) to elucidate how metabolic cost, mechanical variables, and physiological constraints interact to produce an observed movement pattern. Although hopping is not generally used by humans for locomotion, it is a good model for studying the principles that govern locomotion because it has many of the same characteristics of locomotion: it is repetitive and can be performed aerobically, but is mechanically simple: it can be modeled as a one-degree-of-freedom movement (movement in the vertical direction only). Thus, we use a non-locomotory movement to gain insight into the connection between the mechanics and physiology of locomotion.

5.3 HAAK, DC*; MCGINNIS, L; LEVEY, DJ; TEWKSBURY, JJ; University of Washington; *haakd@u.washington.edu*

Environmental Heterogeneity as an Agent of Selection: Why Aren't All Chilies Hot?

Polymorphisms are a source of the variation that constitiutes evolutionary change and as such offer a window for viewing contemporary evolutionary processes. Polymorphisms can be maintained within a population through both neutral and selective processes. Natural selection can maintain polymorphisms as hybrids (heterozygote advantage), as rare/common alleles in a population (negative/positive frequency dependent selection) or through a less well documented process environmental heterogeneity. Environmental heterogeneity can impose natural selection on adaptive traits particularly under conditions of limiting resources. Here we report empirical evidence for selection maintaining a stable polymorphism via spatial heterogeneity in available moisture.

Chili peppers get their "heat" or pungency from a class of chemicals known as capsaicinoids. The relative abundance of two primary capsaicinoids capsaicin and dihydrocapsaicin explain over 95 percent of the pungency found in all chilies. The degree of pungency, or how hot the individual, is subject to environmental influence, ca. 40% genetically determined. However, the state of pungency (hot or not) is entirely genetic. Pungency appears to be a derived character as the most derived chilies (*Capsicum annuum*) are all pungent whereas basal chilies (*Capsaicum cilliatum*) all lack pungency. We have previously reported a species of chili (*Capsicum chacoense*) which occurs in natural populations in a putative center of origin for the chili pepper, Bolivia, that is polymorphic for pungency. If pungency is strictly adaptive then all chilies should be pungent across all environments. Herein we have identified an evolutionary tradeoff and mechanism which may offer an answer to the question, "Why aren't all chilies hot?"

67.4 HABEGGER, M.L*; MOTTA, P.J; HUBER, D.R; University of South Florida, University of Tampa; *mhabegge@mail.usf.edu*

Feeding Biomechanics and Bite Force in bull sharks (Carcharhinus leucas) over ontogeny

Bull sharks (*Carcharhinus leucas*) are one of the most aggressive coastal shark species inhabiting subtropical and tropical seas around the world. Several morphological characteristics such as a broad head, robust jaws, and large serrated teeth are obvious and notorious features of *C. leucas*, making this species an interesting model to study. Surprisingly, however, the feeding biomechanics of this species have not been investigated. The goal of this study is to describe the functional morphology of the jaw apparatus and investigate the ontogeny of bite performance in this top level predator. Theoretical calculations of jaw leverage and bite force were performed for an ontogenetic series of twenty individuals (73 to 258 cm TL) using a three dimensional static equilibrium model. Theoretical anterior bite force ranged from 36 to 1023 N, while theoretical posterior bite force ranged from 170 to 3720 N. Mechanical advantage at the anterior teeth ranged from 0.2 to 0.3 and at the posterior teeth from 1 to 1.2 over ontogeny, characterizing this species with a forceful jaw. Absolute values of bite force increased exponentially, with an abrupt increase in animals above 120 cm TL. Although their feeding ecology is not well known, dietary literature suggests that bull sharks exhibit an ontogenetic dietary shift from bony fishes to elasmobranchs and mammals at approximately 140 cm TL. This dietary data correspond with our results suggesting that animals above 120 cm TL may be more capable of processing harder and/or larger prey. Studying bite force, as a measurement of performance, can provide a better understanding of the feeding ecology and foraging capabilities of this apex predator over ontogeny.

22.5 HABER, Annat; University of Chicago; *annat@uchicago.edu*

Does Morphological Integration Have Macroevolutionary Implications?

The study of morphological integration has received increasing attention in evolutionary biology in the last two decades. Based on previous theoretical and empirical work, an association is expected between ontogenetic integration within a species and that species potential to evolve and diversify. However, both positive and negative relationships have been suggested, and there is as yet little empirical data to support either hypothesis. The goal of my project is to test these hypotheses using the ruminant skull as a model system. Extant ruminant lineages differ greatly in their level and pattern of both diversification and morphological integration, providing a broad comparative basis for studying that relationship from a macroevolutionary point of view. In this talk I will present results from a preliminary database, covering 28 species including representatives of all ruminant subfamilies. 3D landmark configurations were collected from the skulls using Microscribe MXL. Integration was calculated based on inter-landmark distances. Taxonomic diversification was calculated as log-scale rates. Phylogenetic structure was tested and incorporated both globally (using a distance matrix) and locally (using a clade membership matrix) in order to test for a phylogenetic effect at each node. Integration level shows little phylogenetic effect throughout the ruminant clade, but a significant phylogenetic effect was detected at the origin of Caprinae and Capreolinae. In addition, the results suggest a negative relationship between integration and diversification at the species and genus level but positive one at the subfamily level.

62.2 HADFIELD, M. G.*; HUGGETT, M.; University of Hawaii at Manoa; *hadfield@hawaii.edu*

Larval settlement, primary tube formation, and the role of the primary tube in the polychaete Hydroides elegans

Larvae of the serpulid polychaete *Hydroides elegans*, a common member of tropical marine fouling communities, settle selectively on bacterial films. Immediately following behavioral settlement, the larvae rapidly secrete an uncalcified primary tube, which both attaches them to the substratum and provides a refuge within which they complete early stages in metamorphosis. In a recent paper we presented data showing that larvae that settle on a biofilm are more firmly attached than those on a clean surface. In the present study, we examined primary tube formation with electron microscopy and learned that the primary tube is secreted from the post-trochal body surface through small tubules that extend from the epidermal cells through the larval cuticle. Preliminary observations suggest that the primary tube material mixes with bacterial exopolymers in the biofilm to secure the larva more firmly to the substratum.

20.4 HALE, M. E. *; FREMONT, R. T.; Univ. Chicago, Albert Einstein College of Medicine; *mhale@uchicago.edu*

Examining integration of new cells into neural circuits and the evolution of motor control.

One of the fundamental questions in neuroscience is: How does the brain evolve? The brain and its neural circuits, populations of nerve cells that work together to serve specific functions, are thought to be highly conserved. This is, in part, because many neurons play roles in multiple circuits. Due to this overlap, it is possible that changing one type of cell may alter the functions of many circuits. One of the ways the nervous system may change an individual circuit is to add new cells rather than modifying existing ones. However, such an approach has problems. For example, the nervous system has the potentially complicated task of generating many new connections to allow new cells to function appropriately. In addition, there may be fundamental constraints on where and how new cells can be added. We used a simple behavior, the escape response of fishes, to examine how circuits and behaviors can be modified with nerve cell addition. We examined escapes of the larval zebrafish (*Danio rerio*) for which behavioral, genetic and neurophysiological approaches have been established. We manipulated the large reticulospinal Mauthner cells as well as associated cells in the hindbrain. We found that new, experimentally added, Mauthner cells make most, but not all, of the appropriate connections into the startle circuit. Although they can generate a typical startle behavior, their activity patterns differ from those of the normal Mauthner cells. This case study provides an example of a circuit that can change significantly with the addition of new neurons and remain functional. It demonstrates that there is a degree of tolerance to aberrant nerve cell activity built into the startle circuit and suggests that this tolerance may facilitate the addition of new circuit components. Supported by NSF grant IBN0238464 to MEH.

93.3 HAMILTON, Casey*; ROSENGAUS, Rebeca B.; Northeastern University; *hamilton.cas@neu.edu*

Social transmission of immunity in the carpenter ant Camponotus pennsylvanicus

Social insects exploit microbially-rich environments, nesting and foraging in soil, leaf litter, and/or decayed wood. Risk of disease transmission is particularly acute in their densely-populated colonies, and they use a variety of defense mechanisms to cope with disease, including immunological responses. In this study, the carpenter ant *Camponotus pennsylvanicus* was used as a model system to investigate transfer of immunity among nestmates via mouth-to-mouth regurgitation (trophallaxis). These ants store nutrients in their crop and engage regularly in trophallaxis, feeding all colony members through this social stomach. We hypothesize that in addition to nutrients, ants may also be transferring immune proteins and/or immune elicitors via these frequent social exchanges. To induce an immune response, workers were exposed to a lethal dose, to de-activated pathogen solution, or to pathogen-free control solution of either the bacteria *Serratia marcescens* or the entomopathogenic fungus *Metarhizium anisopliae*. To determine the presence of novel immune proteins, regurgitate droplets taken during trophallaxis one to two days post-treatment were analyzed with SDS-PAGE. Our preliminary results indicate the presence of novel proteins in the crop of immunized ants and provide the first evidence that social transmission of immunity may occur during trophallaxis. Future research will include SDS-PAGE assays of hemolymph, fat tissue, and salivary glands to pinpoint the source and identity of these proteins.

24.3 HAMLET, C.L.*; MILLER, L.A.; The University of North Carolina at Chapel Hill; *chamlet@email.unc.edu*

Modeling blood flow through amphibian hearts using flow visualization and the immersed boundary method

Amphibian hearts are characterized by three chambers: two thin-walled atria and a single ventricle with a thick, spongy lumen. The left atrium pumps oxygenated blood into the ventricle and out into body. The deoxygenated blood returns through the venous circulation to the right atrium, into the ventricle, out through the pulmonary artery, and into the lungs. Amphibians may also initiate cutaneous respiration and obtain oxygen primarily through the skin. There are many proposed mechanisms for the flow of oxygenated and deoxygenated blood through a single ventricle, but no clear understanding of how mixing is prevented. Laminar blood flow is commonly proposed as a mechanism since intracardiac pressures are low, allowing the two flows to move against one another with minimal mixing. It has also been suggested that sequential contraction of different parts of the heart keeps the oxygenated and deoxygenated blood separated. The right atrium contracts slightly earlier than the left atrium, and deoxygenated blood moves through the ventricle earlier than the oxygenated blood. The spiral valve alternately blocks flow into the systemic arch or pulmonary arch. The thickened lumen is also believed to play a role in directing fluid flow, though the exact mechanism is unclear. Assuming laminar flow is the primary cause of maintaining separation of the two blood flow suggests constraints on the Reynolds number of the flow or on the size to which an amphibian heart can grow, which in turn constrains the body size of amphibians. In this study, we will construct a simplified physical model to test the laminar flow hypothesis using flow visualization techniques. The role of the thickened lumen will be explored using the physical model. Computational fluid dynamics using the immersed boundary method will be used to consider asynchronous contractions in the heart.

10.4 HAMPTON, P M; University of Louisiana, Lafayette; *pmh3227@louisiana.edu*

Morphological and Anatomical Correlates to Prey Shape in Snakes

Due to their multiple adaptations used to capture and consume prey snakes have proven to be ideal models for investigating relationships between morphology and feeding ecology. However, most ophidian ecomorphology studies have focused on external or osteological characteristics whereas few studies have investigated soft anatomy. I studied how the soft anatomy and morphology in snakes relates to the shapes of preferred prey. To measure heart position, esophagus and stomach lengths, I dissected snakes that frequently consume elongate prey (*Farancia, Lampropeltis* and *Micrurus*) and snakes that consume relatively robust prey (*Agkistrodon, Crotalus, Heterodon* and *Python*). I also took measures of gape and dorsal scale counts. When corrected for size, snakes that commonly consume or specialize on elongate prey had comparatively shorter esophagi and longer stomachs than snakes that consume robust prey. The size-corrected position of the heart is more anterior in snakes that eat elongate prey than those that eat robust prey. Elongate prey consumers show a relatively uniform pattern of dorsal scale numbers along the length of the body, whereas robust prey eaters have a slight peak at mid-body followed by a decline in scale number at the posterior end. Finally, gape size was correlated with both stomach length and heart position. These data suggest that snakes can compensate for smaller gapes by consuming longer prey with smaller diameters.

99.5 HANDRIGAN, GR*; BUCHTOVA, M; LEUNG, KJ; RICHMAN, JM; University of British Columbia, Vancouver, Canada, Academy of Sciences, Brno, Czech Republic; *gregory.handrigan@gmail.com*

How snakes and lizards replace their teeth: Molecular and embryological scrutiny of tooth cycling in squamates

Tooth regenerative capacity varies widely among amniotes and is affected in many human congenital diseases. It is our objective to elucidate the molecular signaling network that directs tooth cycling in amniotes. For this work, we have turned to the Squamata, which generally replace teeth throughout life (polyphyodonty). We are surveying gene expression in squamate dentigenous tissues by radioactive *in situ* hybridization and testing gene function by *in vitro* jaw-explant culture. Model species used by our group include the snake *Python regius*, the leopard gecko *Eublepharis macularius* and the bearded dragon *Pogona vitticeps*. The two former species commence tooth cycling while still *in ovo*, whereas *P. vitticeps* has lost its ability to replace teeth. By comparing odontogenesis among these three species, we can then identify crucial repressive or inductive signals in tooth replacement. Recently, we have explored the role of Hedgehog (Hh) signaling in squamate odontogenesis (Buchtova et al, 2008; PMID: 18456251). Whereas Hh is necessary for dental epithelial ingrowth and polarity, the pathway does not function in replacement tooth initiation. Accordingly, transcripts for each of the Hh pathway ligand *Shh*, receptor *Patched1*, and transcription factor *Gli2* are present in the dental lamina, but conspicuously absent from the generational lamina, the site of replacement tooth-budding. Here we discuss new data that instead implicate the transcription factor *Runx2* and members of three odontogenic pathways, TNF, BMP, and canonical Wnt, in squamate tooth cycling. We propose an epithelial-mesenchymal signaling scheme that integrates all three pathways to mediate tooth succession in squamates and other amniotes.

1.10 HANKE, W.; Rostock University; *wolf.hanke@uni-rostock.de*
Predation strategy in European pike-perch Stizostedion lucioperca: the role of hydrodynamic trail following
The European pike-perch (*Stizostedion lucioperca*) is a piscivorous predator in the open water of lakes and slowly running rivers. Pike-perch prefer turbid waters and hunt mainly at twilight or at night. Although they feature remarkably well developed eyes, there are reports on blind, well-fed specimens (Krizhanovskij SG et al., 1953). I investigated the spontaneous prey capture behavior of *Stizostedion* in complete darkness to life prey and dummies, particularly considering the question whether pike-perch sense and use the vortex trail caused by fishes for prey detection. Four juvenile pike-perch (body length 17 to 24 cm) were kept in a shallow basin (3,6 m * 1,3 m, water level 13 to 25 cm) under an approximately natural day-and-night illumination cycle. In 14 sessions, 121 hours of pike-perch activity in total darkness were recorded on video tape using infrared illumination. Three to six prey fishes (Belica, *Leucaspius delineatus*, body length 3 to 6 cm) were introduced into the basin at the beginning of each session. Two loudspeakers generated acoustic noise (sound pressure > 0.5 Pa below 400 Hz) in 10 out of the 14 sessions. 118 scenes of interest, i.e. predator-prey interactions or the remarkable absence of a reaction to a prey at close range, were defined. No difference between sessions with or without acoustic noise was discernible. Thirty-five attacks started from within one body length without a clear deliberate approach from a distance (28 with acoustic noise). In three successful attacks, six vain attacks, and 8 interactions with no attack, the predator swam on the prey's trail in a way that the shed vortices most likely aided in the orientation. However, although hydrodynamic trails of fish can last for minutes (Hanke et al. 2001, 2004), no scene was recorded that undoubtedly proved the use of an aged hydrodynamic trail far away from the prey.

66.4 HARJUNMAA, E.*; THESLEFF, I.; JERNVALL, J.; Institute of Biotechnology, University of Helsinki, Finland.; *enni.harjunmaa@helsinki.fi*
Tinkering with ectodysplasin reveals the dynamic basis of tooth development and morphology
It is often thought that tinkering with signaling networks produces small changes in development, leading to phenotypic variation, and ultimately to evolutionary change. We have experimented on such tinkering by controlling the amount of the signaling factor Ectodysplasin (Eda) during mammalian tooth development. Tabby-mice lack functional Eda, and consequently have abnormally small molars with a simplified cusp pattern. In order to study in detail the developmental variation between wild-type- and Tabby-teeth, we have made time-lapse monitoring of Tabby-molars cultured in different concentrations of Eda-protein. Our Tabby-line has been crossed with transgenic mice that express Green Fluorescent Protein (GFP) under a Sonic Hedgehog (Shh) promoter. Shh, and thus GFP, is expressed in the signaling centers of the tooth, the enamel knots, which direct growth and give rise to individual cusps. Adding Eda into the culturing media of Tabby-teeth increased their rates of growth and development, apparently through enhancing the performance of the enamel knots. The results show that most enamel knots form in the Tabby-molar, but the poor growth rate fails to accommodate all of them, leading to the simplification of the cusp pattern. Increasing the dosage of Eda caused a gradual expansion in crown dimensions and a stepwise increase in the number of cusps. The enamel knots were initiated in a specific order, which largely reflected the evolutionary order of cusp appearance. Consequently, it was possible to engineer morphologies reminiscent of known evolutionary transitions. These results suggest that the Eda signaling pathway may have provided the material (or the target) for natural selection to modify tooth morphology during mammal evolution.

S1.7 HARTMANN, Mitra JZ; Northwestern University; *m-hartmann@northwestern.edu*
Mechanical and Behavioral Constraints on Neural Encoding in the Rat Vibrissal/Trigeminal Pathway
Rats are nocturnal, burrowing animals that use their vibrissae (whiskers) to tactually explore the environment. Using only its whiskers, a rat can determine object size, shape, orientation, and texture. This makes the rat vibrissal system an excellent model to explore the structure of movements that subserve sensing. I will describe recent experiments in our laboratory that have aimed to understand neural encoding and processing in the vibrissal system using both a "bottom-up" and a "top-down" approach. In the bottom-up approach, a basic analysis of whisker mechanics has provided insight into the physical variables (forces and moments) encoded by primary sensory neurons in the trigeminal ganglion. This analysis has suggested some mechanisms by which the animal might determine the radial distance to an object. In the top-down approach, behavioral studies have helped to constrain the types of neural processing that may enable object localization in the horizontal plane. Our laboratory now aims to merge the two approaches using a new laser-light sheet technology developed to visualize whisker-object contact patterns. I will describe some preliminary results from this system and suggest some ways that the nervous system may interpret the spatiotemporal "flow" of sensory information across the whisker array during natural exploratory behaviors.

S6.9 HARVEY, A.L.; University of Strathclyde; *a.l.harvey@strath.ac.uk*
Bilogical screening assays for plant secondary metabolites
Natural products have been the most productive source of the active ingredients for medicines throughout history. Many of these have been derived from chemicals produced by plants. Some were discovered from exploring traditionally used herbal remedies; some have been found by the process of random screening, i.e. testing a random collection of compounds for activity on biological assays that relate to the intend therapeutic use. The same approaches are available to ecologists: studying samples of plants eaten by animals for activity in various biological systems or testing random samples of plants collected from the area under study. Standard bioassay techniques will be described in the presentation. These are generally biochemical in nature, using isolated enzymes or proteins such as receptors for neurotransmitters, or based on cells in tissue culture where cell growth, proliferation or death are typically studied. Biological effects of plant secondary metabolites can be detected by sensitive read-outs based on light absorbance or on use of fluorescent or chemiluminescent markers in the assays. Since most assays can be run in very small volumes, relatively little test material is required. Because of its use in drug discovery research and in the growing field of chemical genetics, the technology for such studies is becoming more accessible for academic researchers and it should be possible to adapt it for pharm-ecology purposes.

S3.2 HAU, M; Max Planck Institute for Ornithology, Germany; *mhau@orn.mpg.de*

Hormones and life history evolution

Steroid hormones have pleiotropic effects on behavior, physiology and morphology. They also regulate major transitions between phases of the annual cycle in animals. These actions make steroid hormones ideal candidates for mediating life history trade-offs, such as the one between investment in fecundity versus self-maintenance. Intraspecific studies have supported such a role for both corticosterone and testosterone in avian species. We conducted an interspecific comparison of corticosterone and testosterone concentrations in free-living males from various passerine species living in a temperate or a tropical site. Species included in this study varied in life history strategies (annual adult survival rates; breeding season lengths) and body sizes. Breeding season length and survival rates explained most of the variation in baseline corticosterone, whereas maximal stress-induced corticosterone concentrations were best explained by body mass and survival rate. Breeding season length contributed strongly to explaining variation in testosterone concentrations. These data support the hypothesis that these two hormones are part of the physiological system that underlies avian life history strategies. We will discuss these findings in the context of hormone evolution.

102.1 HAVENS, S.B.*; MAGLIA, A.M.; Missouri University of Science and Technology; *sbhdbe@mst.edu*

Larval developmental patterns in Acris crepitans blanchardi (Anura: Hylidae) and their implications

Blanchards cricket frog (*Acris crepitans blanchardi*), a North American hylid, is of ecological and evolutionary importance because of its miniature body size and range-wide population declines/extinctions. In addition to unique post-metamorphic developmental patterns, the species has a short life span and high rates of malformations relative to other hylids. It is possible that the declines and/or malformations in the species relate to its developmental and life history patterns. Unfortunately, the larval development of this species has not been studied previously, nor have the developmental patterns been compared to other hylids. In this project, we examine the pre-metamorphic and metamorphic skeletal development of *A. crepitans blanchardi*, including qualitative descriptions, timing and sequence of ossification, and geometric morphometric analyses of the larval cranium. We compare results from *A. crepitans* to those of other North American hylids, and discuss the implications of our findings relative to miniaturization, hylid evolution, malformations, and population declines.

50.5 HEALY, Jessica E*; DIAZ, Yvonne; FLORANT, Gregory L; Colorado State University, New Mexico State University; *jehealy@simla.colostate.edu*

Expression and phosphorylation of AMPK and ACC in fed and fasted golden-mantled ground squirrels (GMGS)

The golden-mantled ground squirrel (GMGS) is a mammal that hibernates (hibernator) and has a robust annual cycle of mass gain and loss controlled primarily by food intake. There are many pathways, enzymes, and hormones implicated in the control of food intake in hibernators, and the hypothalamic arcuate nucleus is a main control center of feeding. The enzymes adenosine monophosphate-activated protein kinase (AMPK) and acetyl coenzyme-A carboxylase (ACC) have been implicated in control of feeding in hibernators and other mammals. AMPK is a cellular energy sensor which responds to the increased levels of AMP caused by fasting. When AMPK is activated by phosphorylation, it causes a phosphorylation and deactivation of ACC, resulting in an increase in food intake. We hypothesized that GMGS fasted for a short time during the summer would have increased levels of active (pAMPK) and total AMPK, with associated increases in the inactive form of ACC (pACC). Fourteen GMGS were randomly assigned to one of four groups (Control (fed), 1-day fast, 3-day fast, and 5-day fast), and sacrificed after their assigned fasting time. Western blots were used to determine expression of AMPK, pAMPK, ACC, and pACC in muscle, white adipose tissue (WAT), liver, and the arcuate nucleus region of the hypothalamus. We found that pACC and AMPK increased, and ACC decreased as expected, but found no clear trend in pAMPK with fasting. These data indicate fasting changes the expression of AMPK and ACC in several tissues. This change in expression suggests a change in cellular energy level which may activate food intake pathways.

21.4 HEDRICK, TL*; DENG, X; CHENG, B; University of North Carolina at Chapel Hill, University of Delaware; *thedrick@bio.unc.edu*

Scaling of passive damping and maneuverability in flying animals

Most analyses of animal locomotion dynamics place stability and maneuverability on opposite poles; factors that enhance capability one are expected to reduce capability in the other. Here we show that flying animals at scales ranging from fruit flies to large birds benefit from substantial damping of angular velocity through a passive aerodynamic mechanism termed flapping counter-torque (FCT). Furthermore, changes to wing kinematics or morphology that enhance FCT are also expected to enhance maneuverability, allowing flying animals to simultaneously specialize in both maneuverability and a form of passive stability, at a predicted cost of increasing the amount of energy required for flight. We demonstrate these effects by developing a simplified analytic model for FCT, then using it to predict the scaling of damping for 4 species: fruit flies (*Drosophila melanogaster*), hawkmoths (*Manduca sexta*), hummingbirds (*Archilochus colubris*), and cockatoos (*Eolophus roseicapillus*). These predictions were then compared to yaw turns or perturbations recorded from each species. Turn dynamics were consistent with the FCT predictions. Finally, we show that this wide range of flying animals experiences similar passive damping on a per-wingbeat timescale, suggesting that all flying animals may make substantial use of passive mechanisms when reducing angular velocity following a maneuver or when recovering from an unexpected perturbation.

S10.9 HEIDEMAN, Paul D.*; PITTMAN, Julian T.; College of William and Mary; *pdheid@wm.edu*

Evolution of neuroendocrine mechanisms that regulate reproduction in white-footed mice (Peromyscus leucopus)

An important question in evolutionary physiology is how phenotypic variation in reproduction and life history traits are caused by natural genetic variation in underlying neuroendocrine traits. Seasonal timing of breeding involves a large number of traits that are linked genetically and physiologically in complex ways, and most of these traits have more than one function. We predict that levels of genetic variation in seasonal timing of breeding should be positively related to (1) the complexity of the neuroendocrine regulatory systems involved, (2) the number of uncorrelated or weakly correlated selection pressures that act on elements of these systems, and (3) the heterogeneity of seasonal environmental variation in time and space. The amount of genetic variation in seasonal timing of breeding might be negatively correlated with (1) life expectancy and (2) the duration of pregnancy and lactation. Our research on a single population of white footed mice, Peromyscus leucopus, has found high intrapopulation genetic variation in seasonal timing of breeding that is related to substantial genetic variation in melatonin binding, number of immunolabeled GnRH neurons, pituitary gonadotrophin hormone levels, testis size, food intake, daily activity, and metabolic rate. In contrast, genetic variation in circadian rhythms and melatonin secretion patterns appear not to be related to genetic variation in seasonal timing of breeding. We have also found genetic variation in phenotypic plasticity of seasonal timing of breeding. We discuss the importance of identification of within-population genetic variation in seasonal reproduction and correlated life history traits, genome approaches, candidate gene approaches, the potential role of epigenetic change, and modeling of these systems.

S10.10 HELM, Barbara; Max Planck Institute for Ornithology, Seewiesen and Andechs; *helm@orn.mpg.de*

Temporal coordination of life cycle stages: An avian chronobiology perspective

Reproduction of long-lived animals is embedded into a recurring cycle of annual activities. Many studies provide evidence for close links between between the timing of breeding and other life-cycle stages, including effects of calendrical cues experienced during other stages, carry-over effects of nutrition or habitat quality, and preparations for subsequent activities. Taking a chronobiological approach, the present study addresses reproduction as a periodic event within the annual cycle with a focus on birds. A first part highlights the natural diversity of annual cycles, including allocation of time to different activities like reproduction versus regeneration or enhanced survival. A second part addresses inherited programs that underlie the scheduling of annual cycles in many seasonal breeders. To time their activities, most animals use predictive cues like photoperiod, but because schedules differ between species and habitats, implications of a given daylength depend on annual routine and local seasonality. Accordingly, the relationship between photoperiodic cues and breeding undergoes evolutionary adjustments. An underlying (circ)annual cycle of reproductive activation and regression, however, persists in various species even in complete absence of temporal information. Circannual cycles are synchronized, but not driven, by photoperiod. Using data from comparative studies of a songbird, the stonechat (Saxicola torquata), I demonstrate that its geographically distinct schedules are based on conspicuous, heritable differences in circannual organization combined with phase-specific action of photoperiod. A final part addresses the interplay between circannual programming and environmental factors along a spectrum from rigid to flexible timing.

92.5 HELM, Bryan R*; DAVIDOWITZ, Goggy; University of Arizona; *bhelm@email.arizona.edu*

On the physiological determination of body size in Manduca sex: What is the critical weight?

In holometabolous insects, adult body size is determined by exponential growth that occurs during the larval stage. As a result, 90% of growth occurs during the last larval instar. Because growth rates are exponential, slight variation in the timing of the cessation of growth results in large differences in body size, making this a primary determinant of body size. In the tobacco hornworm, Manduca sexta, the cascade of physiological events leading to the cessation of growth is well established. The first of these events, the critical weight, defines when the corpora allata, the glands that synthesize and secrete juvenile hormone, switch off. Once it reaches the critical weight, the larva is committed to the cessation of feeding and pupation. Despite our understanding of the physiological events that regulate body size, the ultimate causes for the cessation of growth and determination of body size remain a mystery. In particular, little is known about what signals attainment of the critical weight to the organism. We investigated the physiological basis underlying critical weight by testing the hypothesis that nutrient accumulation in the the fat body signals attainment of the critical weight. We are surgically implanting fat body into caterpillars that have not yet reached their the critical weight, expecting to see a decrease in the time to pupation. Understanding the mechanism by which an organism ceases growth can ultimately provide an understanding of the physiological regulation of life histories as well and their response to selection.

104.5 HENNINGSEN, J*; HERMAN, R; IRSCHICK, D; University of Massachusetts Amherst; *justinh@bio.umass.edu*

Tail autotomy and escape performance in a stream side salamander

Tail autotomy and the effects thereof have been extensively studied in squamates. However, this trait has evolved independently in a number of taxa. Salamanders are one group that use this technique to escape from predators, but we have little knowledge of how the loss of the tail affects locomotor performance. Here, we examined the effects of tail autotomy on escape performance in the northern dusky salamander (*Desmognathus fuscus fuscus*). In addition to measures of whole-organism performance, we quantified kinematics of escape behavior.

72.1 HERNANDEZ, L. P.*; STAAB, K. L. ; George Washington University; *phernand@gwu.edu*

Turning a model on its head: Using zebrafish to investigate the origin and evolution of morphological novelty

Exploiting the conserved developmental mechanisms seen in vertebrates, the zebrafish has become a popular model organism within the field of biomedical research. Yet, by ignoring what makes this cypriniform fish unique we are overlooking a powerful model organism for investigating the origin and early development of morphological novelties. As cypriniforms, zebrafish possess a number of poorly investigated adaptations associated with feeding: enlarged pharyngeal jaws opposed to an enlarged basioccipital process of the neurocranium instead of upper pharyngeal jaws; a muscular palatal organ found on the roof of the buccal chamber; and the kinethmoid, a rostral ossification associated with premaxillary protrusion. Taking advantage of some of the molecular tools used by developmental biologists we describe the early development, growth and possible evolutionary fates of some of these novel structures. The palatal organ, while less well-developed in zebrafish than in other cypriniforms, is apparent from early ontogenetic stages. Vertebrate morphologists have long examined premaxillary protrusion and pharyngeal jaw function in Perciformes, however appreciably less emphasis has been placed on investigating the convergent acquisition of these functions in Cypriniformes. Given that cypriniform fishes lack oral jaw teeth, there must exist significant selection for efficient pharyngeal jaw processing in these species. The speciose Cypriniformes possess a novel median bony element, the kinethmoid, which allows for a unique mechanism of premaxillary protrusion. We have examined the development of this important feeding innovation. Identifying the developmental mechanisms responsible for the origin of these feeding adaptations will enhance our understanding of how functional novelties arise and evolve.

44.4 HERREL, A*; VELASCO, J; SASA, M; CAMPBELL-STATON, S; CRANDELL, K; FENSTERMACHER, K; FRANK, H; MAHLER, L; MUNOZ, M; VAN MIDDLESWORTH, P; LOSOS, J; Harvard University, Wildlife Conservation Society, Univ. de Costa Rica, Rochester University, Lewis and Clark College; *anthony.herrel@ua.ac.be*

Why are mainland anoles different? An ecomorphological perspective.

Anolis lizards have become a model system for the study of adaptive radiations as species with similar morphologies have radiated independently into similar ecological niches on each island of the Greater Antilles. However, *Anolis* lizards on the mainland of Central and South America have undergone an equally spectacular adaptive radiation, occupying similar ecological niches but without converging onto the same morphologies. Why mainland species have not converged on similar morphologies has remained unclear, but differences in predation pressure, competition, and behavior have been suggested. However, tests of these hypotheses have not been conducted due to a lack of quantitative ecological, morphological, behavioral, and performance data. Here we provide such data for 9 species of *Anolis* from Costa Rica to explore ecomorphological relationships among mainland anoles. Additionally, we provide data on 4 insular *Anolis* from Gorgona island, Colombia belonging to the mainland alpha-radiation of Anolis to test whether differences between mainland and Greater Antillean *Anolis* are associated with insularity. Our data suggest that differences between mainland and Caribbean *Anolis* are not a consequence of insularity per se, but rather indicate basic differences in ecomorphological relationships on the mainland versus the Greater Antilles.

S2.5 HEUCH, P.A.*; BJORN, P.A.; FINSTAD, B.; ASPLIN, L.; HOLST, J.C.; National Veterinary Institute, Oslo, Norway, Norwegian Institute for Fisheries and Aquaculture Research, Tromso, Norwegian Institute for Nature Research, Trondheim, Institute for Marine Research, Bergen, Norway; *peter-andreas.heuch@vetinst.no*

Salmon Lice Infection of Farmed and Wild Salmonids in Norway: an Overview

Salmon lice *Lepeophtheirus salmonis* have three wild host species in Norway: Atlantic salmon *Salmo salar*, sea trout *S. trutta* and Arctic charr *Salvelinus alpinus*, all of which leave the rivers in spring. The parasite infects the marine stages of these fish. In addition, 273 million farmed Atlantic salmon and rainbow trout Oncorhynchus mykiss hosts are kept in open net pens along the coast. Regulations require that adult female lice mean intensity on these must be <0.5 to limit infection of the wild salmonids, but heavily infected wild fish are still found in farming areas. Infection dynamics depend on local host ecology, hydrography and lice control in farms. In a 1998-2004 study, salmon smolts in the far North Alta fjord were seen to run before the other wild hosts, and were hardly infected. Sea trout smolts here run later but can get heavy infections even though the production of lice in farms is very low. In the Southern Sognefjord, salmon smolt infections were high until the fish farm regulations were in operation in 2004, when they were much lower, but also here the sea trout infections have remained high. In the neighbouring Hardanger fjord, farmers have organized strategic treatments in winter, with the aim of no egg-producing lice on farmed fish in spring. This has lead to a very low lice abundance on farmed fish, but wild salmonids are some years heavily infected. This paper summarizes research on the interactions between biotic and abiotic factors with respect to salmon lice infections, and discusses new strategies for lice control in farms.

53.6 HICE, LYNDIE A.*; CONOVER, DAVID O.; Stony Brook University; *lhice@ic.sunysb.edu*

On the adaptive significance of Jordan's Rule: comparing the temperature-dependence of critical swimming speed among latitudinal populations of the Atlantic silverside, Menidia menidia

The Atlantic silverside, *Menidia menidia*, displays a very strong and spatially fine-scale increase in vertebral number with latitude along the east coast of North America, consistent with Jordan's Rule. Most of this variation is genetic and such tight clinal patterns implicate natural selection as the cause but its adaptive significance is unclear. High latitude populations are thought to have evolved a greater number of vertebrae to allow for increased body flexibility in colder, more viscous water, however empirical evidence is limited. To test this theory, we hypothesized that at high temperatures, southern Atlantic silverside populations would show significantly higher critical swimming speeds than northern populations, but the reverse would be true at lower temperatures. Critical swimming speed experiments were conducted on southern (South Carolina) and northern (Nova Scotia) populations reared in a common environment. Each population was tested at four larval or juvenile sizes ranging from 10 to 30mm and three experimental temperatures. Swimming speed increased with size in both populations. The southern population exhibited maximum swimming speed at the highest experimental temperature, while the northern population performed best at intermediate temperature. There was no strong evidence of reversal of swimming ability at low temperature as expected. Few studies have investigated the link between vertebral number and swimming ability and these results provide evidence of potential agents of vertebral number selection in the wild.

11.2 HICKMAN, C.S.; University of California, Berkeley; *caroleh@berkeley.edu*

Drawing Lines in Wallacea: Historical Biogeography meets Geophysics in the Deep Sea

The biogeographic realm of Wallacea is famous as a terrestrial biodiversity hotspot, encompassing thousands of the tropical islands of eastern Indonesia. In spite of some recent recognition of significant shallow marine endemism in the region, it is the poorly documented deep-sea (>200 m) fauna that is most closely tied to the turbulent geologic history, submarine features, and deep tectonic boundaries that define modern Wallacea. Discovery of two endemic genera and six endemic species in ancient orders of marine gastropods (Vetigastropoda: Seguenzioidea and Trochoidea) in Sulawesi and Halmahera make sense in the context of the active tectonics, double subduction, and closure of the Molucca Sea between the two islands. Is it coincidental that two relict taxa are part of a disappearing oceanic microplate that was once much larger? Is new evidence of deep-sea marine endemism in Wallacea an artifact of insufficient sampling of the bathyal and abyssal fauna of other biogeographic regions in the Indo-West Pacific? Compilation of biogeographic distributions of 60 species of deep-sea calliotropine gastropods suggests that the deep endemism in Wallacea is real. When distributions are mapped onto tectonic features and viewed over the last 200 million years, a deep marine Wallacea takes on new meaning. Modern Wallacea must be viewed as a product of fusions as well as fragmentations in the terrestrial realm and of crustal disappearance (consumption) as well as generation of new habitat in the deep marine realm. A geophysical approach to biogeography may help in developing a more effective strategy for sampling deep marine biodiversity in the Indo-West Pacific.

S5.11 HICKS, J.W.; Univ. of California, Irvine; *jhicks@uci.edu*

How to Integrate Cell-Mol Evolution

Understanding the evolution of complex physiological systems remains a major goal in biology. In the 60s and 70s, the evolution of complex organs and organ systems were often based on just so stories, with little, if any, mechanistic understanding of the factors that drove specific evolutionary trajectories. In the 1980s, comparative physiology began incorporating phylogenetic information into analyses of correlated traits. This approach has proven useful and is resulting in stronger inferences about the evolution of physiological, morphological and behavioral traits. However, understanding the mechanistic basis for the evolution of complex systems, for example endothermy or heart-lung interactions, remains elusive. Over the past several decades significant advances in cellular and molecular biology have deepened our understanding of the underlying genetic basis for cell-cell signaling and the cascading events that may determine cell, tissue and organ structure and function. Integration of cellular and molecular tools with comparative phylogenetic approaches will provide useful insights into the mechanistic basis for the evolution of physiological systems.

82.3 HIEBERT, S.M.*; MORSE, M.P.; Swarthmore College, PA, Univ. of Washington, Seattle; *shieber1@swarthmore.edu*

Undergraduate Research: Benefiting Students and Professors

Undergraduate teaching and research are viewed by many faculty as competitors for valuable time. Integrating undergraduate research projects into the laboratory sections of regular courses, as well as into intensive summer research programs, allow faculty to provide outstanding learning opportunities for undergraduates while at the same time benefiting their own research programs. In addition, providing such hands-on opportunities for undergraduates has been shown to increase retention of women and under-represented minorities in the sciences, and to reduce or eliminate performance gaps in the classroom; thus these activities contribute substantially to the broader impacts of a research program and can greatly enhance this aspect of a grant proposal. In this presentation, we describe two models for incorporating independent research by undergraduates into a larger research programa collaborative apprenticeship program held during the summer at a biological research station (Friday Harbor Laboratories) and an independent research project component of a course in Animal Physiology. In both, we stress the aspects of the programs that contribute to success, the ways in which the products of the research accomplished by undergraduates contribute to the overall research effort of the PI, and unique opportunities for low-risk exploration of ideas that these programs afford.

25.1 HIERONYMUS, T.L.*; WITMER, L.M.; Ohio University Department of Biological Science, Ohio University College of Osteopathic Medicine; *th108702@ohiou.edu*

Evolution of Avian Compound Rhamphothecae: Homology of Simple and Compound Horny Beaks in Birds

The topology of separate elements in avian compound rhamphothecae is strongly similar within different clades, not only in external appearance but in how these elements conform to underlying structures. We conducted a morphological survey of 81 extant bird species, and tested superficial similarities between external beak morphology in compound and simple rhamphothecae for substantive similarity in associated skeletal structures and nerve courses. A revised set of morphological characters for compound rhamphothecae was optimized onto three recent phylogenetic hypotheses to assess the relationships of homology and homoplasy in rhamphothecal morphology. Osteological correlates of rhamphothecae from fossil basal ornithurine birds *Hesperornis*, *Parahesperornis*, and *Ichthyornis* show that compound rhamphothecae are the primitive state for living birds (Neornithes). Simple rhamphothecae are the result of the loss of softer keratinous grooves between rhamphothecal components, and there are many examples of transitional forms between compound and simple rhamphothecae in which the grooves remain as shallow depressions without a pronounced edge. Ancestral character state reconstructions of rhamphothecal morphology within Neornithes also show a considerable amount of homoplasy. We suggest that the frequent occurrence of homoplastic characters in rhamphothecal morphology is the result of underlying similarity in facial development.

98.4 HIGHAM, T.E.*; BIEWENER, A.A.; Clemson University, Harvard University; *thigham@clemson.edu*

Fatigue fiddles with fowl function: Altered muscle function during locomotion

For over a century, scientists have been captivated and challenged by the mechanisms and effects of muscle fatigue, which is defined as a reduction in muscle force as a consequence of exercise. Because muscle force is important for executing a behavior with maximum performance, fatigue likely has important implications for fitness. Although much is known about whole-limb force generation and muscle activation patterns in relation to fatigue under controlled conditions, we know little about the effects of whole-body fatigue on the *in vivo* dynamics of limb muscles. Following fatiguing exercise (5-8 min) on an inclined treadmill at 2.0 m/s, we show here that limb kinematics and contractile function in the lateral (LG) and medial (MG) gastrocnemius of helmeted guinea fowl (*Numida meleagris*) are significantly altered during subsequent steady running at 2 m/s on a level treadmill. Stride frequency was significantly lower in the fatigued trials (2.80.04 Hz) compared with the non-fatigued trials (3.10.03 Hz), and this was correlated with a decrease in mean EMG frequency. Related to this was a decrease in the time to peak force for both the LG and MG with fatigue, suggesting selective fatigue of the fast-twitch fibers. Variation in peak force measured directly from the muscles distal tendons increased significantly with fatigue, suggesting that locomotor stability might be compromised. Negative work increased in all muscles and regions with fatigue, revealing the dynamic changes that can occur within muscles during fatigue. Fascicle shortening in the proximal MG, but not the distal MG, decreased significantly with fatigue. This is surprising given that these two synergists are often thought to function uniformly. This work was funded by an NIH grant (R01-AR047679).

85.3 HILL, G. E. *; MCGRAW, K. J.; LIGON, R. A.; Auburn Univ., Auburn, Arizona State Univ., Tempe; *ghill@auburn.edu*

The evolution of carotenoid pigment systems: a biochemical and phylogenetic approach

More elaborate or costly sexually selected traits are commonly thought to evolve from less exaggerated or expensive character states, but rarely can we trace evolutionary patterns of sexual signaling at a mechanistic level to uncover the true trajectories of trait evolution. Carotenoid-based colors in birds offer the unique opportunity to investigate the phylogenetic history of sexual ornaments because we can determine the types of carotenoid molecules that are deposited into the integument. Some species acquire their bright plumage using basic dietary carotenoids while others deposit more costly, metabolically derived pigments in feathers. We used published phylogenies and data on the carotenoid content of feathers to examine the evolution of pigment systems across a genus-level phylogeny of cardueline finches and a family-level phylogeny of oscine passerines. Outgroup and basal members for both cardueline finches and a subgroup of oscine passerines used only dietary carotenoids to color their feathers yellow; metabolically derived yellow and red feather colorants appeared later in more derived taxa. These results demonstrate a pattern of directional color evolution and provide biochemical support for the prediction that more costly animal signals evolve from those that are comparatively easier to develop.

37.2 HINTERWIRTH, A.J.*; DANIEL, T.L.; University of Washington; *ahinterw@u.washington.edu*

Antennae mediate an abdominal flexion response to body rotations in the hawkmoth Manduca sexta

The crepuscular moth *Manduca sexta* does not rely on vision alone for flight control. It uses mechanosensory information from its antennae to mediate rapid responses to aerodynamic disturbances (Sane et al. 2007). Specifically, antennae may act as vibrational gyroscopes detecting Coriolis forces that occur when a moth undergoes rotational motion. However, there are no data that clearly show moths respond to pure rotational motion stimuli in absence of any other inputs, such as visual or wind stimuli. To address the role of antennae as sensors of body rotations, we developed an experimental setup that allows us to investigate the respective influences of the visual and rotational mechanosensory systems. We tether a moth in an LED visual arena that can be mechanically rotated (after Sherman & Dickinson, 2003). Visual or mechanical rotations can thereby be presented independently, or in any arbitrary phase with respect to each other. At the same time, we monitor two behavioral responses: abdominal flexion and wing trajectory. Our results show that antennae mediate abdominal flexion as a response to pure mechanical rotations. The angle of flexion increases when the rotational velocity is increased (up to 250 deg/s). Moreover, removing the antennal flagellum diminishes the response significantly, in many cases completely (Mean reduction to ~18% of control groups gain, N=14 animals). The abdominal response, however, can be rescued by gluing back a flagellum on each antennal base, as long as mechanoreceptors on the scape and pedicel are left intact. (Rescue to ca. 70% of the control groups gain in 7 of 8 animals in which antennal re-attachment was performed.) These results thus provide strong evidence for the antennal gyroscope hypothesis.

46.5 HITT, Lauren R*; TOMANEK, Lars; California Polytechnic State University, San Luis Obispo; *lhitt@calpoly.edu*

Proteomic response of the Pacific oyster, Crassostrea gigas, to nitrate and salinity fluctuations

Pacific oysters, *Crassostrea gigas*, are commonly grown in California estuaries where they experience great fluctuations in nitrate and salinity. Nitrate enters the marine environment through freshwater run-off during heavy winter rains, often from agricultural areas and sewage effluent, and therefore it is important to study the response of oysters to hyposaline conditions. To investigate the global changes in protein expression that accompany nitrate and salinity stress in *C. gigas*, we applied a proteomics approach using two-dimensional gel electrophoresis and mass spectrometry. Gill tissues were exposed to a range of nitrate levels (0 mg/L, 5 mg/L, 25mg/L, 50mg/L and 100mg/L NaNO3) for six hours. Subsequently tissues were homogenized to prepare proteins for separation according to their isoelectric point (pI) and molecular mass using two-dimensional gel electrophoresis. The analysis yielded twenty-two proteins that changed expression when compared to the control (p-value< 0.05). We also exposed gill tissues to changing levels of salinity (100%, 90%, 80% and 70% filtered seawater) for 6 hours and analyzed their protein expression. We found a total of eighteen proteins that were significantly (p-value< 0.05) different. The proteins of interest were excised and digested with trypsin. A matrix-assisted laser desorption ionization (MALDI) tandem time-of-flight mass spectrometer was used to produce peptide fingerprints for each protein. Preliminary results show that several stress proteins are up-regulated with nitrate exposure. Other proteins are currently being analyzed to establish their identity in order to describe the physiological response of oysters to nitrate and hyposaline conditions.

S2.2 HO, J.-S.; California State Univ., Long Beach; *jsho@csulb.edu*
The five wonders of the parasitic Copepoda
Although Copepoda is not the largest group of Crustacea, it embraces the highest number of symbiotic forms among Crustacea. They live on/in every major group of organisms found in the aquatic environment. Judging from the high degree of morphological modification of the oldest known fossil of Copepoda, *Kabatarina pattersoni* Cressey & Boxshall, a parasite found on the gills of a fossil teleost fish, *Cldocycls gardneri* Agassiz, preserved in calcareous nodules of Lower Cretaceous in Brazil, copepods must have lived in close association with aquatic animals for long, long time; perhaps, long before the Age of Dinosaurs. With such long history of association, symbiotic copepods today exhibit certain unusual traits in their way of living. While many traits are rarely seen in their free-living peers, some traits are so unusual that they are not even known in other metazoans like them leading a parasitic mode of life. To illustrate such unusual traits, the following five wonders are selected for discussion: 1) occurrence in mesoparasitism, 2) development of an enigmatic attachment organ and switching appendages, 3) specificity in microhabitat, 4) mysterious sexuality with two types of male, and 5) ignorance of host's immune recognition and attack.

36.9 HOBBS, N.J.*; AVEN, A.M.; FERKIN, M. H.; University of Memphis; *nhobbs@memphis.edu*
Self-grooming response of meadow voles to the odor of opposite-sex conspecifics in relation to the dietary protein content of both sexes
Many animals self-groom when they encounter the scent marks of opposite-sex conspecifics. Self-grooming transmits odiferous substances that contain information about the groomers condition, which is affected by its nutritional state. We tested the hypothesis that the amount of time that individuals self-groom to opposite-sex conspecifics is affected by the amount of protein in their diet and that of the scent donor. We did so by feeding meadow voles (*Microtus pennsylvanicus*) a diet containing 9%, 13%, or 22% dietary protein for 30 days and observing their self-grooming behavior when they were exposed to bedding scented by an opposite-sex conspecific (odor donor) fed one of the three diets, or fresh cotton bedding (control). The hypothesis was partially supported. We found that the protein content of the diet of male and female groomers did not affect the amount of time they self-groomed. However, the protein content of the diet of male odor donors affected the amount of time that female voles spent self-grooming. Female voles self-groomed more in response to male odor donors fed a 22% protein-content diet than to those produced by male odor donors fed either a 9% or a 13% protein-content diet. Interestingly, the amount of time males self-groomed was not affected by the protein content of the diet of the female odor donor. These results may, in part, be explained by the natural history of free-living meadow voles, sex differences in costs associated with mate attraction and reproduction, and the direct or indirect benefits that females receive from males fed a diet high in protein content.

95.4 HOCH, JM; Stony Brook University; *jmatthoch@gmail.com*
Sex allocation and reproductive success in simultaneously hermaphroditic acorn barnacles
Semibalanus balanoides is a simultaneously hermaphroditic acorn barnacle that mates with its neighbors using a long, agile penis. Sex allocation theory (Charnov 1980, 1982) predicts that simultaneous hermaphrodites maximize total reproductive success by increasing allocation to the male role towards an asymptote at 50% as competition (between functional males) for eggs increases. Acorn barnacles present an ideal system testing this theory, because they are sessile and therefore limited to mates within reach of their penises. Offspring are easily collected, as they are brooded for several weeks after mating. I created experimental groups of barnacles with small or large numbers of potential mates. I allowed these to grow and develop egg-masses and testes specific to their mating group size. Before the brief period of mating activity (in the fall), I reciprocally transplanted individual barnacles from large groups to small groups (and vice versa). At the same time, I retrieved un-mated barnacles from similarly sized groups to measure allocation to male and female function. After the mating activity had ceased, I collected all of the experimental mating groups and measured total reproductive output for the focal individuals. I calculated fitness gained as a female by counting the larvae in each focal individuals brood. I calculated fitness gained as a male by genotyping several highly variable microsatellite loci for a subset of each neighbors brooded larvae and comparing those to potential parents. This allows a comparison of total reproductive fitness of experimentally transplanted barnacles (mating in groups for which they have not strategically allocated energy to the sex roles) with un-transplanted control barnacles. This experiment provides a critical test of sex allocation theory and demonstrates the dynamics of mate competition for sessile, copulating simultaneous hermaphrodites.

58.1 HOEKSTRA, L.A.*; MOROZ, L.L.; HEYLAND, A.; Friday Harbor Labs; Indiana University , Friday Harbor Labs; The Whitney Laboratory for Marine Bioscience, University of Florida, Friday Harbor Labs; University of Guelph; *lhoekstr@indiana.edu*
A new perspective on the echinoderm nervous system: abundant histaminergic and FMRFaminergic-like cells in the sea cucumber Leptosynapta clarki
Understanding of the echinoderm nervous system remains elusive. The semi-transparent, brooding sea cucumber *Leptosynapta clarki* provides a new opportunity for detailed description of echinoderm nervous system structure and function. Clear evidence for histaminergic and FMRFaminergic-like immunoreactivity is reported in several distinct cell types distributed throughout the holothurian body. Surprisingly, no significant evidence could be found to support a role for serotonin. Additionally, pharmacological tests show a strong, directed peristaltic response to the application of histamine. Together these data indicate a lack of any discrete subdivision of the echinoderm nervous system and suggest a function for histamine in this nervous system. Future research will focus on further describing the functional role of histamine and on understanding the molecular regulatory machinery underlying the histaminergic system.

35.4 HOFMANN, C.M.*; SEEHAUSEN, O.; CARLETON, K.L.; University of Maryland; *chofma1@umd.edu*

Light environment limits gene expression in rapidly evolving cichlid radiations

Sensory adaptation to the light environment has been repeatedly demonstrated in opsin genes. However, recent work suggests that changes in gene expression may also play a large part in tuning visual sensitivity. Cichlids have seven different cone opsin genes, with different species expressing different subsets of opsins, making them an ideal system for investigating adaptive gene expression. We examined how gene expression differed in two independent cichlid radiations that differ in their global light environment. Lake Malawi has some of the clearest water on the planet, which results in a relatively blue-green light environment, while shallower Lake Victoria has more turbid water, and thus a red-shifted light environment. We found large differences in the sets of opsins that cichlids in these two lakes expressed. Two opsins, the UV and the RH2B (blue green), were not expressed in any of the Lake Victoria species we examined and all Lake Victoria cichlids expressed LWS opsin. Thus, Lake Victoria cichlids only express a longer-wavelength shifted subset of the opsins that are expressed in Lake Malawi. Furthermore, we examined species with a variety of life histories and foraging modes, suggesting that the light environment may override other ecological factors, such as foraging mode in rapidly evolving radiations.

S8.10 HOFMANN, HA; Univ. of Texas, Austin; *hans@mail.utexas.edu*

Evolution of Cichlid Mating Systems: How Social Behavior Sculpts Brains and Genomes

Complex brains and behaviors have arisen repeatedly in vertebrate evolution. What adaptive pressures drive such changes? And what are the molecular and physiological mechanisms that underlie these behaviors constraining or facilitating evolution? East African cichlid fishes provide a superb opportunity to analyze the social and ecological correlates of neural phenotypes and their evolution. As a result of rapid, recent, and repeated radiations, there are hundreds of closely-related species available for study, with an astonishing diversity in habitat preferences, social behaviors and brain structures. We use the (monophyletic) Ectodini clade of Lake Tanganyika as our model system, where according to our phylogenetic analyses at least four independent transitions from polygamous to monogamous mating systems have occurred within the past 1.5 million years. I will present ecological, neuroanatomical and genomic results that show how (i) environmental and social factors differentially affect the brain; (ii) arginine vasotocin regulates pairbond formation in cichlids in a way similar to rodents, thus implying a shared mechanism for social affiliation across 400 million years of vertebrate evolution; and (iii) similar as well as novel gene sets have been recruited during these independent transitions towards implementing monogamous phenotypes. These studies provide important insights into the molecular and physiological underpinnings of social behavior and its evolution.

51.5 HOLZMAN, Roi*; WAINWRIGHT, Peter; Univ. of California, Davis; *raholzman@ucdavis.edu*

Tuned to the right signal: Suction feeding interactions with bow wave increase detection distance of fish by aquatic prey

Predation on zooplankton by fish is a major trophic pathway in aquatic communities, and this predator-prey interaction represents a challenging encounter for both prey and predator. To capture the prey by suction feeding, a fish must get sufficiently close to the prey, rapidly open its mouth and expand its buccal cavity to draw the water and the prey towards it. Both the swimming towards the prey and the suction flows create a hydrodynamic disturbance, which can elicit an escape response by the prey. However the hydrodynamic disturbance generated by suction feeding fishes was previously assumed to result exclusively from the bow wave produced by the swimming fish. Using Particle Image Velocimetry (PIV) we directly measured flow speeds and strain rate at the location of the prey through the fish's approach, and compared those measurements to the flow speeds and strain rates that are due to swimming alone, as measured at an upstream point. At the prey, water was first pushed away from the fish due to the bow wave but later flow speed reversed due to suction, while at the upstream point water was only pushed away from the fish. The velocity magnitude of flow was similar between the two sampling points. However, strain rate, a measure of fluid deformation that is a proxy for copepod escape responses, was 3 times higher at the location of the prey due to the opposing forces of the bow wave and suction flow. By inference, the distance at which an escape response of a copepod is initiated was ~30% longer at the prey, due to the interaction of the bow wave and suction flows. Sensory tuning to strain rate, rater than velocity magnitude, seems to be an important adaptation to fish avoidance in zooplankton.

3.2 HOOD, Wendy R*; BOOHER, Christina M; Auburn University; *wrhood@auburn.edu*

Mineral dynamics during reproduction in insectivorous bats: skeletal integrity is favored over increased reproductive output

Mammalian mothers supply most to all of the minerals necessary to support the development and ossification of their offsprings skeleton(s) from conception until weaning. Mother support this demand by partitioning dietary minerals and minerals mobilized from their own skeleton to growing offspring; if mineral availability is low offspring number and growth may be reduced. It has been suggested that the low calcium content of an insectivorous bats diet limits reproductive output to one or two young per reproductive bout. However, skeletal mineral dynamics and response to available calcium have not been adequately considered. With this presentation, we will review data on changes in maternal whole body and bone mineral content, examine changes in the 3-dimensional architecture of maternal bone, and describe the effects of calcium supplementation on reproductive output. We suggest that mothers are accumulating necessary mineral prior to demand. Although mineral is mobilized during lactation, maternal mineral reserves do not appear to drop below non-reproductive levels, as is observed in other mammals. We also show that mothers consuming supplemental calcium produce litters comparable in size and mineral content to mothers consuming a low amount of calcium equivalent to the calcium intake of free-ranging bats. The cumulative results of these studies suggest that adult female insectivorous bats are adapted to protect the structural integrity of the skeleton and efficiently utilize minimal calcium intake during reproduction, but are unable to increase reproductive output when dietary calcium is plentiful.

98.2 HORNER, AM*; RUSS, DW; BIKNEVICIUS, AR; Ohio Univ., Athens, OH, Ohio Univ. School of Physical Therapy, Athens, OH, Ohio Univ. College of Osteopathic Medicine, Athens, OH; *ah312505@ohio.edu*

Effects of aging on locomotor dynamics and hindlimb muscle force production in the rat

Attenuation of locomotor function is common in many species of animals as they age. Examples of age-related locomotor impairments include increased joint stiffness, decreased ability to repair muscle tissue, and decreasing fine motor control capabilities. These factors may contribute to gait abnormalities and substantially limit an animals maximum speed. Consequently, the effect of aging on locomotion has important implications for survivorship in numerous animal taxa. In this study we examined age-related changes in locomotion and muscle mechanics in young (~6 months) and old (~24 months) rats (*Rattus norvegicus*, Fischer Brown-Norway 344 crosses). Analyses of gaits and kinematics revealed that older rats moved significantly slower, had longer support durations at comparable Froude numbers, performed fewer symmetric gaits, and moved with greater spinal flexion at all phases within a stride. Additionally, aged rats did not tend to move exclusively with either pendular mechanics or spring-mass mechanics as was found in the young rats; rather, the external mechanical energy profiles of the older animals were extremely variable and mostly within the domain of intermediate mechanics. In situ analyses of the plantarflexor muscles (soleus, plantaris, medial and lateral gastrocnemius) demonstrated similar reduced maximum force generation in old vs. young muscles, despite comparable muscle masses and force-frequency characteristics. These force deficits were shown to be more extreme when normalized to body weight.

2.6 HORROCKS, N.*; HINE, K.; MATSON, K.D.; TIELEMAN, B.I.; University of Groningen, The Netherlands; *n.p.c.horrocks@rug.nl*

Antibacterial proteins in eggs as a marker of disease risk in different environments

Bird eggs contain several antibacterial proteins that likely help protect developing embryos from microbial infections. These proteins, which are located predominantly in the albumen, may be particularly important in protecting eggs from infection in microbe-rich environments or under other conditions favourable to bacterial penetration of the shell and membranes. Ovotransferrin, lysozyme and avidin are three such proteins that can be measured using simple assays. Together these proteins constitute nearly 20% of the total protein composition of chicken albumen, and have been shown to be present in the albumen of other avian eggs too. The degree to which their concentrations vary, and how this may reflect broader differences in life history and disease pressure remains unclear however. To investigate these relationships, we collected eggs from 7 species of larks (*Alaudidae*) living in very dissimilar habitats (Saudi Arabian desert, high altitude Afghanistan, lowland temperate Netherlands). Larks are ground-nesting passerines with open-cup nests and their eggs are potentially exposed to a wide variety of microbes from both the soil and the air. We measured levels of ovotransferrin, lysozyme and avidin in the albumen of these eggs and compared values across species and environments. Here we present our findings and discuss how the quantification of egg antibacterial proteins relates to our broader goal of understanding how the disease risks in different environments shapes the evolution of physiological systems.

84.5 HU, Zheng; DENG, Xinyan*; University of Delaware; *deng@udel.edu*

Aerodynamic Effect of Forewing-Hindwing Interactions in Hovering and Forward Flight of Dragonfly

Dragonflies move each wing independently and therefore may alter the phase differencebetween the forewing and hindwing stroke cycles. They are observed to change the phase difference for different flight modes. We investigated the aerodynamic effect of phase difference during hovering and forward flight with a 60 inclined stroke plane by using a pair of dynamically scaled robotic dragonfly model wings. Aerodynamic forces were measured while phase difference was systematically varied. The results showed that, i) for hovering flight, 0 phase difference enhanced the lift force on both forewing and hindwing; 180 was detrimental for lift generation, but was beneficial for vibration suppression and body stabilization. This result may help understand the dragonfly behavior that 0 was used in acceleration mode while 180 was used in hovering mode. ii) For forward flight, wing-wing interaction was always beneficial for forewing lift while detrimental for hindwing lift; the total lift was only slightly reduced with 0~90 phase difference and significantly decreased by 38% with 270 phase difference. This result may explain why dragonflies employ 50~100 during forward flight, while 270 is never favored. Thrust force was also reduced by wing-wing interaction to some extent. We experimentally investigated the wing-wing interaction mechanism and measured two types of interaction flow: sharp upwash and mild flow. The former was caused by the leading edge vortex (LEV) of hindwing and resulted in lift enhancement on the forewing, while the latter is a kind of local flow interaction which resulted in either an upwash or downwash.

62.1 HUANG, Ying*; HADFIELD, Michael G; Univ. of Hawaii at Manoa; *yinghuan@hawaii.edu*

Identifying genes from a marine bacterium that are involved in metamorphic induction of the tube worm Hydroides elegans

The marine tube worm *Hydroides elegans* provides an excellent model for laboratory studies of invertebrate metamorphosis. Competent larvae of *H. elegans* are induced to settle and metamorphose by single- or multiple-species bacterial biofilms. A marine bacterium, *Pseudoalteromonas luteoviolacea*, isolated from a seawater-aquarium biofilm in our lab, has been shown to strongly induce settlement of competent larvae of *H. elegans*. However, the factors in bacterial biofilms that induce settlement and metamorphosis of these larvae are unknown. To determine the nature of these factors, transposon mutagenesis was applied to *P. luteoviolacea* to identify genes that are involved in inducing metamorphosis of *H. elegans*. Using a mini transposon, Tn10, a piece of foreign DNA was randomly inserted into the chromosome of *P. luteoviolacea* to create a mutant library. This insertion was expected to disrupt the function of genes into which it is incorporated. Two strains which are deficient in their inductive ability were isolated from the mutant library. By sequencing genes flanking the transposon, two genes whose expression is necessary to metamorphic induction of *H. elegans* were isolated and partially sequenced (on going). Recombined mutants, prepared for both gene loci, lost their inductive capacity for larvae of *H. elegans*, strongly suggesting that both of the isolated genes are essential for metamorphic induction. Understanding the structures and products of these two genes will help us to understand the mechanisms by which biofilms influence settlement and metamorphosis of marine invertebrate larvae.

70.5 HUBEL, Tatjana*; BREUER, Kenneth; SWARTZ, Sharon; Brown University; *tatjana_hubel@brown.edu*

Individual variability in the aerodynamics and kinematics of bat flight

Many studies on the aerodynamics of flight in birds and bats use relatively few individuals. However, previous work in our lab has shown that the kinematics of flight can vary significantly from individual to individual within a species. In this study, we sought to determine the degree to which differences in kinematics were reflected by the wake patterns generated during flight. We made measurements of bat flight in a wind tunnel using four high-speed cameras (200 Hz) and time-resolved PIV (200 Hz) perpendicular to the flow stream, behind the bat. Five Lesser dog-faced fruit bats (*Cynopterus brachyotis*) were trained to fly in the wind tunnel at speeds of three to seven ms-1. Several landmarks on the body, wing bones, and wing membrane were marked to allow high fidelity 3D reconstruction of wing kinematics. Each PIV acquisition sequence was correlated to the kinematics, accounting for the varying distance between the PIV laser light sheet and the bat wing, and correcting for the acceleration of the bat with respect to the wind tunnel. Our PIV recordings show the development of the tip vortex and circulation over the course of each wing beat cycle. The variability in position of the bat (maneuvering), and in the kinematics of the bat from wingbeat cycle to wingbeat cycle were substantial and this is reflected in the resulting wake signature measured using PIV.

S6.6 HUFFMAN, MA; Kyoto University, Primate Research Institute, Inuyama; *huffman@pri.kyoto-u.ac.jp*

Primate Self-Medication

Plant secondary metabolites (PSM) are traditionally viewed as the means by which plants inhibit or limit damage done to them by herbivores. This stimulated research into how animals are sometimes able to detoxify PSM in order to utilize the plants nutritional properties. Some herbivorous species also exploit PSM for their curative value, as humans traditionally do around the world. A growing body of research shows that primates ingest PSM for positive benefits, in particular for their therapeutic and passive preventative properties. A growing body of evidence for this comes from the emerging field of animal self-medication, particularly from the study of primates. Self-medication primarily take on three forms, ingestion of plants for their structural barriers to digestion (e.g. silicate) or bioactive / toxic properties and / or external application of PSMs. African great apes, and chimpanzees in particular, practice the first two forms in response to parasite infections. A substantial number of such plant species have been recorded and are also known to be traditionally utilized by some African cultures for the treatment of similar symptoms / diseases. New PSM have also been discovered which may have potential use for humans. Thirteen novel compounds and their biological activities have been discovered from the investigation of one species alone; Vernonia amygdalina. Other examples exist. Traditionally humans around the world have looked to animals as a source of medicinal wisdom. In this way too, PharmEcology has much to benefit from the study of animal self-medication.

1.5 HUGHEY, M.C.*; ROGGE, J.R.; WARKENTIN, K.M.; Boston University, Boston; *mchughey@bu.edu*

Deciding when to hatch: Predator and embryo cues in wasp-induced hatching of red-eyed treefrogs

Predator-induced hatching allows embryos to avoid predation, but to be effective embryos must accurately assess and respond to threats. Red-eyed treefrog (*Agalychnis callidryas*) embryos face many natural enemies, including wasps (*Polybia rejecta*). Embryos can hatch up to 30% early in response to wasp attack, even without direct contact with wasps. Embryos are unresponsive to wasp vibrations alone; they may use other cues from wasps or cues from neighboring embryos to inform hatching. We assessed cues used by embryos when deciding to hatch during wasp attacks. We videotaped wasp attacks that induced hatching at a feeding station where wasps were trained to forage. From the videos, we identified the first and last five embryos to hatch from a clutch and characterized their experiences during the time period when the first five embryos were hatching (N = 103 focal embryos). We quantified behavior of focal embryos, neighboring and more distant embryos, and wasps. We compared experiences of focal embryos that hatched 1) during the sampled period vs. later, 2) with vs. without direct wasp attack, and 3) early, but without direct attack, vs. later. We also assessed which wasp and embryo behaviors best predicted hatching. Embryos that hatched experienced substantial wasp activity on or near them, while for later-hatching embryos wasp activity was mostly farther away. Both focal hatching embryos and their close neighbors were more active than later-hatching embryos and neighbors. Embryos that hatched without direct wasp contact nonetheless experienced high amounts of wasp activity nearby. Red-eyed treefrog embryos thus assess risk on a fine spatial scale in wasp attacks and appear to use cues from both wasps and other embryos when deciding to hatch.

S8.1 HULSEY, CD; Univ. of Tennessee; *chulsey@utk.edu*

Cichlid Genomics and Phenotypic Diversity in a Comparative Context

The genome of your favorite organism will soon be fully sequenced. What are you going to do with it? With the complete sequencing of several cichlid fish genomes, we will know the genetic blueprints used to build the incredible evolutionary diversity of this textbook adaptive radiation. In my introductory talk, I will broadly compare species number, trophic habits, coloration, and mating behaviors in cichlids and other diverse vertebrate groups. The repeated phenotypic convergence in cichlid fishes, that makes this group so exceptional for comparative analyses of genetics and development, will be highlighted. Our symposium will outline how researchers studying cichlids and other model vertebrate organisms are working to understand how genomes are translated into adaptive phenotypic diversity

8.6 HUMPHRIES, S; University of Sheffield, UK;
s.humphries@sheffield.ac.uk

Filter feeders and plankton increase particle encounter rates through flow regime control

Collisions between particles or between particles and other objects are fundamental to many processes that we take for granted. They drive the functioning of aquatic ecosystems, the onset of rain and snow precipitation, and the manufacture of pharmaceuticals, powders and crystals. Here I show that the traditional assumption that viscosity dominates these situations leads to consistent and large-scale underestimation of encounter rates between particles and of deposition rates on surfaces. The new theory provides a good match to empirical data and has great implications for our understanding of selection pressure on the physiology and ecology of organisms; for example filter feeders that are able to gather food at much greater rates than previously estimated. I provide evidence that filter-feeders have been strongly selected to take advantage of this flow regime and show that the predicted dynamics of plankton blooms are dramatically changed with the incorporation of the new theory.

54.5 HUNT VON HERBING, I*; CASHON, ; BABCOCK, ; University of North Texas, University of Maine, Dahl-Chase Diagnostics; *vonherbing@unt.edu*

Hemoglobin Polymerization in Fishes: A Physiological Antioxidant?

Observations of teleost red blood cells have shown that regular paracrystalline arrays of polymerized hemoglobin (Hb) tetramers form under low oxygen and low pH conditions in several species, including Atlantic cod (Gadus morhua) and Atlantic Toadfish (Opsanus tau). The phenomenon of Hb polymerization is also termed hemoglobin gelation and/or sickling, and its physiological characteristics, importance to physiology, and survival is presently unknown. In this study, data were obtained on the frequency and physiological nature of Hb gelation in fishes that inhabit several different environments from the Arctic, boreal and tropical regions. Thirty-three fish species were examined for the occurrence of gelation and only 13 exhibited the trait. Further, in these 13 species, 100% of the red blood cells became crystallized when exposed to hypoxia and/or low pH. Evidence for the formation and presence of the paracrystalline Hb matrix in whole red blood cells was provided by light microscopy, transmission electron microscopy and was supported by in situ observations. Data provided by purification and subsequent polymerization of the Hb extracted from whole blood showed that gelation is an intrinsic property of the Hb, not dependent on the surrounding intracellular matrix, likely occurs in conditions that are found in vivo, and may occur in fishes found in several environments. Proposed models of Atlantic cod Hb constructed by homology modeling of the primary Hb sequence found that at least three amino acid substitutions have occurred in the Hb beta chains. Two of these substitutions result in extra cysteines that may induce polymerization by forming interchain disulphide bonds. These disulphide bonds may serve an antioxidant role in the protection against Reactive Oxygen Species (ROS), often produced during aerobic metabolism in environments characterized by fluctuating oxygen and pH conditions.

11.3 HUNTER, Rebecca L*; HALANYCH, Kenneth M; Auburn University;
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Contrasting phylogeographic patterns among three Antarctic brittle star species

Antarctica and its surrounding waters are isolated environments typically characterized as stable over ecological time scales, but physically and geologically dynamic over evolutionary time scales. This region has been isolated for approximately 40 million years, due largely to the Antarctic Circumpolar Current (ACC) and Antarctic Polar Front (APF) that flow uninterrupted around the continent. The structure of marine populations inhabiting the Antarctic continental shelf has been influenced by the ACC and APF as well as smaller gyres and eddies. Additionally, Pleistocene glacial cycles likely played a significant role in shaping marine populations, especially of marine invertebrates. Many Antarctic marine invertebrates have circumpolar distributions, however, levels of connectivity between circumpolar populations are largely unknown for most groups. Another factor contributing to population structure is mode of development, which for marine invertebrates includes brooding, where a dispersive larval stage is lacking, lecithotrophy, which involves a non-feeding larval stage, and planktotrophy, where a feeding larvae is present. In an attempt to evaluate the relative contributions of oceanographic features, Pleistocene glacial cycles and life history constraints on resulting population structure of Antarctic marine invertebrates, three species of brittle stars with contrasting life histories were compared. Mitochondrial sequence data was used to determine levels of genetic connectivity throughout a portion of the Antarctic benthos where the ranges of these three species overlap, the Antarctic Peninsula. Preliminary data analyzed using statistical parsimony suggest that life history mode may not predict population structure among some brittle star species. Further analyses will attempt to elucidate which factors have been most influential in shaping the Antarctic benthos.

S3.1 HUSAK, J. F.*; IRSCHICK, D. J.; Virginia Tech, U Mass at Amherst;
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Hormones as mediators of animal performance

While recent studies have begun to address how hormones mediate whole-animal performance traits, the field conspicuously lags behind research conducted on humans. We define whole-animal performance to place it into an ecologically relevant context for non-human animals and explain its evolutionary significance. We also discuss how the pleiotropic nature of hormone actions can create tradeoffs among performance traits, ultimately affecting evolutionary trajectories. We then review studies of hormonal regulation of human performance, emphasizing major findings that will help direct future research efforts on non-human animals. Specifically, we discuss hormonal effects on human muscle physiology as well as the effect of training on hormone-performance relationships in experimental studies.

47.4 HUYGHE, K.*; HUSAK, J.F.; VANHOOYDONCK, B.; HERREL, A.; MOORE, I.T.; VAN DAMME, R.; University of Antwerp, Belgium, Virginia Tech University, Harvard University; *katleen.huyghe@ua.ac.be*

Testosterone and performance in a population of color polymorphic lizards

Through their direct action on behavior or through their influence on morphology and performance, circulating testosterone levels can be mediators of aggressive displays and interactions. We tested these ideas in a population of lizards, which exhibits a distinct and striking color polymorphism. Males occur in 3 different colors (white, yellow, orange), providing an opportunity to test the idea that morphs are alternative solutions to the evolutionary challenges posed on the link between hormones, morphology, performance, and behavior. Our results show that morphs differ in size, and bite force capacity, but do not differ in locomotor performance. Here, we provide data to test the hypothesis that these differences are related to differences in steroid hormone levels between morphs, suggesting a balance between different fitness effects. Secondly, we test for the presence of a correlation between testosterone and different performance traits, as organismal performance can be expected to be important in mediating the outcome of aggressive male-male interactions and may play a role in female choice.

S2.9 HUYS, R*; LLEWELLYN-HUGHES, J; British Museum; *r.huys@nhm.ac.uk*

What can 18S rDNA do for copepod phylogeny and classification?

No group of plants or animals on Earth exhibits the range of morphological diversity as seen among the extant Crustacea. This is best demonstrated by the Copepoda, which by virtue of their immense vertical distribution are also arguably the most abundant metazoans. Their current position of world predominance can be attributed to two principal, recurrent, radiation events, i.e. their major habitat shift into the marine plankton, and the evolution of parasitism. Given their moderately high host specificity in conjunction with the incredible spectrum of potential marine hosts, it is highly conceivable that parasitic copepods significantly outnumber their free-living counterparts in species diversity. Their successful colonization or utilization of virtually every metazoan phylum has generated a great diversity in copepod body morphology, which is arguably unparalleled among the Crustacea. Families such as the Monstrillidae and Thaumatopsyllidae demonstrate how extremely powerful natural selection can be in shaping morphology to meet functional needs so that distantly related taxa may appear uncannily similar. Here I will show how small subunit ribosomal sequence data (18S rDNA) can help resolving controversial issues that had reached a temporary impasse in the phylogeny and classification of the symbiotic copepods, such as the placement of the Thaumatopsyllidae, the paraphyly of the Cyclopoida and the origin of parasitism in freshwater. I will demonstrate how the use of such data can lead to the discovery of previously overlooked morphological characters and how they impact on the ordinal level classification of the Copepoda.

97.10 HYNDMAN, K/A*; EDWARDS, S/L; KRATOCHVILOVA, H; CLAIBOREN, J/B; EVANS, D/H; Medical College of Georgia, Vascular Biology Center, Augusta GA, Appalachian State University, Boone NC, Georgia Southern University, Statesboro GA, Georgia Southern University, Statesboro GA, University of Florida, Gainesville FL ; *khyndman@ufl.edu*

The effect of short-term, low-salinity acclimation on gill NHE, AE1 and HAT expression in the longhorn sculpin, Myoxocephalus octodecemspinosus,.

We previously reported that the marine, longhorn sculpin, *Myoxocephalus octodecemspinosus*, can acclimate to 20% SW for days with no change in plasma osmolality, ion concentrations, or hematocrit level. Sculpin, however, lose ions during acclimation to 10% SW for 24 and 72 h and this reaches a lethal level after 6 days. During these acclimations, the sculpin is incapable of down-regulating gill NKCC or CFTR, suggesting that they cannot turn off their gill ion secreting mechanisms. The counterpart to this is whether they can upregulate the transporters necessary for ion uptake during acclimation to low salinity water, such as the Na+/H+ exchangers (NHE), anion exchanger 1 (AE1) or H+-ATPase (HAT), and thus maintain proper ion and water balance. We determined that sculpin upregulate gill NHE3 mRNA and NHE2c, while significantly down regulating AE1 during acclimation to 20% SW, and have undetectable levels of NHE2b during acclimation to 10% SW. There were no significant changes in HAT or NHE8. These transporters were immunolocalized in the sculpin gill, and we determined that during acclimation to 10 or 20% SW they are distributed in different aspects of the ion transporting cells of the gill. Thus, we conclude that longhorn sculpin are incapable of properly regulating gill ion transporters; thus, this is a physiological barrier from living in low-salinity (below 10% SW) or fresh water.

25.6 IDE, Celine*; DE SCHEPPER, Natalie; DUMONT, Betsy; HERREL, Anthony; ADRIAENS, Dominique; Ghent University; *celine.ide@ugent.be*

Divergent head shape variation in European eel: how well does skeletal morphology reflect functional demands?

The existence of naturally occurring narrow- and broad-headed individuals within the European eel (*Anguilla anguilla*) populations is since long known. Previous studies demonstrated sexual differences in growth, with females growing faster than males, but which is irrespective of the observed difference in head shape. The apparent divergent head shapes have been related to differences in the diet, where broad-headed eels would feed on bigger and harder prey items. Although some research has been focusing on this dimorphism, very little is still known about how and when this dimorphism arises and what parts of the body plan are involved. What has already been observed is that broad-headed types have larger jaw muscles than narrow-headed ones, where modeling of bite-force suggested higher bite force in broad-headed once. Whether differences observed between the two morphotypes at the skeletal level is a reflection of dealing with differences in mechanical stress during prey manipulation still remains unclear. Using Finite Element Analysis we thus wanted to see to what degree differences in skull morphology between narrow- and a broad-headed eels have an effect on stress distribution when a force is being applied. With this analysis we wanted to find out if the skull architecture in broad-headed eels allows dealing with higher biting forces, and hence is more resistant to mechanical loading force when feeding on harder prey items.

6.6 IDJADI, Joshua*; KARLSON, Ronald; New England Aquarium, University of Delaware; *jidjadi@neaq.org*

Spatial aggregation promotes species coexistence among corals: Evidence from experiments and modeling

Scleractinian coral species with varying competitive abilities often occur in communities where shared resources are limited. Despite this, these communities can be very diverse, without dominance by the best competitors. We experimentally tested the role of spatial heterogeneity, specifically the spatial arrangement of competitors, in promoting species coexistence among corals. Using a strong competitor (*Porites rus*) and a weaker one (*P. lobata*) we addressed the hypothesis that when corals are intraspecifically aggregated, coexistence is increased. When these corals were placed into artificial competitive neighborhoods, weaker competitors grew at almost twice the rate when they were grown in aggregated versus non-aggregated patterns. Further experimental work suggested that aggregation is most important when there is no refuge from competition for weaker competitors. The results of these experiments were extrapolated to larger spatial and temporal scales by a cellular automata model. The persistence of weaker competitors was increased substantially when the beneficial effect of aggregation was applied to this model system. This research adds to evidence from other work in plant systems that spatial arrangement can promote species coexistence in competitive, resource limited communities.

70.3 IRIARTE-DIAZ, J*; RISKIN, D. K.; SWARTZ, S. M.; Brown University; *jiriarte@uchicago.edu*

No net thrust on the upstroke: the effect of wing inertia on body accelerations of fruit bats during flight

During slow flight, some bats species produce a tip-reversal upstroke, where the distal portion of the wing is moved upward and backward with respect to still air. Tip-reversal upstroke has been widely hypothesized to produce thrust during upstroke, based on the observation that a bat accelerates its torso forward during upstroke in low speed flights. This forward acceleration, however, could be produced by inertial forces generated by the backward flapping motion of the wings at that part of the wingbeat cycle, rather than acceleration of the center of mass (CoM) resulting from the interaction of the wings with the airflow. To investigate the instantaneous aerodynamic force production during the upstroke and downstroke portions of the wingbeat cycle, we developed a model of the mass distribution of the wing and body of the lesser dog-faced fruit bat, *Cynopterus brachyotis* during flight at speeds of 3 to 8 m s^{-1}, based on detailed high-speed, three-dimensional kinematics. The mass model allowed us to determine the position of the CoM and therefore to calculate the accelerations of the CoM independently of torso accelerations. We found that bats used tip-reversal upstroke only during slow flight and that the torso accelerated forward during tip-reversal upstroke. This acceleration, however, was the result of the inertial force produced by the motion of the wings. Inertial forces affected both vertical and forward acceleration measurements at all speeds, but the horizontal inertial component decreased as speed increased while the vertical component remained constant across speeds. Our results highlight the importance of the incorporation of inertial components to the study of acceleration in flapping organisms.

98.6 IRSCHICK, DJ*; HENNINGSEN, J; University of Massachusetts at Amherst; *irschick@bio.umass.edu*

Trade-offs between force and accuracy in human performance

A simple yet profound functional trade-off involves force and accuracy. High levels of force would seem to necessarily result in lower levels of accuracy, and vice versa, but testing this functional trade-off is challenging. We have been studying human hammering as a means to understand this trade-off. Specifically, we are interested in the relative roles of target sizes, such as different sizes of nails, and the relative ability of individuals to strike such targets with accuracy. Human hammering is unique kind of performance because it involves high levels of force but must necessarily be accurate. We filmed a large sample of able adults hammering in different conditions and measured both their relative hammering performance (i.e., velocity, acceleration), as well as their ability to hit a target accurately. We are also interested in differences both among individuals (i.e., different individual strategies) and among sexes (men vs. women). Individual strategies seem to diminish this trade-off somewhat, implying that human performance may be difficult to extrapolate to animal performance because of the high level of choice involved.

34.3 JACKMAN, W.R.*; STOCK, D.W.; Bowdoin College, Univ. of Colorado; *wjackman@bowdoin.edu*

Ectopic expression of Fgf ligands results in supernumerary and fused teeth in zebrafish larvae

Fibroblast growth factor (Fgf) signaling is required for teeth to progress beyond the earliest stages of development in both mammals and zebrafish. Whether Fgf signaling is sufficient for tooth initiation remains unclear. To investigate further the role of Fgfs in tooth initiation and delimit the regions competent to respond to them, we used the heat-inducible *hsp70* promoter to drive the ectopic expression of *fgf10a* in zebrafish embryos. Teeth in zebrafish are restricted to the posterior pharynx. A single tooth is visible on each side of the midline at 4 dpf, and these sites are marked two days prior by restricted foci of *dlx2b* expression. We found that larvae injected with the *hsp70:fgf10a* construct and exposed to heat shock exhibited dramatic local expansion of *dlx2b* expression early in development and formed up to five teeth on a side by 4 dpf. Bicuspid teeth, which we interpret as the result of fusion of teeth that initiated simultaneously and in close proximity, were also observed. Despite the induction of Fgf expression throughout injected embryos, supernumerary teeth were limited to the posterior pharynx. We tested additional Fgf ligands for similar activity, and preliminary results indicate that some but not all exhibit this property. These ectopic tooth phenotypes qualitatively resemble those predicted by reaction-diffusion models for the control of the spacing of vertebrate ectodermal appendages (*e.g.* feathers and hairs), in which Fgf signaling serves as an activator of placode formation. Finally, the inability of ectopic Fgf signaling to induce tooth formation in the anterior pharyngeal and oral cavities raises the possibility that evolutionary reduction of dentition in the zebrafish and other cypriniform fishes was caused by the restriction of competence to respond to tooth initiation signals.

90.1 JACKSON, B.E.*; DIAL, K.P.; Univ. of Montana;
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Ontogeny of locomotor performance in a ground bird

Due to post-natal predation pressure many juvenile animals face a developmental tradeoff between escape ability and investment in other systems. In birds these tradeoffs are unique because birds transition through hindlimb- to flap-running to wing-dominated locomotion to execute their escape. Early reliance on hindlimbs is compulsory until their diminutive wings can generate aerodynamic power, making young ground birds particularly vulnerable. This is the first study for any animal of the ontogeny of flap-based locomotion and the 3-D movements of wings. Using four synchronized high-speed video cameras we recorded the escape behavior of developing Chukars (*Alectoris chukar*). Wing-assisted incline running (WAIR) and controlled flapping descent (CFD) performance approach adult levels when the birds are ~10% of adult mass at ~20 days post hatching (dph). We define three stages of locomotor development. In stage I (1-7 dph) birds use assymmetrical flapping, quadrupedal crawling, have high wing-loading (WL 162±14 Nm^{-2}), low wingbeat frequency (*f*, 14±1.4 Hz) and stroke amplitude (AMP, 90±9°), but global stroke angle (SA 106±6°) and angle of attack (AoA 42±4°) approach adult values during WAIR, and they have high falling acceleration (9.1±0.1 ms^{-2}). In stage II (8-19 dph), birds flap symmetrically and have lower WL (69±4 Nm^{-2}), while AMP (141±4°), *f* (21±0.8 Hz), SA (106±3°) and AoA (44±2°) approach adult values. WL decreases (min: 62±1.2 Nm^{-2}) until stage III (20 dph-adult) when birds can ascend 90° and transition to level flight from a fall. WAIR and CFD provide transitional adaptive value to incipient wings and reduce the potential constraints of the hindlimb-forelimb developmental trade-off. Funded by NSF.

14.3 JACOBS, M.W. *; LAUFER, H.; STUART, J.S.; CHEN, M.; PAN, X.; Univ. of Connecticut, Kunming Univ. of Science & Technology;
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Spatial and Temporal Patterns of Contamination by Endocrine-Disrupting Alkylphenols in the Blood of the American Lobster, Homerus americanus

Alkylphenols are vertebrate estrogenic endocrine disruptors widely used in manufacturing of plastics, detergents, and many other products. Environmental contamination by these chemicals and their breakdown products in rivers, oceans, and sediments is well known and widespread. We isolated four alkylphenols from the blood and tissues of lobsters from New England waters. In a survey of lobsters from Connecticut, Rhode Island, and Massachusetts, we found at least one alkylphenol in the blood of 223 of 630 lobsters (35%). Contamination varied geographically: 58% in lobsters from western Long Island Sound, 17% from central Long Island Sound, 32% from eastern Long Island Sound, 29% from Rhode Island, and 26% from Massachusetts. Different alkylphenols display different geographic distributions. Contamination levels for all areas combined decreased significantly between 2001 and 2008, although levels varied geographically and by compound. We have previously shown that all four compounds are endocrine disruptors with crustacean juvenile hormone activity. We also have strong evidence that alkylphenols weaken lobster shells by interfering with sclerotization and tanning after molting. Weaker shells may increase mortality during molting or susceptibility to diseases such as shell disease. Our results show that this risk to lobster stocks (and the potential for remediation) varies both spatially and temporally in New England.

28.3 JANOSIK, A.M*; MAHON, A.R.; HALANYCH, K.M; Auburn University, Auburn, AL, University of Notre Dame, Notre Dame, IN;
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Molecular phylogeography of three Southern Ocean species in the genus, Odontaster (Odontasteridae; Asteroidea) separated by the Drake Passage

Many marine invertebrates that possess a life history characterized by a planktonic mode of development often have the potential for vast dispersal. *Odontaster validus* is one of the most conspicuous seastars in the Antarctic; with a circumpolar distribution extending into the Sub-Antarctic, and has been referred to as a keystone species. By way of a planktotrophic mode of development, *O. validus* exhibits great potential for dispersal, although the Antarctic Circumpolar Current (ACC) and the Antarctic Polar Front (APF) maybe acting as biogeographical barriers, potentially preventing transport between South American and Antarctic waters. Two other members of this genus in the Southern Ocean, *O. penicillatus* and *O. meridionalis* recognized in South America and Antarctica, respectively, exhibit morphological similarity, as well as planktotrophic life history stages. Population structure, genetic connectivity, and distribution of these species have never been rigorously examined using molecular tools. These relationships were examined with a combined mitochondrial 16S ribosomal and cytochrome COI dataset from adult and larval specimens. The results show low genetic differentiation between *O. validus* populations throughout the Antarctic, but higher differentiation between Odontaster populations across the Drake Passage into South American waters. In addition, conclusions concerning population demographics, species distribution, cryptic speciation, and possible species expansions are discussed.

3.1 JAVONILLO, R.*; MALABARBA, L.R.; WEITZMAN, S.H.; BURNS, J.R.; George Washington University, Universidade Federal do Rio Grande do Sul (Porto Alegre, Brazil), National Museum of Natural History, Smithsonian Institution; *rjavonil@gwu.edu*

Evolution of sexually dimorphic novelties and reproductive strategies in fishes of the family Characidae (Teleostei: Ostariophysi)

Approximately 1,000 freshwater fishes from South and Central America are assigned to the family Characidae. Both reproductive modes of external fertilization and insemination occur in this group. The latter is relatively uncommon among teleost fishes, yet appears widespread within a characid lineage called Clade A, and may be correlated with the evolution of certain anatomical traits. Quantitative studies of such correlations have been impeded by lack of a well-resolved phylogenetic hypothesis. We present a phylogeny that includes representatives of several subfamilies and *incertae sedis* genera, and is based on DNA sequence data from nuclear and mitochondrial genes. Reproductive modes and sexually dimorphic traits, such as fin-ray hooks and gill glands, are optimized onto the phylogeny, allowing assessment of the homology of and correlation among such traits across the family. These preliminary data reject the monophyly of several suprageneric taxa and imply that insemination has multiple origins in Characidae.

79.1 JAWOR, Jodie*; DEVRIES, Susan; University of Southern Mississippi; *jodie.jawor@usm.edu*

Response to gonadotropin-releasing hormone and behavior in female northern cardinals, (Cardinalis cardinalis).

In birds, testosterone (T) has been shown to have a strong influence on behavior. Testosterone can decrease paternal behavior and increase aggressive behavior in both sexes. Previous studies have used the physiological response to a gonadotropin-releasing hormone (GnRH) challenge as a proxy for the stimulation of the hypothalamic-pituitary-gonadal (HPG) axis that naturally occurs during aggressive interactions. Here we report on the T response of female northern cardinals to a standardized GnRH challenge during different time points in the pre-breeding and early breeding season. In 2008 we administered 40 GnRH challenges to female cardinals. Blood samples were collected pre- and post-challenge with a 30min period between collections to allow T elevation. Response to the GnRH challenge was compared to melanin-based ornamentation (face mask) and nestling feeding behavior. Overall, female cardinals responded to GnRH challenges with a measureable increase in T and this was most pronounced in the pre-breeding season. Face mask expression negatively co-varied with response to GnRH challenge only when females were feeding nestlings. However, feeding behavior positively co-varied with nestling feeding behavior. This research shows that female northern cardinals can respond to GnRH challenges with an increase in T, however this response varies over the season. We suggest that this may have a strong impact on aggressive behavior observed in this species and may influence parental behavior as well.

7.1 JENNINGS, D.E.*; ROHR, J.R.; University of South Florida; *dejennin@mail.usf.edu*

Do carnivorous plants and spiders partition resources?

Competition is traditionally believed to be greatest in strength between closely related taxa, and as a consequence relatively little attention has been paid to competition between distantly related taxa. To assess the potential for competition between taxa from different Kingdoms, we examined resource partitioning between a carnivorous plant (the pink sundew, *Drosera capillaris*) and spiders (Araneae) in Odessa, FL. We sought to answer four questions regarding these taxa: 1) to what extent do the diets of *D. capillaris* and spiders overlap? 2) how selective are their diets?; 3) do these taxa segregate themselves spatially?; and 4) do these taxa affect one anothers phenotypic traits? Sampling was conducted from July to September 2008 using a combination of quadrats, pitfall-traps and sticky-traps. Preliminary analysis of the results indicated that the most abundant spider species in the area was *Sosippus floridanus* - a sheetweb-building Lycosid. The diets of both *D. capillaris* and *S. floridanus* predominantly consisted of springtails and ants, which were also the most abundant prey taxa found in their habitat. There was a positive spatial association between *D. capillaris* and *S. floridanus*. However, *S. floridanus* webs were generally located further away from *D. capillaris* as *D. capillaris* density increased. The quantified phenotypic traits such as leaf and web area did not seem to be affected by the presence of the other species. Our results suggest that there is the potential for competition between these two species, and that future work should include manipulative field studies.

51.3 JIANG, H.*; GROSENBAUGH, M.A.; JANSSEN, J.; STRICKLER, J.R.; Dept. of Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, Great Lakes WATER Institute, 600 East Greenfield Avenue, Milwaukee, WI 53204, Great Lakes WATER Institute, 600 East Greenfield Avenue, Milwaukee, WI 53204; *hsjiang@whoi.edu*

Hydrodynamic imaging of a self-propelling zooplankton prey by the lateral line system of a fish: A computational fluid dynamics study

Consisting of spatially distributed canal and/or superficial neuromasts, the mechanosensory lateral line system enables fishes to detect various water currents at their body surface. A fish may use its lateral line to form hydrodynamic images of its immediate vicinity, reflecting the spatial-temporal hydrodynamic signatures due to nearby prey, predator, conspecifics, obstacles and etc. Previous observations have provided ample evidence that freely swimming zooplankton preys can be detected by the lateral line system. However, through many previous studies using dipole-source potential flow modeling, we are most familiar with the spatial-temporal hydrodynamic signal patterns of a vibrating sphere (a rather artificial stimulus). Here, using computational fluid dynamics (CFD), we numerically simulate the hydrodynamic flow field around a self-propelling zooplankton prey that jumps from rest and is nearby a fish body. We quantify the hydrodynamic images formed at the lateral line of the fish due to jumping of the prey. We highlight the differences between a self-propelling zooplankton prey and a vibrating sphere in terms of the spatial-temporal hydrodynamic signal patterns.

60.10 JIMENEZ, A.G.; LOCKE, B.R.; KINSEY, S.T.*; University of North Carolina Wilmington; *kinseys@uncw.edu*

The influence of oxygen and high-energy phosphate diffusion on metabolic scaling in three species of tail-flipping crustaceans.

We examined the influence of intracellular diffusion of O_2 and high-energy phosphate (HEP) molecules on the scaling with body mass of the post-exercise whole animal rate of O_2 consumption (VO_2) and muscle arginine phosphate (AP) re-synthesis rate, as well as muscle citrate synthase (CS) activity in 3 groups of tail-flipping crustaceans. Two size classes in each of three taxa (*Palaemonetes pugio*, *Penaeus* spp. and *Panulirus argus*) were examined that together encompassed a 27,000-fold range in mean body mass. In all species, muscle fiber size increased with body mass and ranged in diameter from 70 1.5 to 210 8.8 m. Thus, intracellular diffusive path lengths for O_2 and HEP molecules were greater in larger animals. The body mass scaling exponent, b, for post-tail flipping VO_2 (b=-0.21) was not similar to that for the initial rate of AP re-synthesis (b=-0.12), which in turn was different from that of CS activity (b=0.09). We developed a mathematical reaction-diffusion model that allowed an examination of the influence of O_2 and HEP diffusion on the observed rate of aerobic flux in muscle. These analyses revealed that diffusion limitation was minimal under most conditions, suggesting that diffusion may act on the evolution of fiber design, but usually does not directly limit aerobic flux. However, both within and between species, fibers were more diffusion limited as they grew larger, particularly when hemolymph PO_2 was low, which may explain some of the divergence in the scaling exponents of muscle aerobic capacity and muscle aerobic flux.

60.6 JIMENEZ, A.G.*; KINSEY, S.T.; University of North Carolina Wilmington; *agj6818@uncw.edu*

Reduced cost of Na+-K+ pump activity in large muscle fibers of the lobster, Homarus americanus.

Large muscle fiber size imposes constraints on muscle function while imparting no obvious advantages, making it difficult to explain why muscle fibers are often among the largest cells in the animal kingdom. Recently, however, Johnston et al. (2003; 2004; 2006) proposed the optimal fiber size hypothesis, which states that some fishes may balance the need for small fibers that promote rapid diffusive flux against potential metabolic cost savings associated with large fibers. Since the fiber surface area to volume ratio (SA:V) decreases with increasing fiber size, there will be less membrane surface in large fibers over which ions must be pumped to maintain the membrane potential. We tested this hypothesis in abdominal muscle of the lobster, *Homarus americanus*. This muscle mass represents a large fraction of the animals body mass, but is rarely active, so there may be strong selection to minimize maintenance costs. Juvenile lobsters had a mean fiber diameter of 315.8 10.8 m and adults had a mean fiber diameter of 670.1 25.5 m, meaning that juvenile lobsters had a 2-fold higher SA:V than adults. These results suggest a potential advantage of large muscle fibers.

S3.5 JOHN-ALDER, H.B.*; COX, R.M.; HAENEL, G.J.; SMITH, L.C.; Rutgers Univ., New Brunswick, NJ, Dartmouth Col., Hanover, NH, Elon Univ., Elon, NC, Richard Stockton Col., Pomona, NJ; *henry@aesop.rutgers.edu*

Hormones and Performance: Insights from Natural History and Endocrine Manipulations

Whole-animal performance, defined as the ability to accomplish ecologically relevant tasks, represents the integration of morphological, physiological, and behavioral traits and is thus an obvious target of endocrine regulation. Hormonal control of performance can be identified in a top-down approach beginning with studies of natural history followed by experimental endocrine manipulations to establish functional relationships. We investigated seasonal, sexual, and developmental variation in growth and exercise performance in field-active Sceloporus lizards to find candidate hormonal regulators and to inform the context and design of subsequent endocrine experiments. Further, we undertook focal observations and demographic studies coupled with determinations of paternity in the field to test associations between performance traits and measures of fitness. In S. undulatus, seasonal variation in running endurance, home range activity, and breeding behavior are associated with variation in plasma testosterone and corticosterone, and in both female-larger and male-larger species of Sceloporus, sex differences in growth are associated with sexual divergence in plasma testosterone. In experimental studies, testosterone enhances running endurance and its underlying physiological support as well as home range activity, and, depending on the species, testosterone either stimulates or inhibits male growth. Running endurance and body size help to determine a male lizards ability to patrol home range and gain access to potential mates. Our studies exemplify the power of natural history combined with endocrine manipulations to identify testosterone as a regulator of performance traits linked to fitness.

53.2 JOHNSEN, S.*; KIER, W.M.; Duke Univ., Univ. of North Carolina, Chapel Hill; *sjohnsen@duke.edu*

You can hide, but you can't run: trade-offs between muscle activation and transparency in glass catfish

While the camouflage aspects of organismal transparency have been fairly well explored, little is known about its physical basis, particularly in more muscular species. We examined two species of silurid catfish, the transparent *Kryptopterus minor* and the opaque *Silurichthys indragiriensis*. Stained electron micrographs of longitudinal and transverse sections of muscle fibers were analyzed using Fourier and autocorrelation methods. The myofibrils of *K. minor* were wider than those of *S. indragiriensis* (1.13 vs. 0.805 um; $p < 0.0001$, t-test). This difference has both optical and physiological consequences. While the myofilament lattice is essentially crystalline and highly transparent, each myofibril is bounded by the sarcoplasmic reticulum (SR), which has a much lower refractive index and scatters light. Because light attenuation is exponential and there are thousands of such interfaces along the light path through the animal, a 30% reduction in the number of interfaces due to larger myofibrils can significantly affect transparency. While exact values are impossible due to lack of knowledge about the width and orientation of the SR, modeling of light transmission using matrix methods showed increases in light transmission of 2 to 5 fold. However, larger myofibrils cannot be activated or deactivated as rapidly because the calcium sequestered in the SR must diffuse over larger distances. Because diffusion time is proportional to the square of distance, the observed 30% increase in myofibril size leads to a doubling of diffusion time. *K. minor* is indeed less agile than *S. indragiriensis*, as is true of many transparent species, and it is possible that this difference in myofibril size is a factor in the evolutionary trade-off between transparency and organismal function.

95.3 JOHNSON, A.S.*; SELDEN, R; ELLERS, O; Bowdoin College, Maine; *ajohnson@bowdoin.edu*

Crab scent induces thicker skeletons, smaller gonads and size-specific adjustments in growth rate in sea urchins

Indirect predator-induced effects on morphology of marine invertebrates have been studied in snails, mussels, bryozoans, cladocerans and others but not in post-metamorphic sea urchins. We tracked the growth of a size range (0.065-161.385 g) of sea urchins, *Strongylocentrotus droebachiensis* with or without upstream odor cues from Jonah crabs, *Cancer borealis*. In an initial experiment, at ambient temperatures (14.9ºC average) during one summer month, growth of small urchins (less than 17 mm diameter) was slowed in the presence of crab scent whereas growth of larger urchins was not detectably affected. In a second, longer experiment during 22 weeks over winter (6.0 ºC average) we tracked several measures of growth. Similar to the summer results, odor cues induced slower growth in small urchins (less than 7 mm in the winter). However in contrast to the summer results, the growth rates of larger urchins increased slightly in the presence of crab scent. Furthermore, odor cues from crabs induced thicker skeletons and smaller gonads for urchins between 10 and 30 mm diameter, but did not affect spine length or jaw size. These growth responses suggest size-specific shifts in gonadal and somatic investment. Thicker skeletons may be stronger and thereby reduce predation risk. Smaller urchins may have grown more slowly because they foraged less as has been observed in other studies for smaller urchins hiding from predators. Mid-sized urchins may increase their somatic growth rate to outgrow sizes more vulnerable to predation. Higher somatic growth may be achieved at the expense of gonadal production.

85.5 JOHNSON, S.L.*; BROCKMANN, H.J.; University of Florida; *sheriljohnson@ufl.edu*

Do Horseshoe Crabs Benefit from Polyandry?

Why females mate with several males when the sperm from a single male is often sufficient to fertilize all their eggs is one of the most perplexing questions in evolutionary biology. Direct benefits (e.g., nuptial gifts, paternal care) to multiple mating are not expected in externally fertilizing species. Females may gain from mating multiply by insuring fertilization, increasing offspring diversity, improving male quality (good genes) or increasing genetic compatibility. Alternatively, multiple mating may result in a net cost to females as a by-product of male-male competition (convenience polyandry). We compare the reproductive success of monandrous and polyandrous females and evaluate the importance of good genes and genetic compatibility in a natural population of the American horseshoe crab, *Limulus polyphemus*. In this species attached pairs migrate to shore and spawn on high tides; the male fertilizes the females eggs externally with free-swimming sperm as the eggs are being laid in the sand. Unattached males are attracted to spawning pairs by visual and chemical cues and become satellites of some (polyandrous) females while ignoring others (monandrous). When present, satellites fertilize a high proportion of the females eggs. We observe monandrous and polyandrous females and compare reproductive measures such as the rate of egg laying, the number of eggs layed, and developmental rates of offspring. We evaluate the importance of good genes and genetic compatibility by conducting *in vitro* fertilization experiments. As an ancient and independently evolved arthropod, and the only arthropod with external fertilization, *Limulus* provides a unique opportunity to extend our understanding of the evolution of multiple mating.

97.8 JOHNSTONE III, W. M. *; BALTZEGAR, D. A.; BORSKI, R. J.; North Carolina State University, Raleigh; *wmjohnst@unity.ncsu.edu*

Characterization of Serum and Glucocorticoid Induced Kinases (SGK) in a teleost fish, the Mozambique tilapia (Oreochromis mossambicus)

Serum and glucocorticoid kinase (SGK) is a Serine/Threonine kinase belonging to the AGC [cAMP-dependant protein kinase (PKA), protein kinase G, protein kinase C (PKC)] kinase family. SGK is an immediate early response gene inducible by a plethora of stimuli including, but not limited to glucocorticoids, mineralcorticoids, cell shrinkage, cell swelling, various growth factors, DNA damage, stress, and p53. The structure and regulation of SGK has yet to be characterized in teleost fishes. We have cloned the full transcript of the SGK1 (1296 bp) isoform in the euryhaline Mozambique Tilapia. Using CLUSTALX alignment, we show that tilapia SGK1 shares 98% and 92% homology with the human and mouse isoform at the transcript and protein level, respectively. Classic structures associated with the AGC family of kinases, including a conserved ATP binding domain and active site have also been identified. We also cloned a 510 and 535 bp partial coding regions of two other isoforms identified as SGK2 and SGK3, respectively. We show that the gene for SGK1 is expressed in the teleost gill, heart, kidney, posterior intestine, brain, and pituitary. It is our hypothesis that SGK and its downstream mediators are integral in the ability of euryhaline fish to osmoregulate when faced with environmental salinity fluctuations.

28.2 JONES, S.J.*; WETHEY, D.S.; Univ. of S. Carolina, Columbia; *sierra@biol.sc.edu*

Large scale shrinkage: climate change and distributional contractions of Mytilus

Intertidal ecosystems are physically rigorous habitats which may serve as models for the effects of climate on biogeography. Organisms residing in the intertidal zone are exposed to a suite of stressful abiotic factors, such as desiccation stress and variable salinity, and must be able to cope with both water and aerial conditions. Changes in the environment can occur rapidly, and extreme temperatures may be experienced. Most organisms have latitudinally discreet biogeographical distributions. While various factors may affect these distributions, the range limits are likely to be set primarily by environmental temperature. Thus, with changing climatic conditions, the biogeographic ranges of organisms are predicted to shift polewards. Historical records indicate that the southern limit of the arctic-boreal blue mussel, *Mytilus edulis*, is in the vicinity of Cape Hatteras, NC. This system has been investigated to determine if temperature is the limiting factor of distribution, and whether it is contracting in a manner predictive of a warming climate. Thermal tolerance experiments were conducted to establish survivorship for a range of temperatures in both air and water, and transplant experiments were carried out at a latitudinal scale in order to determine survival in the field. A survival model was developed and predicts, with reasonable accuracy, mortality events observed in the field. Results suggest that the southern limit of *Mytilus edulis* on the east coast of the United States is contracting polewards. Sea surface temperatures for field sites have increased by approximately 1C since 1960. Modeling survival in relation to water and air temperature profiles indicate that both water and air temperature limit survival at southern sites, while at more northern sites observed mortality is due to aerial exposure.

51.6 JORDAN, LK*; KAJIURA, SM; GORDON, MS; Univ. of California, Los Angeles, Florida Atlantic University; *ljordan@ucla.edu*

Performance Differences in Stingrays with Varying Electrosensory System Morphology

Electrosensory signals are important during the final stages of prey capture in elasmobranch fishes (sharks, skates, and rays), and may be particularly useful for dorso-ventrally flattened batoids with mouths hidden from their eyes. In stingrays, the electrosensory system extends over the dorsal and ventral body surfaces with pore numbers and densities relating to foraging habitat. This study tests functional hypotheses based on quantified differences in the electrosensory system morphology of three stingray species; the benthic round stingray, *Urobatis halleri*, benthopelagic bat ray, *Myliobatis californica*, and the pelagic stingray, *Pteroplatytrygon* (*Dasyatis*) *violacea*. Behavioral experiments were performed to compare responses to prey-simulating dipole electrical signals (5.3 to 9.6 μA). Electrical field intensities calculated at orientation points were similar among these species though they differed in response type and orientation pathway. Minimum voltage gradients that elicited feeding responses were well below 1 nV cm^{-1} for all species. Individual stingrays most commonly displayed single turn orientations with a resulting trajectory leading directly to the center of the dipole, demonstrating the ability to determine the direction of the dipole source from afar. A small percentage of orientations included spiral tracking turns where rays appeared to follow curved voltage equipotentials to locate the center of the dipole. By quantifying the electric field intensity on both the right and left sides of the body we determined that rays conform to the predicted model by maintaining a constant voltage gradient on either side of the body midline. These results are the first to relate quantified morphological differences in electrosensory anatomy with behavioral differences in the detection capabilities of batoid fishes.

102.2 JORGENSEN, M.E.; Ohio University; *mj207406@ohio.edu*

Comparative locomotor morphology of hyloid and non-neobatrachian anurans

Frogs are characterized by a unique locomotor morphology that includes (but is not limited to) a craniocaudal elongate pelvis, hindlimbs with modified tarsal elements, reduced number of pre- and postsacral vertebrae, and the presence of an urostyle. Across the diverse order (5600+ species), jumping remains the characteristic locomotory mode for these animals. I investigated anatomical variation that may be related to differences in locomotory function by examining bone morphology from x-rays of at least one species representative (n = 5+ indviduals/species) from over 200 hyloid and non-neobatrachian genera. Multivariate statistics were used to assess patterns of morphological variation and convergence and results are viewed in light of previous characterizations of "locomotor type" in frogs. Musculature patterns in different functional regions are combined with osteological data to present preliminary interpretations of the evolution of locomotor morphology in hyloid and non-neobatrachian anurans.

43.3 JUSUFI, A*; GAO, P; FULL, RJ; DUDLEY, R; Univ. of California, Berkeley; *ardianj@berkeley.edu*

Gliding Geckos actively use tails for turning.

During free fall geckos reorient from an upside-down to a rightside-up posture by swinging their tail in one direction causing the body to rotate in the other as predicted by the conservation of angular momentum. Upon completion of air-righting, we observed that geckos used tail movements during aerial descent. To test whether active tails play a role, we simulated equilibrium gliding conditions by using a vertical wind tunnel. Geckos, *Cosymbotus platyurus*, attained terminal velocity at ventral airflows ranging from 4.0 to 7.0 m/s. We observed that turning maneuvers coincided with systematic circular tail movements. Animals that rotated their partially dorsi-flexed tail in a clockwise direction when viewed head-on initiated a clockwise turn to the right in yaw when viewed from above. A clockwise tail rotation when viewed head-on produced an anticlockwise rotation of the tail's center of mass motion when projected on the plane of the body. Tail rotations in the anticlockwise direction caused an anticlockwise turn in yaw to the left. The sharpest turning maneuvers in yaw occurred when the tail rotated predominately in the plane perpendicular to the gecko's sprawled torso, thereby projecting the largest circular motion onto the body plane. Moreover, ventral flexion of the tail accompanied pitch-down and dorsal flexion resulted in pitch up. Geckos were capable of actively inducing translation in cranial direction by alternating dorsal and ventral flexion of the tail. Tailless geckos were less effective at maintaining position in the three orthogonal axes of rotation. Reptilian tails can be highly effective appendages for attitude control during aerial locomotion.

36.8 KAATZ, I. M.*; STEWART, D. J.; SUNY College of Env.Sci.Forestry; *imkaatz@yahoo.com*

Phylogenetic variation of swimbladder disturbance sounds and morphology for twenty genera of doradoid catfishes with outgroup comparisons

This is the first comprehensive phylogenetic survey of sound signal design in a clade of catfishes (Families Doradidae and Auchenipteridae). We described the swimbladder acoustic mechanism and disturbance sounds of catfishes representing 29 species in 24 genera. Outgroup taxa included mochokid, pimelodid, pseudopimelodid and aspredinid species. The acoustic parameters were: 1. waveform; 2. sound duration (5 - 5,727 ms); 3. dominant frequency (mean 71 - 520 Hz) and 4. acoustic behavioral effort = total time for all sounds per individual (mean 337 - 28,996 ms). Waveforms of most taxa were continuous "growls". Several species produced unique "buzz" groups, "foghorn" sounds, and "whistles" with harmonic shifts. Duration fell into two overlapping categories: "shorter" (mean 12 - 78 ms) with few or no sounds above 100 ms and "longer" (mean 124 - 730 ms) including sounds >100 ms. Duration was statistically significantly different within but not between doradid and auchenipterid families. Mochokids were significantly different from all families producing the longest sounds. Acoustic effort was lowest for basal families and derived doradids and highest for basal doradids and two auchenipterid species. We are testing hypotheses on the morphological correlates of this variation: a. swimbladder shape (round or cardioid to elongated ovoid, smooth edge vs. horns or diverticulae); b. swimbladder volume (length 0.4 - 4.5, width 0.5 - 3.3, depth 0.2 - 1.5 cm); c. shape of the bony "esa", elastic spring apparatus (disk- or plug-shaped); d. "esa" dimensions (width 0.8 - 12.5, height 0.8 - 11.1, thickness 0.18 - 1.47 mm); e. acoustic muscle mass (0.0026 - 1.2473 g) and f. muscle dimensions (origin-insertion 2.1 - 20.2 mm).

55.1 KACENAS, S.E.*; PODOLSKY, R.D.; College of Charleston; *sklunsfo@edisto.cofc.edu*

Role of Parental Control in the Symbiotic Relationship Between Melanochlamys diomedea Egg Masses and Photosynthetic Algae

The intertidal zone is a uniquely stressful marine environment characterized by abrupt changes in salinity, high risk of desiccation, daily thermal extrema, and varying exposure to UV radiation. To counter these stresses, intertidal species often possess adaptations that serve to concomitantly dampen the effects of stress and increase overall survival probability. Encapsulation, one method by which intertidal organisms buffer their developing embryos from environmental stress, can result in hypoxia-induced delayed embryo development at the center of the egg mass. Symbiosis between egg masses and photosynthetic algae is a well-documented solution to this oxygen limitation dilemma, however little research has been conducted to investigate possible parental influence over the type and extent of this relationship. This research aimed to investigate 1) if differences in photosymbiont colonization between populations of *Melanochlamys diomedea* Bergh egg masses exist, and 2) if possible inherent differences in egg mass composition may be fueling these differences in photosymbiont density. Results indicate that photosymbiont density is dependant upon collection location and the age of the egg mass. In addition, data collected from a transplantation experiment indicate that the location from which an adult *M. diomedea* was initially collected more completely explains variations in photosymbiont density as opposed to the location into which the masses were transplanted. These results suggest the occurrence of transgenerational plasticity, a response by *M. diomedea* adults to environmental influence resulting in parental control over the biochemical composition of egg masses, as opposed to direct plasticity by encapsulated embryos in response to environmental stress.

33.6 KAJIURA, Stephen M; Florida Atlantic University; *kajiura@fau.edu*
Lanthanide Metals as Shark Repellants
Sharks possess an exquisitely sensitive electrosensory system that enables them to detect voltage gradients in their environment. At close range, this sensory modality overrides other senses and provides the sharks with spatial information to localize their prey. The electric field surrounding prey items is approximated by a dipole and sharks vigorously bite at prey-simulating dipole electric fields in the environment. Whereas higher order electric fields are also present, monopoles are absent in nature. However, the electropositive nature of lanthanide metals may provide a monopole source with a sufficiently strong local electric field to disrupt the sharks electrosense. This was tested by quantifying the electric field characteristics of various lanthanide metals and alloys (Nd, Nd-Pr, Cs-La) at the range of temperatures (10, 20, 30C) and salinities (0, 15, 35ppt) naturally encountered by sharks. All metals produce a measurable electric field in the seawater, in the range of millivolts, with the alloys generating a greater voltage than the Nd. The voltage of all metals declines with distance with a power function of $y=x^{-1.3}$. Although the measured voltage did not demonstrate a strong correlation with temperature, it did exhibit a strong inverse relationship with salinity. Behavioral assays demonstrated that various elasmobranch species were repelled from a food source when any of the metals were present, but readily ate in the absence of a metal. Teleost fishes were unaffected by the metals. The strong adversive reaction of the sharks to the metals suggests a possible utility of the metals as a bite deterrent which could reduce shark by-catch on long line fishing gear.

85.6 KARSTEN, K.B.*; ANDRIAMANDIMBIARISOA, L.N.; FOX, S.F.; RAXWORTHY, C.J.; Oklahoma State University, University of Antananarivo, American Museum of Natural History; *k.karsten@tcu.edu*
Sexual selection on body size and secondary sexual characters in two closely related, sympatric chameleon species in Madagascar
In polygynous mating systems, sexual selection can drive the evolution of male characters beneficial to winning fights (intrasexual selection), for improving the mating success of males through mate choice (intersexual selection), or both. However, it may be difficult to disentangle the relative contributions of intra- and intersexual selection on multiple traits that may be of dual utility. We used field arena trials to determine which morphological traits best explained male fighting ability and male mating success in two species of chameleons in Madagascar, *Furcifer labordi* and *F. verrucosus*. In *F. labordi*, male fighting success was best predicted by body size and cranial casque height and male mating success was best predicted by body size and width of the rostral appendage. In *F. verrucosus*, we found strong intrasexual selection for increased male body size and fewer counted dorsal cones, a trait that may correspond to age and experience. Although there appears to be little mate choice in this species, male mating success with receptive females is highly variable. Fewer counted dorsal cones and larger size-corrected casque height best explained male mating success; traits that may again indicate age or experience. Although difficult to determine the relative contributions of intra- and intersexual selection on traits with dual benefits (both fighting and mate choice), we documented both types of selection on body size and secondary sexual characters in these two chameleon species.

81.4 KATAYAMA, Hidekazu; CHUNG, J. Sook*; University of Maryland Biotechnology Institute, Baltimore; *chung@comb.umbi.umd.edu*
Co-localization of the specific binding sites of crustacean hyperglycemic hormones (CHHs) of eyestalk and pericardial organ on multiple tissues of the blue crab, Callinectes sapidus
Despite a large number of isoforms of hyperglycemic hormone (CHH) have been structurally characterized from many crustacean species, their physiological functions of those particularly found in non-eyestalk tissues are not clearly demonstrated. In the search of target tissue(s) of the pericardial organ crustacean hyperglycemic hormone (PO-CHH), we employed a second messenger assay and a radiolabeled ligand receptor binding assay to locate putative target tissues, along with eyestalk-CHH (ES-CHH). The membranes were prepared from various tissues of Callinectes sapidus: hepatopancreas, hindgut, midgut, gills, heart, abdominal muscles, and scaphognathites. Like ES-CHH, PO-CHH showed multiple target tissues and specifically bound membranes of scaphognathites = abdominal muscles > midgut > gills > heart > hindgut and hepatopancreas (listing order corresponds with the number of binding sites). The specific binding sites of [125I] ES-CHH in hepatopancreas and gills were saturable and displaceable. The binding sites of abdominal muscles membrane were specific and saturable, but appeared to be promiscuous by binding to both CHHs, while they showed differences in displacement. The results obtained from the binding study suggest that PO-CHH also has multiple target tissues in which abdominal muscles and scaphognathites are the primary tissues. As for the second messenger, we observed the difference in the amount of cGMP production by ES-and PO-CHHs in these tissues. The differences in the primary amino acid sequences of ES- and PO-CHH, may be responsible for the truncated responses of hyperglycemia, cGMP stimulation, and binding affinity.

12.1 KAVANAGH, KD*; JERNVALL, J; TABIN, C; Harvard Medical School and Stony Brook University, University of Helsinki and Stony Brook University, Harvard Medical School; *kathryn_kavanagh@yahoo.com*
Developmental Influence in the Evolution of Phalanges
Phalanges (finger and toe bones) originate from a single condensation that grows and segments sequentially along each digit, repeatedly deploying the same activator-inhibitor gene networks as each element is formed. The developmental processes involved in determining where joints are positioned, effectively segmenting the developing digit and determining phalanx size, are unknown, however understanding the developmental relationship between sequentially-developing phalanges is essential to modeling the evolution of phalanx size. In this study we evaluate in this system the usefulness of a previous model, the inhibitory cascade, that allows prediction of the evolution of molar tooth proportions (Kavanagh et al., 2007. Nature 449:427-432). Using experimental studies in the chick embryo autopod in combination with comparative studies of vertebrate lineages with hyperphalangy (e.g. cetaceans, ichthyosaurs, birds, amphibians), we are studying the developmental relationship among phalanges during morphogenesis and evolution. We are interested in the timing of formation of elements, growth rates, and the role of inhibition in establishing joint spacing. The adaptive significance of phalangeal morphology will be discussed in the context of the inhibitory cascade model.

S9.1 KELLEY, Keith W.*; DANTZER, Robert; University of Illinois; *kwkelley@illinois.edu*

Inflammation: History and future of PNI and potential synergy with Integrative Biology

Psychoneuroimmunology (PNI) formally began as an interdisciplinary science in the 1980s. It is rapidly growing today because it combines the expertise of scientists in clinical medicine, immunology, neuroscience, psychology, psychiatry, physiology and pharmacology. Among the many immune processes studied in PNI, inflammation has become the basis for translating fundamental PNI research into human clinical medicine. This development was mainly due to comparative biology. Dorso-ventral development in Drosophila melanogaster is dependent on Toll and regulated by Dorsal. Toll is homologous to the type I IL-1 receptor and Dorsal is similar to NF . Toll-like receptors bind to pathogen-associated molecular patterns in a very conserved manner. TLRs are also present in the brain. Their activation induces sickness behavior in both invertebrates and humans The syndrome of sickness behavior refers to behavioral changes that occur in an infected organism: lassitude, social withdrawal, fatigue, sleepiness, an increase in pain sensitivity, loss of appetite and weight loss. Sickness behavior is transient and fully reversible after the immune response has cleared the body of pathogens. If the acute inflammatory response is not down regulated, sickness behavior can develop into depression, chronic fatigue, enhanced pain and altered learning and memory. PNI research in mouse has now been applied to humans, leading to development of a quasi-experimental model for inducing depression: injection of interferon- into patients with malignant melanoma or hepatitis C. The model of interdisciplinary approach used in PNI research is ripe to be applied in traditional integrative biology research to promote a better understanding of the mechanistic underpinnings that regulate development of evolutionary and ecological components of cognition and behavior.

92.9 KEOGH, M.J.*; MANISCALCO, J.M.; ATKINSON, S.; University of Alaska Fairbanks, Alaska SeaLife Center; *mandyk@alaskasealife.org*

Development of Endocrine and Immune Function in Endangered Steller Sea Lion Pups (Eumetopias jubatus)

Several species of marine mammals and birds in the Northeast Pacific have been in decline since the mid-1970s including the endangered Steller sea lion (SSL; *Eumetopias jubatus*). A leading theory is the nutritional stress associated with a reduction in prey abundance or quality. The impact of limited resources would be greatest during periods of development and rapid growth. This study seeks to determine if body condition and maternal investment influences the immune and endocrine systems in SSL pups. At Chiswell Island, Alaska, a SSL rookery was monitored by a remote video camera enabling the determination of the age of pups, maternal investment, and survival rates. A total of 61 pups (24 female, 37 male) were sampled during 2005, 2007, and 2008 ranging in age from 5 to 38 days old. Each pup was measured, weighed, and branded. Blood samples were collected for complete blood cell counts, lymphocyte proliferation, serum chemistries and circulating hormone levels. Female pups were significantly smaller than males in mass (F= 26.7 4.1 kg, M=32.2 4.6 kg; F =16.276, $p<0.001$) and length (F=101.6 4.7 cm, M=108.0 4.9; F =17.331, $p<0.001$). Age also significantly effected mass (F =49.802, $p<0.001$) and length (F =17.331, $p<0.001$) with older pups being larger. While there was a significant difference between male and female pups in body condition these differences were not found in circulating hormones or lymphocyte proliferation. Circulating TT4 (F =6.007, p=0.017), FT4 (F =6.405, p=0.014), and T cell proliferation (F =4.984, p=0.038) decreased while leptin (F =5.679, p=0.020) increased with age. Further analysis will incorporate a body condition index to determine if overall condition significantly affects immune and endocrine parameters.

83.5 KERFOOT, J.R.*; TURINGAN, R.G.; Florida Institute of Technology; *jkerfoot@fit.edu*

Similarity and disparity in prey-capture kinematics between the invasive Belonesox belizanus and the native Micropterus floridanus, with implications for the ecological interaction between invasive and native species.

The intensity of competitive interactions between invasive and native fish species may be inferred from the degree of overlap in patterns of resource use and metrics of performance between the two competing species. In this study, the kinematics and mode of prey-capture were compared between the native centrarchid, *Micropterus floridanus*, and the invasive poeciliid, *Belonesox belizanus*. Principal component analysis revealed a pattern of overlap in prey-capture kinematic space between species. Subsequent independent t-tests comparing the loadings scores of each of the first two principal components, using species as a grouping factor revealed that in general, the kinematics of prey-capture was similar between *M. floridanus* and *B. belizanus*. However, both species differed in feeding mode, with *B. belizanus* employing more of a ram-feeding mode compared with *M. floridanus*. Similarity in prey-capture kinematics and disparity in feeding mode may underlie the competitive interaction between these coexisting native and invasive species in south Florida, including the Everglades National Park and Big Cypress National Preserve.

S3.3 KETTERSON, E.D.*; ATWELL, J.W; Indiana Univ.; *ketterso@indiana.edu*

Phenotypic Integration and Independence: Hormones, Performance, and Response to Environmental Change

The concepts of hormonal pleiotropy, physiological epistasis, and hormonal correlations raise many unanswered questions with respect to the links between hormones and whole-animal performance. One such question is the functional importance of hormonal correlations between the sexes and whether they might serve to constrain the evolution of sexual dimorphism. Another such question is the nature of individual variation in hormonal systems and how that variation relates to phenotypic evolution. Hormonally mediated characters can evolve owing to changes in hormone secretion, hormonal affinity for carrier proteins, rates of degradation and conversion, and interaction with target tissues. Critically, we know very little about whether these changes occur independently or in tandem, and thus whether hormones promote phenotypic integration or allow for phenotypic independence. Thus, when a population encounters a new environment that leads to altered expression of hormonally mediated characters, is that alteration likely to have come about through changes in hormone secretion (signal strength) or changes in response to a fixed level of secretion (target tissue sensitivity) or both? If the phenotype is tightly integrated and only the signal responds, adaptive modification may be limited by past selection for phenotypic integration. If individual target tissues readily unplug from a hormone signal in response to selection, then the phenotype may be seen as a loose confederation that responds on a trait-by-trait basis, readily allowing adaptive modification. Studies reviewed here and questions for future research will address the relative importance of integration and independence by comparing sexes, individuals, and populations.

79.5 KIDD, M.R.*; HOFMANN, H.A.; Univ. of Texas at Austin; *mrkidd@mail.utexas.edu*

Sex and Prostaglandin: Towards a Mechanistic View of Mate Choice

Mate choice is regulated by the complex interaction of endogenous and exogenous cues interpreted and mediated by the brain in order to maximize reproductive success. In teleosts, the regulation of female sexual behavior is based on either steroid (Poeciliids) or prostaglandin (all other teleosts) responsive systems. However, considering the astonishing diversity of teleost mating strategies, it is surprising that the proximate mechanisms controlling female sexual behavior have been well studied in only a few species with similar reproductive strategies. We examined the effects of the fatty acid derivative prostaglandin F2alpha (PGF2) on female sexual behavior and mate choice in the lek-breeding African cichlid fish, *Astatotilapia burtoni* , a major model system for studying the neural mechanisms underlying socially regulated plasticity in brain and behavior. While PGF2 is considered to be one of the principal endogenous cues eliciting female sexual behavior in teleosts, our results suggest that endogenous levels of PGF2 are in a marked state of decline as spawning approaches. However, when we administered exogenous PGF2 (0.1g/g body weight) to non-reproductive females in a simultaneous choice paradigm they exhibited a proceptive response (visiting behavior) toward the more attractive male (ANOVA, $p<0.05$), yet failed to complete the full suite of sexual behaviors typically associated with cichlid mate choice. Importantly, the effect of exogenous PGF2 on female sexual behavior is mediated by both social context and the prior priming of stimulus males with female pheromones. These results indicate a previously unreported, secondary control over the PGF2 induced sexual response, which may be a prerequisite for the prolonged period of male assessment exhibited by females in polygamous cichlid species.

90.7 KILBOURNE, BM; University of Chicago; *bmkilbou@uchicago.edu*

ONTOGENETIC ALLOMETRY OF LONG BONES IN MAMMALS AND DINOSAURS AND ITS USE AS A PREDICTOR OF LIFE HISTORY TRAITS

In addition to providing insight into the ontogenetic development of the locomotor system, ontogenetic limb bone allometry may reflect other aspects of an organism's life history, such as adult and neonatal body mass or growth rate. Similar patterns in ontogenetic long bone allometry in extinct and extant taxa may be useful for inferring life history parameters in extinct taxa. To investigate trends in ontogenetic allometry in biomechancially/functionally similar taxa, femoral allometry was assessed in 23 non-avian dinosaur and 24 terrestrial mammal species. Isometric growth is the most common pattern of growth in dinosaur and mammalian femora. Non-avian theropods have a distinct pattern of femoral growth with little to no overlap with mammals and non-theropod dinosaurs. To examine how ontogenetic allometry varies with life history parameters in mammals, regressions were calculated between femoral allometry and the following life history traits: adult and neonatal body mass, ontogenetic range of body mass, and growth rate. Regressions between femoral allometry and all of the above life history traits were statistically significant, but the majority of the variance in femoral allometry was explained by growth rate. Mammal taxa with high growth rates possess femora that grow isometrically, whereas taxa with lower growth rates have femora that become more gracile during ontogeny. Overall, changes in body mass influence changes in limb bone proportions during mammal ontogeny. Non-avian dinosaurs lack correlation between maximum estimated growth rate and femoral allometry. Caution is warranted when inferring life history traits from long bone allometry in dinosaurs. Future work should be performed on extant birds for a phylogenetic perspective on the allometry of long bones in non-avian dinosaurs.

80.2 KIM, Tae Won*; KIM, Sunhye; CHOI, Jae Boong; CHOE, Jae Chun; Ewha Woman's University, Sungkyunkwan University; *ktwon@ewha.ac.kr*

Angkor Wat on the intertidal mudflats: Towers built by the manicure crab Cleistostoma dilatatum (de Haan) for thermo-regulated ventilation

In Kanghwa Island, South Korea, the manicure crab *Cleistostoma dilatatum* living on the mudflat constructs an extraordinary tower at the entrance of its own burrow. The tower is the highest ever known among structures built by various crabs living on the intertidal flats. The tower has a hole connected to the burrow of the crab, which has a very small diameter (1-3mm) on its top but becomes wider downwards. The function of the structure is unknown but the possible role of ventilation has been suggested. The crabs build towers at the beginning of neap tides when the water does not cover the habitat and the sediment becomes dry. The mud surface temperature decreases as it comes to the center of the tower and this probably would help air on the top mixing with air below the burrow. The result suggests that the tower of *C. dilatatum* has been evolved for optimal ventilation. The tower of *C. dilatatum* is thought as an adaptive phenotype for enduring dryness on the mudflat during neap tides without being active on the mudflat.

40.6 KING, HM*; HALE, ME; Univ. Chicago; *hking@uchicago.edu*

Paired fin-based locomotion in the lungfish

Lungfish are one of only two extant non-tetrapod sarcopterygian taxa, the other being coelacanths, and are of interest to biologists from anatomical, physiological and evolutionary perspectives. Despite this, little is known of their locomotion, particularly locomotion involving the paired pectoral and pelvic fins. In order to better understand diversity of locomotor modes in the Sarcopterygii, we examined paired fin and axial movement in the African spotted lungfish (*Protopterus annectens*). Because of the importance of hindlimb-driven locomotion in coelacanths and tetrapods, we focused on the patterns of pelvic fin movement. Spontaneous swimming and investigator-initiated startle responses were filmed in a still tank at 60Hz. A ventral view was used to determine limb/axial patterns and a lateral view was used to determine the location of the fish in the water column. We found a broad diversity of coordination patterns between the paired fins, and the paired fins and axis. The pelvic fins were used frequently to move along the bottom of the tank and, in some locomotor bouts, were coordinated with axial undulation. Both alternating and synchronous pelvic fin gaits were used. The pectoral fins were more active when the fish was swimming higher in the water column. During high speed swimming, as after a startle response, pectoral and pelvic fins were tucked and the fish was propelled by axial undulation alone. While pelvic fin-based locomotion is rare in ray-finned fishes, our finding that pelvic fins are key propulsors in lungfish demonstrates the importance of pelvic fins locomotion across the major sarcopteryigan lineages. Beyond the pelvic fins, lungfish have a rich diversity of gaits, making them an interesting group in which to examine control, coordination and evolution of sarcopterygian locomotion. Supported by NSF grant IBN0238464 to MEH.

19.5 KLINE, RJ*; HOLT, GJ; KHAN, IA; Univ. of Texas Marine Science Institute; *rjkline@mail.utexas.edu*

NEUROENDOCRINE CONTROL OF SEX CHANGE IN THE ROCK HIND, Epinephelus adscensionis

The following research is being conducted to investigate the linkage between behavioral and gonadal sex change in hermaphroditic fish. In fish, the brain produces both arginine vasotocin (AVT) and gonadotropin releasing hormone (GnRH) within the preoptic area anterior hypothalamus (POAH). Both of these hormones have been implicated in sexual change in hermaphroditic species of wrasse and goby. However, little is known about these hormones regulating sex change in grouper species. In our laboratory, a small protogynous grouper, rock hind *Epinephelus adscensionis*, is being used as a model to investigate neuroendocrine control of sex change. We have placed rock hind in small social groups and have successfully induced sex change by removing the dominant male from the group. Video documentation of male type behavior will be presented demonstrating striking but temporary changes in color pattern during dominance displays. The AVT V1a receptor has been identified as a key receptor mediating behavioral sex change. In other species, blocking this receptor by an antagonist inhibits male type behavior. In the present study, AVT V1a receptor cDNA was isolated and cloned from rock hind brains. Based on the predicted amino acid sequence, an AVT V1a receptor antibody specific to rock hind was developed. This antibody recognizes a single band of the expected size (~ 45 kDa) in Western blots from rock hind brain membrane fractions. The antibody is being used to quantify changes in AVT receptor levels in the POAH from male and female rock hind and to examine changes in AVT V1a receptor expression during behavioral sex change. Ongoing research will also identify the relationship of AVT to GnRH in the POAH using co-localization and quantification of mRNA in fish undergoing sex change.

S8.8 KOCHER, Thomas D; University of Maryland; *tdk@umd.edu*

Evolution of Sex Determination in East African Cichlid Fishes

Sex determination is a fundamental developmental decision in which the bipotential gonad is directed into specific pathways of male or female development. Our long term goal is to discover and characterize the gene regulatory network responsible for this central developmental switch in vertebrates. We focus our experimental work on cichlid fishes, including cultured tilapias and the haplochromine cichlids of East Africa. These species descend from a common ancestor within the last 15MY and share most of the regulatory network for sex determination. Among these closely related species we have discovered at least four distinct sex determining loci. The Nile tilapia (*Oreochromis niloticus*) has an XX-XY (male heterogametic) system controlled by a major gene near marker UNH995 on LG1. The blue tilapia (*O. aureus*) has a WZ system near UNH168 on LG3 which is epistatic to the XY system on LG1. Malawi haplochromines segregate for an XY locus near UNH973 on LG7. At least four Malawi species also segregate for a WZ locus near *cski* on LG5. When both loci segregate in a single family, the W allele on LG5 trumps the XY locus on LG7. These four loci can be considered new mutants in the sex-determining pathway, which provide windows on the gene network underlying vertebrate sex determination. By comparing the function of regulatory networks in these species, we will gain insight into the structure of the network, and the mechanisms by which the output of the network is controlled by different genes.

56.3 KOCOT, K. M.*; HALANYCH, K. M.; Auburn University; *kmkocot@auburn.edu*

Molluscan phylogeny investigated using three nuclear protein-coding genes

With over 130,000 described extant species, Mollusca is the second most diverse animal phylum. Surprisingly, the phylogenetic relationships among the eight major lineages of Mollusca remain largely unknown. Although relatively few molecular phylogenetic studies have addressed mollusk higher-level relationships, the results of these studies have called into question several long held hypotheses of molluscan phylogeny such as the Diasoma hypothesis, the monophyly and basal position of the aplacophorans, and even the monophyly of Bivalvia and Gastropoda. These studies which have relied mostly on 18S, 28S, and mitochondrial genes have been unable to resolve most higher-level molluscan relationships. Conserved nuclear protein-coding genes have been shown to be useful for higher-level metazoan phylogenetics but little work using such genes as molecular markers has been done on molluscs. Therefore, we have employed constitutively expressed nuclear protein-coding genes novel to deep mollusk relationships which can be relatively easily obtained from molluscs and other lophotrochozoans. Specifically, we have sequenced large fragments of heat shock protein 90A (Hsp90A), sodium/potassium ATPase alpha subunit (NaK), and elongation factor 1 alpha (EF-1a) for a total of ~6.6 kbp per taxon from a diverse set of molluscs. These highly conserved, single copy genes were carefully selected for use as molecular markers on the basis of analyses of available sequence data from GenBank, genomes and EST libraries. These preliminary phylogenetic analyses indicate that these genes have good potential to provide insight into mollusc higher-level phylogeny. This approach allows us to collect a complete set of data for a large number of taxa relative to phylogenomic (EST-based) investigations at a much lower cost.

8.5 KOEHL, MAR*; CRIMALDI, JP; DOMBROSKI, DE; HADFIELD, MG; Univ. of California, Berkeley, Univ. of Colorado, Univ. of Hawaii; *cnidaria@socrates.berkeley.edu*

Effects of benthic community topography on water flow, dispersal of chemical cues, and hydrodynamic stresses on settling larvae

Many bottom-dwelling marine animals disperse to new habitats via microscopic planktonic larvae. A critical step in recruitment of these larvae into benthic communities is settlement (landing and attaching to a surface). Flowing water can both deliver larvae to and dislodge newly settled larvae from surfaces. We used fouling communities that develop on docks to investigate how the fine-scale topography of a benthic community affects the nearby ambient water flow, and how that flow disperses chemical cues released by the community and hydrodynamic stresses on larvae settling into the community. Measurements of water flow along surfaces in Pearl Harbor, HI, showed that fouling communities are exposed to oscillatory flow (wind chop, ship wakes) superimposed on slow currents. We exposed fouled plates at different stages of community development to such flow regimes in a wave flume, used laser-Doppler velocimetry to measure water velocities 500µm from surfaces to determine instantaneous hydrodynamic stresses encountered by larvae settling onto different spots within each community, and calculated larval settlement probabilities. We also used simultaneous planar laser-induced fluorescence and particle image velocimetry to quantify fine-scale turbulent structure of the flow and the spatio-temporal patterns of odor dispersal above fouling communities. Community surface roughness increases turbulent transport of larvae and dispersal of chemical cues in the water, but provides flow microhabitats where hydrodynamic forces on settled larvae can be low. In turbulent flow, hydrodynamic stresses on settled larvae are episodic, and are higher if wind chop or ship wakes occur.

100.5 KOHL, K.*; BRZEK, P.; CAVIEDES-VIDAL, E.; KARASOV, W.H.; University of Wisconsin, Madison, Universidad Nacional de San Luis-CONICET, Argentina; *pbrzek2@wisc.edu*

Phenotypic plasticity of intestinal dissacharidase activity is fully reversible in young House sparrows

Environmental variation during development can produce significant variation among individuals phenotypes (phenotypic plasticity). This variation includes also digestive morphology and physiology. We showed previously in House sparrow (*Passer domesticus*) nestlings that the presence of starch in diet between days 3 and 12 posthatch significantly increased maltase activity. However, it remained unclear whether this modulation is irreversible or reversible reflecting, respectively, a developmental plasticity or a phenotypic flexibility. To answer this, nestlings were raised from 3 days of age until 30 days on diets with either 0% starch or 25% starch (+starch), with some individuals experiencing a switch in their assigned diet at 12 days of age. Thus, there were four treatment groups: 1) fed 0 starch diet throughout, 2) fed + starch diet throughout, 3) initially fed 0 starch diet then switched to +starch, and 4) initially fed +starch diet then switched to 0 starch. Birds in both groups fed on +starch diet on days 12-30 showed ca. 50% higher summed activity of disaccharidases (maltase and sucrase) than those fed on diet 0 starch. Digestive enzyme activities in 30-day-old birds were not influenced by the diet prior to day 12. Therefore, observed plasticity in activity of intestinal dissacharidases is completely reversible, revealing a phenotypic flexibility. Supported by NSF IOS-0615678 to W.H.K.

87.4 KOHLSDORF, T*; NAVAS, CA; University of Sao Paulo, FFCLRP, University of Sao Paulo, IB; *tiana@usp.br*

Evolutionary relationships between locomotion and morpho-physiology in Tropidurinae Lizards

The locomotor performance of wild lizards results from interactions between behavioral, physiological and morphological characteristics of individuals and the structural properties of the habitat they occupy. If animals exhibit proper performance in a given ecological setting, traits of external morphology are probably finely tuned with biomechanical and physiological traits. Such associations were assessed by a multivariate approach detecting principal components among parameters of morphology (5 traits), muscle physiology (3 traits) and energetics (2 traits), measured in eight Tropidurinae species from a wide range of Brazilian non-forested habitats, and then correlating the scores of the components with locomotor performance (running on different substrates and jumping). A phylogenetic complementary approach (with independent contrasts) was also used. Four factors were retained in the conventional PCA: 1) tail and foot lengths and resting metabolic rates, 2) body size and proportion of FG and FOG muscle fibers, 3) limb lengths, and 4) SO muscle fibers and activity metabolic rates. From all locomotor performances measured, only sprint speeds on sand correlated with one of the factors retained, which was related to tail and foot lengths and resting metabolic rates. The PCAs performed using independent contrasts retained the same four factors, but body size was associated to the component relating tail and foot lengths with resting metabolic rates, which was positively correlated with jumping capacity. Therefore, in Tropidurinae lizards morpho-physiological associations can be detected, but only one morpho-physiological component (of foot and tail morphology associated with resting metabolic rates) correlates with the locomotor performance exhibited.

S2.6 KOLBASOV, G.A.; Moscow State University; *gakolbasov@gmail.com*

Parasitic microcrustaceans of the class Tantulocarida, external and internal morphology, development and life circle

The tantulocaridans represent tiniest exoparasites of other benthic crustaceans. They have a unique life circle among crustaceans characterized with absence of true subsequent molts. The material on two tantulocarid species including different instars was collected at the White Sea during 2004-2007. These are *Arcticotantulus pertzovi* parasite of the harpacticoid species *Bradya tipica* and *Pseudobradya acuta* and a new species of family Microdajidae parasite of the tanaid genus *Typhlotanais* sp. Additionally, a material on a new species of the family Basipodellidae (a tantulus larva) from deep-sea of Indian Ocean has been examined. The morphology of tantulus larva, parthenogenetic female and male was studied with SEM and TEM. Both larval cephalon of tantulus and cephalothorax of male lack the lattice organs, representing a synapomorphy for the class Thecostraca. Stylet, a funnel-shaped organ and rudimental, closed cuticular gut were observed inside the cephalon of larva. Stylet is covered by several layers of thick cuticle, hollow at base, at least, and situated within special chamber inside the gut. A funnel-shaped organ lies inside an own chamber above the gut, and having a separate opening above mouth aperture. A tip of funnel-shaped organ ends with dense cuticle. Four canals or peculiar cavities putatively of secretory nature open into a funnel-shaped organ. They may produce special cement glues a tantulus to host. Probably, a gut of tantulus penetrates inside a host through a puncture made with stylet.

100.6 KONOW, N.*; THEXTON, A.; CROMPTON, A. W.; GERMAN, R. Z.; Johns Hopkins University, Physical Medicine and Rehabilitation, Kings College, Guy's Campus, Museum of Comparative Zoology, Harvard University; *nkonow@jhmi.edu*

Regional specialization in the mammalian sternohyoideus

The complex array of oropharyngeal muscles is critical to multiple behaviors in mammals. The sternohyoid is recruited during several behaviors, including respiration and vocalization, food acquisition (infantile suckling and adult biting), food processing and swallowing. Given its relatively simple architecture, we hypothesized that the mammalian sternohyoid would exhibit limited intra-muscular variation in EMG activity and recruitment patterns, and that variation in sternohyoid length dynamics would be restricted both within and among behaviors. Therefore, we investigated the level of intra-muscular variation in length-dynamics, measured using sonomicrometry, relative to the EMG of the sternohyoid in infant mini-pigs during suckling and swallowing. The sternohyoid behaved as a single unit during swallowing, which is an ancestral reflexive activity. However, regional differences in contraction-dynamics occurred during rhythmic suckling, indicating that one muscle section contracted isotonically while another section underwent eccentric contraction. Our results suggest that the mammalian sternohyoid contains unrecognized populations of regionally specialized motor units involved with the novel mammalian suckling behavior. We propose that this pool of variation is the historical legacy of this ancient muscle. Research funded by NIH DC03604 to RZG.

8.10 KOPLOVITZ, G*; MCCLINTOCK, JB; AMSLER, CD; BAKER, BJ; University of Alabama at Birmingham, University of South Florida; *gilkop@uab.edu*

Palatability and anti-predatory chemical defenses in a suite of ascidians from the Western Antarctic Peninsula.

Fourteen species of colonial and solitary ascidians were collected from hard and soft bottom habitats at depths ranging from 0 to 40 m near Palmer Station, Antarctica (64 46 S, 64 03 W) on the Western Antarctic Peninsula. Palatability was evaluated in laboratory bioassays using the sympatric omnivorous fish *Notothenia coriiceps* and the omnivorous sea star *Odontaster validus*. When compared to a control food, small bite-sized pieces of outer body tissue of all 14 ascidian species were unpalatable to fish (spit out), while 9 of the 14 species tested were unpalatable (rejected from the ambulacral feeding groove) to sea stars. Eleven ascidian species were collected in sufficient quantity to prepare lipophilic and hydrophilic extracts and incorporate these at tissue level concentration into alginate food pellets. Control (no extract) and experimental alginate food pellets tested in fish and sea star bioassays indicated that only the lipophilic extract of the colonial ascidian *Distaplia colligans* was deterrent, and in this case to both predators. Similarly, the omnivorous sympatric amphipod *Gondogeneia antarctica* was fed ascidian extracts (10 species) in alginate food pellets and only one species (the colonial *Distaplia cylindrica*) deterred feeding, while extracts in 7 species actually stimulated feeding. Thus, while Antarctic ascidians are unpalatable to sympatric consumers, their lack of palatability appears to be rarely based on organic chemical defenses, but rather be related to one or more of the following: 1) inorganic acids, 2) structural defenses (e.g., tunic toughness), or 3) low nutritional value. This research was supported by NSF grants # OPP-0442769 and OPP-0442857.

10.2 KOT, B.W.; University of California, Los Angeles; *bkot@ucla.edu*

New Minke Whale (Balaenoptera acutorostrata) Lunge-Feeding Processes and Behaviors

Minke whales (*Balaenoptera acutorostrata*) are the smallest members of the filter-feeding rorqual whales (Balaenopteridae). Like most rorquals minkes feed by lunging into schools of fishes or krill with their mouths agape. They engulf a large volume of water and prey then channel it into their expandable ventral pouch. Musculature and elastic material properties of the pouch then generate hydraulic pressure that forces water back out the mouth through a set of baleen plates which retain prey. My investigations into the complex behaviors, processes and mechanisms central to this unique feeding system are possible because minke whales often feed visibly at the surface in my study area. During the summers of 2004, 2006 and 2007 I observed and obtained video footage of surface-feeding minkes from inflatable boats in the Gulf of St. Lawrence in eastern Canada. Individual whales were photographically identified and new photogrammetric techniques using digital video allowed me to determine some of the first acceleration and velocity information for lunge-feeding minke whales. I also calculated motions of the mandibles and ventral pouch which appear to play important roles in prey filtration. Over 100 feeding minkes were studied which allowed me to identify new aspects of their feeding processes and behaviors. I also conducted a short-term study which provided evidence that a minke whale with entanglement-like injuries to its ventral pouch had decreased feeding abilities versus five uninjured minkes in the area. Collectively this study demonstrates that new methods are revealing more information about the mostly misunderstood rorqual feeding system; it also suggests that more conservation measures are needed to help address the threats that fishing gear pose to whales with specialized feeding systems.

52.2 KREFT, J.K.*; WALDROP, L.D.; KOEHL, M.A.R.; Univ. of California, Berkeley; *jkreft1@berkeley.edu*

Low landings lead to lofty living: forces on newly settled invertebrate larvae in realistic flow environments

Many benthic marine animals disperse via microscopic planktonic larvae. Recruitment, which begins with settlement onto substrata, affects community structure and population dynamics. Flowing water can deliver and dislodge newly settled larvae to and from surfaces. Using the nudibranch *Phestilla sibogae* we studied how flow microhabitats affect the hydrodynamic forces acting on settling larvae and newly-metamorphosed juveniles. Juvenile and adult *P. sibogae* only settle on its prey, the reef-building coral *Porites compressa*. The living coral tissue that juveniles and adults eat is only at the top of the reef, where ambient water velocities are much faster than they are in the interstices within the reef. Calculations (assuming spherical larvae and measured adhesion strengths for *P. sibogae*) indicate larvae are more likely to settle within the reef. Using dynamically-scaled physical models, we measured the effects of metamorphosis, orientation and posture on drag forces under flow conditions at the top of and within a reef. We used particle image velocimetry (PIV) to examine flow fields surrounding the models, which are interesting as our conditions span a poorly-understood intermediate range of Reynolds Numbers (Re's of 2 to 17). Drag at the reef top was significantly lower than within the reef. Drag on juveniles was significantly lower than on larvae, enabling juveniles to withstand the high flows at the top of the reef that would dislodge larvae. PIV showed that both skin-friction drag and form drag are important, but that the drag differences between various body postures and shapes were due to form drag. Our results support hypotheses that *P. sibogae* larvae must first settle and metamorphose in lower, more protected regions of reefs before migrating to the top to feed.

S10.6 KRIEGSFELD, L.J.*; GIBSON, E.M.; WILLIAMS, W.P.; BENTLEY, G.E.; TSUTSUI, K.; University of California, Berkeley, Waseda University; *kriegsfeld@berkeley.edu*

The Circadian Control of Neuroendocrine and Ovulatory Function: Lessons From the Young and Old

To allow organisms to anticipate daily environmental change and synchronize their activities accordingly, individuals have evolved an endogenous timekeeping mechanism called the circadian clock. The brain clock resides in the suprachiasmatic nucleus (SCN) in the anterior hypothalamus. The requirement for precision in the temporal coordination of behavioral, neural and hormonal events is readily apparent for female reproduction. In hamsters (*Mesocricetus auratus*), for example, the preovulatory luteinizing hormone (LH) surge required for ovulation occurs at a specific time of day and is stimulated by the timed activation of the reproductive axis by the circadian system. Additionally, the hormonal events associated with ovulation coordinate sexual motivation and receptivity with the time of maximal fertility. The research to be presented uses the rodent ovulatory cycle as a model system for exploring the neural circuits and neurochemical mediators contributing to hormonal timing. In our research, two key neuropeptides in the RFamide family, RFamide-related peptide (RFRP) and kisspeptin, have emerged as key mediators in the circadian control of the ovulatory cycle. Additionally, because reproductive senescence associated with advanced age results, in part, from deficits in clock function, we have begun to use the aging female to further explore the role of the circadian system in reproductive control. Results will be discussed in the context of the importance of hormonal timing for the maintenance of normal health and reproductive functioning.

94.6 KROCHMAL, Aaron R.*; BAKKEN, George S.; LADUC, Travis J.; Washington College, Chestertown MD; *akrochmal2@washcoll.edu*

Phylogenetic perspectives on learning in pitvipers (Viperidae: Crotalinae) with comments on one-trial learning in rattlesnakes

Little effort has been devoted to investigating learning in snakes. Those studies that have been conducted generally lack biological relevance and a phylogenetic framework, curtailing the scope of these investigations and the results thereof. As part of an ongoing study on the thermoregulatory behavior of pitvipers (Viperidae: Crotalinae), we surveyed the abilities of 13 pitviper species to navigate a maze based only on thermal cues. We placed snakes in a Y-maze that was held at a stressful but sub-lethal temperature save one extreme end which was held at a favorable temperature, and recorded the time it took the snakes to navigate the maze in each of 6 trials. Using temperature as the motivation and the reward and surveying species across the phylogeny of pitvipers cast our study within a biologically relevant context. Rattlesnakes (7 species) quickly learned to escape the thermal stress (no species-specific differences were seen; trial 1, pooled mean time= 803 sec, 95%CI= &plusmn58 sec; trials 2-6 did not differ significantly from each other, pooled mean time= 72 sec, 95%CI= &plusmn13 sec), while the 6 other species failed to demonstrate this trend (no species- or trial-specific differences were found; mean time trials 1-6 = 837 sec, 95%CI= &plusmn73 sec). Our results show that in the context of thermoregulation, rattlesnakes exhibit one-trial learning, an ability apparently absent in the other pitvipers surveyed. One-trial learning may represent a derived trait in the rattlesnakes, reflecting the unique conditions under which they evolved. These results underscore the importance of considering biological- and phylogenetic relevance when conducting investigations of learning.

S9.5 KUHLMAN, Joshua R*; MARTIN, Lynn B; University of South Florida, Department of Biology, Division of Integrative Biology, Tampa, Fl 33620, USA.; *jkuhlman@mail.usf.edu*

Stress Effects on Immune Activity in House Sparrows (Passer domesticus).

Implantation of dental sponges under the skin of lab rodents has been used to evaluate whether acute stress enhances leukocyte infiltration to a surgical site. We replicated this technique in house sparrows, *Passer domesticus*, to test whether transient stressors cause similar immunoredistribution (i.e., movement of immune cells out of circulation and to the periphery) in a wild animal. As placement into captivity alone may serve as a stressor to wild animals, we first compared sponge infiltration over different periods of captivity. House sparrows were randomly assigned to one of three groups: sponge implantation at capture, after short duration captivity (1 or 2 days), or long duration captivity (1 month). Total leukocyte infiltration into the sponge varied among the three groups. Birds implanted at capture had greater leukocyte infiltration to the sponge compared to birds kept in captivity 1 or 2 days before implantation. Birds placed into captivity for 1 month before implantation showed similar sponge infiltration relative to the immediate implant group. However, time in captivity altered the dominant type of leukocytes present in the sponge at explant with lymphocytes decreasing with time in captivity and granulocytes increasing. Our study indicates that in house sparrows, time in captivity affects the magnitude and character of immune responses to surgery and more importantly data are suggestive of immunoredistribution.

3.5 KUNZ, Thomas H.*; MUNOZ-ROMO, Mariana; DUMONT, Elizabeth R; RISKIN, Daniel K; SWARTZ, Sharon M; Boston University, University of Massachusetts--Amherst, Brown University; *kunz@bu.edu*

Non-Flight Use of Wings by Bats

Wings represent one of the most important features that have contributed to the success of bats, birds, and insects. Numerous studies have shown how form and function of wings strongly influence flight performance. While wings of bats are primarily used to sustain powered flight and gliding, these highly modified forelimbs also have evolved and/or retained other critical functions. We identify and review functions of wings of bats that are not directly associated with either powered or gliding flight. Many of these non-flight uses occur during roosting periods, although some occur during flight. We suggest that the non-flight use of wings by bats may have compromised some types of flight. We have identified nearly 60 non-flight uses of wings by bats, most of which are associated with roosting, defense (e.g. crypsis and boxing), courtship (e.g. wing shaking, wing clapping), mating, parturition, parental care, grooming, non-flight locomotion (e.g. crawling, climbing, and swimming), scent marking, gas exchange, thermoregulation (e.g. wing-fanning), feeding (e.g. prey capture), and to facilitate urination and defecation. While these non-flight uses of wings are secondary to powered or gliding flight, the constraints imposed on wing form and function by these other uses also have contributed to the unique suite of life-history traits that characterize bats as a group.

3.4 KUPFER, A; KUEHNEL, S; VETTER, J; OLSSON, L*; Friedrich-Schiller-Universit Jena; *Lennart.Olsson@uni-jena.de*

Reproductive and developmental biology of caecilian amphibians

Amphibians are of prime interest for evolutionary reproductive biology because offspring nourishment encompasses a continuum from lecithotrophy to matrotrophy combined with oviparity and viviparity. Caecilians are limbless tropical amphibians, which display a high diversity of reproductive modes. In contrast to most amphibians caecilians mostly favour terrestrial reproduction, which includes oviparity with either indirect developing aquatic larvae or direct development, and viviparity. Among amphibians caecilians also show an exceptionally high level of parental care and investment ranging from egg guarding to intra-oviductal feeding and the recently discovered maternal dermatotrophy, a.k.a. "skin feeding". Relatively little is known about caecilian reproduction and development. All caecilians have internal fertilization and the male phallodeum operates as an intromittent organ during copulation. We are investigating the anatomy of the caecilian cloaca using histology and 3D reconstruction, in particular the functional association between the specific male and female morphology and their reproductive mode. We analyzed the genital morphology of male and female *Ichthyophis cf. kohtaoensis*, and present the first 3D reconstructions and visualizations of genital systems of caecilians. To study comparative aspects of caecilian cloacal development, we have set up a breeding colony of the viviparous *Geotrypetes seraphini* in the lab in order to obtain embryos and young. Colonies of other species such as direct-developing *Boulengerula* ssp. are planned. Developmental studies will include study of early cloacal development and an investigation of early head development. Comparisons with our earlier studies of cranial neural crest migration and cranial muscle morphogenesis will facilite an understanding of the evolution of caecilian head morphogenesis.

55.3 LAFLEUR, N.*; MEROW, C.; RUBEGA, M.; SILANDER, J.; University of Connecticut; *nancy.lafleur@uconn.edu*

Predicting the rate of spread for a bird-dispersed invasive plant using simulation modeling

The spread of invasive plants threatens natural resources and environments, but in many cases the mechanisms by which invasive species spread are not well understood. Here, we use simulation modeling techniques to investigate the contributions of seed dispersal distances and plant survival to the rate at which Oriental bittersweet (*Celastrus orbiculatus*), an invasive plant, spreads when dispersed by an invasive bird, the European starling (*Sturnus vulgaris*). Using data collected from plots and radio-tagged birds in northeastern Connecticut, we examined the relative contributions of mean seed dispersal distance, seedling survival, and number of seeds dispersed per km^2 to rates of plant spread. We validated our model by comparing predicted rates of spread to actual rates of spread as estimated by herbarium records from New England. Our results suggest that mean seed dispersal distance and juvenile plant survival most affect rates of spread. Further, our model accurately estimates Oriental bittersweet spread in New England, and may therefore prove useful for predicting the spread rates of newly-introduced fleshy-fruited plants.

89.4 LAILVAUX, S.P.*; HALL, M.D.; BROOKS, R.C.; University of New South Wales; *slailvaux@gmail.com*

Does whole-organism performance indicate genetic quality? A test using the black field cricket (Teleogryllus commodus)

The genetic benefits that attractive males confer on their offspring are a source of ongoing debate in evolutionary biology. Females are considered likely to mate preferentially with males of high genetic quality, but it is currently unclear which traits best reflect good genes. A growing number of studies examining whole-organism performance capacities have shown that males who are good performers not only enjoy a survival advantage in several species, but may accrue fitness benefits in terms of increased number of offspring as well. Males exhibiting superior performance capacities might therefore be considered to be high "quality" males. Here, we present the results of a large breeding experiment wherein we tested for genetic correlations between jump performance, male sexual advertisement and male sexual attractiveness in a model organism for the study of sexual selection, the black field cricket (*Teleogryllus commodus*). In particular, we examine whether jump performance might be under direct or indirect sexual selection in this species, and consider the potential evolutionary implications of links between performance and sexual selection from the perspective of quantitative genetics.

69.5 LAMMERS, A.R.*; ZURCHER, U.; Health Sciences Dept., Cleveland State University, Ohio, Physics Dept., Cleveland State University, Ohio; *a.Lammers13@csuohio.edu*

How does a small arboreal mammal use its tail to maintain its balance while traveling on tree branches?

Animals which travel on tree branches must avoid toppling from these narrow substrates because a fall may be energetically expensive or cause injury or death. Changing footfall patterns and speed, crouching to bring the center of mass closer to the substrate, and using the tail as a counterbalance are a few examples of mechanisms that an animal might use to maintain balance during locomotion. The tail might be used as a simple counterweight so that the animals weight is balanced over the narrow branch. It is also possible that the tails *movement* is important to counterbalance the bodys momentum in the mediolateral axis. We sought to quantify the means by which the tail was used during arboreal locomotion in the Siberian chipmunk (*Tamias sibiricus*). This small quadrupedal mammal is proficient at arboreal and terrestrial locomotion. Its tail is approximately the same length as the head and body length combined, and it appears that the tail is used in some way as a counterbalance. We trained the chipmunks to run across an arboreal trackway about half the diameter of the animals body. Part of the trackway was instrumented to measure torque around the long axis of the branch and substrate reaction forces. We used high speed video to measure the position of the body and tail, and the contact locations of the hands and feet as the moved across the branch. Kinetic data collected from the instrumented trackway provide a way of quantifying the degree to which the animals were off-balance during a trial. Data are being collected as of this writing; we hypothesize that both the position and the movement of the tail will contribute to balancing the animal on a narrow arboreal trackway.

5.5 LANDBERG, Tobias; University of Connecticut; *tobias.landberg@uconn.edu*

Evolution of maternal effects in sister salamander species

Egg size is a key life history trait of amphibians that varies dramatically across almost every level of organization from within individuals to between habitats. Despite harboring great adaptive potential, the phenotypic effects of egg size variation have remained elusive because other sources of variation are difficult to control or measure. To begin to address this question, I experimentally removed small quantities of yolk from embryonic salamanders of two closely related species (*Ambystoma texanum* & *A. barbouri*) that live in ponds and streams respectively. While the adults are essentially indistinguishable, they differ in reproductive traits including egg size, egg number and larval traits such as stage at hatching and time to metamorphosis. This allometric engineering experiment utilized a split-clutch design, several levels of yolk removal and a sham that controlled for the surgical procedure without actual yolk removal. Animals that had the most yolk removed hatched earliest indicating that some of the species differences in hatching time are explained by differences in yolk reserves. Body size was not as strongly affected in the pond species as it was in the stream species. Survival rates also showed interactions between species and treatment. Surprisingly, developmental rates did not appear to be strongly affected, however analysis is ongoing. Egg size effects have potential to cascade through ontogeny affecting multiple fitness-related traits and can therefore be viewed as a means of integrating complex phenotypes and potentially addressing multiple selective problems simultaneously. However, any one selective agent could drive the evolution of many traits if egg size responds to selection. This study has revealed that the plastic response to egg size can evolve even among closely related species.

29.1 LANDRY, S.O,; State Univ. of New York, Binghamton;
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Why Are There no Giant Teleosts?

Why are there no giant teleosts? Every other vertebrate clade that has entered the ocean has produced giant forms (chondrichthyans, placodermii, reptiles, mammals), Defining a giant as above 30 feet (10 meters) and one tonne, no living teleost even comes close Largest: bluefin tuna, 14 feet, and 1496 lbs (680 kg), but among living chondricthyans; Basking shark (Cetorhinus), 11.8 meters and 17.3 tonnes; whale shark (Rhyncodon), 12.2 meters and 12.7 tonnes,), Very large acquatic animals are usually filter feeders. The characteristic operculum of teleosts covers the gills and restricts the flow of water through them All teleost filter feeders are small. On the other hand the forward position of the teleost mouth parts, restricts the size of the bite, making the attacking of large prey by large fish less feasible. The characteristic gape and suck mechanism of teleosts thus restricts their ability to take large prey.

44.1 LANGKILDE, T; Penn State University; *tll30@psu.edu*

Surviving in the face of invasion: native lizards modify their behavior and morphology following the introduction of fire ants

Non-native species introductions are becoming increasingly common. We know remarkable little about the long-term consequences of the novel pressures invaders impose on the native species they encounter. In addition to being critical to the effective management of invaders, this information provides valuable insight into processes that structure communities and permit species coexistence. The red imported fire ant, *Solenopsis invicta*, is an invasive species of potential global consequence. I took advantage of the well-documented spread of fire ants across the USA to examine how interactions between this novel antagonist and a native lizard species change across invasion time. Fence lizards, *Sceloporus undulatus*, co-occur with fire ants across much of their invasive range. Attacks by fire ants on fence lizards are common and can be lethal: as few 12 ants can kill an adult lizard within a minute. Field surveys and studies of museum species reveal fence lizards have adapted to this novel threat, employing strategies that improve their chances of surviving aggressive encounters, within 70 years of invasion. Adult lizards from populations invaded by fire ants longer ago are more likely to behaviorally respond to fire ant attack than those from naive or recently invaded sites. Lizards from these populations also have relatively longer hind limbs, which increase the effectiveness of this behavior for removing attacking ants. These data contribute to our growing awareness that ecological invasions can prompt adaptive responses, altering the nature of interactions between invaders and the natives they contact.

54.9 LANGLOIS, L.; MCWILLIAMS, S.*; Univ of Rhode Island;
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Protein requirements of seasonally frugivorous songbirds decrease during migration

Many songbirds are seasonally frugivorous in that they switch to eating primarily fruit during migration and then eat insects or seeds during nonmigratory periods. Previous work suggests that most wild fruits may have plenty of carbohydrates or fats but inadequate protein for birds. Assessing the nutritional adequacy of fruit requires knowing the protein requirements of wild birds during migration in relation to the composition of available fruits. We conducted total collection trials and estimated protein requirements of two species of songbirds, the more frugivorous hermit thrush (*Catharus guttatus*) and the less frugivorous white-throated sparrow (*Zonotrichia albicollis*), during nonmigratory and migratory stages of the annual cycle. During both stages, hermit thrush and sparrows lost body mass and had more negative nitrogen balance as dietary protein decreased; hermit thrush but not sparrows ate less as dietary protein decreased even though the diets were isocaloric. Protein requirements of hermit thrush and sparrows in migratory-state (4.3 mg/day, 15.8 mg/day respectively) were significantly lower than when these birds were in nonmigratory-state (53.1 mg/day, 46.0 mg/day respectively). These findings may partially explain why birds during migration can adequately refuel on low-protein foods such as fruits.

36.2 LATTIN, Christine; Eastern Kentucky University;
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Is song length an important signal of aggression in Blue Grosbeaks?

Although investigators have examined how males in some bird species use different songs in their repertoire for different signaling purposes, less is known about how birds alter the characteristics of individual songs to convey different messages. To test the hypothesis that song length is an important signal of aggression for male Blue Grosbeaks (*Passerina caerulea*), I did playback experiments (n = 15) using short, medium-length and long songs. In addition, I recorded male Blue Grosbeaks (n = 18) from 1 May to 31 July 2007 in natural aggressive contexts ranging from spontaneous advertisement to short-range countersinging with conspecifics. Playback experiments ran from 7-29 July 2007. Playback order was randomly determined, and tests separated by several days. I noted the focal male's location every 15 s, as well as the closest approach to the playback speaker, number of flights, number of calls ('chip' notes), and number of songs. Compared to their response to short and medium-length songs, male Blue Grosbeaks came closer to the speaker ($p = 0.0026$) and remained closer to the speaker (mean distance; $p = 0.0072$) during and after playback of long songs, and uttered more songs ($p = 0.023$) in post-playback. The mean number of syllables per Blue Grosbeak song increased in more aggressive natural contexts ($p=0.0002$), from a mean of 12.02+/-0.3 syllables/song during spontaneous advertisement to 17.21+/-0.3 syllables/song in short-range aggressive encounters. These results suggest that altering song length is one way male Blue Grosbeaks can signal different levels of aggressive intent to conspecific males.

1.6 LAVALLI, K.L.*; HERRNKIND, W.F.; Boston University, Boston, MA, Florida State University, Tallahassee, FL; *klavalli@bu.edu*

Defensive Strategies of Caribbean Spiny Lobsters: Effects of Lobster and Predator Group Size

Migrating queues of Caribbean spiny lobsters *Panulirus argus* can potentially suffer attacks during daylight by variable numbers of piscine predators, particularly triggerfish that are found on reefs and open terrain that lobsters use. When attacked, queued lobsters assemble into outward facing radial groups, remain coherent, and defend against attack by parrying with ther antennae. The studies presented here summarize both field tethering trials and mesocosm free-ranging trials. In 1-hour long field tethering trials, solitary lobsters were subdued 44% of the time while lobster groups of five suffered only minor bites; triggerfish present numbered from 4-23. In a series of experiments in large seawater enclosures, we pitted 1, 3, 5, 10 or 20 free moving lobsters against 2, or 5 gray triggerfish, *Balistes capriscus*, all of which had previously killed lobsters. We hypothesized that larger fish numbers would be more effective in subduing the prey independent of lobster group size, but that lobsters in larger groups would benefit by a higher per capita survival rate, as compared to smaller groups. We found that per capita mortality declined with lobster group size, but remained the same statistically whether there were two or five triggerfish, due to interactions between the triggerfish that reduced the effectiveness of attacks. Additional survival advantages arise with increasing lobster group size, such that individuals may potentially have to expend less energy in defensive behaviors. These results suggest that the communal defense of spiny lobsters is primarily a selfish action of individuals, rather than true cooperation.

101.8 LE CAM, Sabrina; VIARD, Frederique; CAGNON, Mathilde ; PECHENIK, Jan A.*; Station Biologique de Roscoff , Tufts University; *jan.pechenik@tufts.edu*

Role of multiple paternity in causing variation in larval growth rates in the gastropod Crepidula fornicata

The gastropod *Crepidula fornicata* has a long-lived larval stage that feeds on phytoplankton. During development, the larvae grow from about 400-450 µm to about 1000 µm in shell length, with the rate of growth varying markedly even among individuals from a single hatch from a single female. Some of that variation might be due to a familial component associated with multiple paternity, which is commonly observed in this species. To test that hypothesis, we reared the larvae from 6 females for about 1-2 weeks and then measured about 40 of the smallest (i.e., slowest-growing) individuals and about 40 of the largest (i.e., fastest-growing) individuals and preserved each larva separately for genetic analysis. We also preserved all of the conspecifics associated with each female. Paternity analyses based on microsatellite genotyping were then used to determine the father of larvae from each of the 2 categories. Among the 6 sampled females, most of the larvae were convincingly assigned to a male that was physically associated with the mother at the time of collection. The larvae sampled from each female had from 2-5 different fathers, most of which contributed to producing both fast and slow growing larvae. However, some fathers produced primarily fast-growing larvae within a brood. Our results suggest that multiple paternity in this species may increase the range of larval growth rates among siblings. To the extent that growth rates correlate with time to metamorphic competence, multiple paternity might contribute also to a larger range of planktonic periods and dispersal distances for sibling larvae.

S3.9 LEARY, C.J.; University of Utah; *leary@biology.utah.edu*

Hormonal regulation of vocalization in anuran amphibians: insights from toads with alternative mating tactics

Despite the long history of anuran amphibians as models in physiology and acoustic communication, relatively little is known about the relationships between circulating hormone levels and vocal performance. In this presentation, I will present data on hormone-vocal relationships in two toad species, *Bufo woodhousii* and *B. cognatus*, that conditionally alternate between calling and non-calling mating tactics. In both species, high levels of corticosterone (CORT) suppress vocalization and elicit the adoption of the satellite mating tactic. In the former species, CORT level does not appear to alter various call parameters important in mate selection. In *B. cognatus*, however, CORT administration experiments indicate that, prior to cessation of vocalization, there is a progressive decrease in call duration as CORT levels increase. This effect of CORT on call duration also influences interactions among males in natural choruses; calling males with associated satellite males have lower levels of circulating CORT and longer calls than calling males without satellites. Satellite males thus appear to maximize their chances of intercepting mates by associating with those calling males that are also preferred by females. Attractive males with low levels of circulating CORT may, however, experience a decrease in mating success by attracting satellite males. In none of these studies could the behavioral changes be attributed to changes in androgen levels, as has been predicted by recent models for the regulation of vocal performance in anuran amphibians. These results highlight that stress hormones like CORT can have considerable influence on male traits important for sexual selection.

54.6 LEASE, HM*; KLOK, CJ; KAISER, A; HARRISON, JF; University of New Mexico, Willamette University, Arizona State University, Midwestern University; *hlease@unm.edu*

The Scaling of Critical P_{O2} in Coleoptera

Because diffusion rates are highly dependent on distance, and because tracheal length increases with size, gas exchange has traditionally been thought to be more difficult for larger insects. However, intraspecific studies in grasshoppers and caterpillars, and interspecific studies in grasshoppers suggest that critical P_{O2} values do not increase with body size in insects. The lack of a positive correlation between body size and critical P_{O2} may occur because larger insects have enhanced respiratory capacity (Greenlee and Harrison 2004), partially attributable to increased relative investment in the tracheal system as body size increases. For example, intraspecific and interspecific tracheal volume have been shown to scale with mass$^{1.3}$ (Lease et al. 2006, Kaiser et al. 2007) for some insect groups. However, as yet the effect of body size on critical P_{O2} has not been measured for the single group of insects (beetles) for which there is interspecific data on tracheal scaling. In this study, we address this deficiency by measuring the critical P_{O2} for CO_2 emission rates across 4 orders of magnitude of body size (1 mg to 4 g) of two families of Coleoptera (Tenebrionidae and Scarabaeidae). We exposed adult beetles to progressively lower oxygen levels, and measured their ability to maintain CO_2 emission rates. As predicted, absolute metabolic rates increased with beetle body size at both normoxic and hypoxic conditions; and as oxygen levels decreased, mean CO_2 output for all species decreased. Critical P_{O2}, however, was independent of size. These data suggest that tracheal conductance increases as insects get larger, enabling similar oxygen delivery safety margins for large and small beetles. These data support the hypothesis that larger insects achieve these similar oxygen delivery safety margins by increasing relative investment in the tracheal system. This research was partially supported by NSF IBN 0419704 to JFH.

50.2 LEE, Trixie N.*; BUCK, C. Loren; BARNES, Brian M.; O'BRIEN, Diane M.; Univ. of Alaska, Fairbanks, Univ. of Alaska, Anchorage; *fttnl@uaf.edu*

Using stable isotopes to track tissue catabolism during hibernation in an extreme arctic hibernator, Spermophilus parryii

Arctic ground squirrels (*Spermophilus parryii*) are small hibernators in the extreme arctic environment. Although lipid is the sole fuel source during hibernation in many species, *S. parryii* also utilizes considerable amounts of lean mass to meet the high energetic demands of maintaining a large thermal gradient in subzero ambient temperatures. Changes in stable nitrogen isotope ratios can reflect protein metabolism during fasting and may be useful to elucidate the source of lean mass loss during hibernation. Ambient hibernation temperatures of -10C invoke an 8-fold increase in metabolic rate during torpor and a shift toward metabolism of glucose and amino acids. We divided *S. parryi* hibernating in captivity at 2C into two thermal regimes, -10C (thermally regulating) and 2C (thermally neutral), and measured nitrogen isotope ratios in a suite of tissues collected at the beginning of hibernation and after 45, 68, and 90 days of hibernation. Tissues varied dramatically in nitrogen isotope ratios: organs, including heart, liver, brown adipose tissue, and small intestine, enriched during hibernation while four skeletal muscles did not. The pattern of enrichment differed with thermal stress as animals at -10C were generally more enriched. Plasma reflected organ metabolism while red blood cells remained stable. These results indicate that muscles are not a source of protein during early hibernation. By pairing this knowledge with field measurements of thermal regime, lean mass loss, and isotope enrichment, we hope to arrive at a more complete understanding of protein catabolism and its physiological impact on these extreme hibernators.

24.6 LEE, W.-K.; SOCHA, J.J.*; Argonne National Laboratory, Virginia Tech; *jjsocha@vt.edu*

Direct visualization of hemolymph flow in the heart of a grasshopper

Most insect circulatory systems are open, consisting solely of a muscular tube that runs from the abdomen to the anterior body. The heart system includes ostial valves, which can effect incurrent and excurrent flows, and fan-like muscles that originate at the body wall and insert serially along the heart. The combination of complex valving and muscle actuation can result in flow patterns that are not easily predicted from first principles; for instance, some insects are known to periodically reverse heart flow direction. Previous work on insect circulation has determined heartbeat patterns using indirect methods such as contact thermography or infrared light absorbance, but these methods only record bulk flow. Here, we used synchrotron x-ray phase contrast imaging combined with tracer particles to directly visualize intra-heart flow patterns in a grasshopper (*Schistocerca americana*). We used medical-grade microbubbles (~5 μm) and air bubbles (~10-40 μm) as flow markers, injected into the abdomens of grasshoppers, and recorded videos in real time using 25 keV x-rays. Analyses of x-ray videos reveal that: 1) Flow patterns were complex and time and location dependent, and some flows appear to exhibit a three-dimensional geometry; 2) At times there was no overall transport, but simply a back-and-forth oscillation of the hemolymph; 3) Respiratory structures (tracheae and/or air sacs) were compressed in patterns both synchronous or asynchronous to the local heartbeat; and 4) Maximum measured flows of were on the order of 1.0 cm/s with a Reynolds number of about 5. In addition, we observed possible vortices and incurrent flow through ostial openings. This work represents a new method of visualizing fluid flows in small (millimeter-to-centimeter scale) animals, and may have broad applications across fields, particularly involving developmental studies of vertebrate circulatory systems.

86.4 LEE, J.*; CHOI, J.T.; BASTIAN, A.J.; COWAN, N.J.; Johns Hopkins University; *jsl@jhu.edu*

Fitting the closed-loop dynamics of human running on a split-belt treadmill

Healthy humans alter their gait when walking or running on a split-belt treadmill (i.e. a treadmill that allows independent speed control for each leg). When one leg is driven to move faster than the other, people immediately use feedback to change stance and swing times to maintain a 1:1 antiphase gait pattern. If the perturbation is sustained, they also slowly adapt feedforward control of their gait to further optimize spatial and temporal patterns. Here we present the first empirically fitted closed-loop dynamical model of steady running (i.e. no adaptation) on a split-belt treadmill. We captured body kinematics from a healthy human subject running on a treadmill under various belt-speed perturbations. A linear discrete-time model parsimoniously captures the evolution of the subject's state, namely, forward body position, body height, and forward speed, at apexes. The model determines the next apex state by a linear combination of the current and previous apex states as well as the current and previous treadmill inputs. For our next step, we will fit our proposed model to perturbation trials in which subjects are adapting to a sustained split-belt condition. With proper detrending of the data as well as accounting for nonlinearities, we will test whether or not adaptation contributes to the overall closed-loop dynamics on the split-belt. If not, it would imply that feedback gains are not adapted, and that the adaptation can be attributed to modifications of the feedforward pattern alone.

62.5 LENKOWSKI, J.R.*; MCLAUGHLIN, K.M.; Tufts Univ., Medford, MA; *jenny.lenkowski@tufts.edu*

Disruption of tissue morphogenesis in pesticide-exposed Xenopus laevis tadpoles

A countless number of anthropogenic chemicals are released into the environment every day without a full understanding of how they may affect non-target organisms. One such chemical is the widely used herbicide atrazine. Atrazine was originally designed to inhibit photosynthesis in weeds, but has since been implicated as a contributing factor to anomalies in development and reproductive systems observed in wild and laboratory amphibian populations. As amphibians are particularly sensitive to environmental contaminants due to their use of both aquatic and terrestrial habitats, studies have continued to use amphibians to examine the effects of environmental contaminants. We have previously described increased malformations and apoptosis following acute atrazine exposure during the specific developmental window of organ morphogenesis in the model species *Xenopus laevis*. In our laboratory studies we are now further examining the effects of atrazine exposure during these stages on the morphogenesis of muscle and cartilage, as well as expression of matrix metalloproteinases (MMP) that degrade the extracellular matrix. We have found muscle degradation in the tail and gut of malformed animals using an acute atrazine exposure. In addition, misregulation of the thyroid-hormone regulated MMP, MMP18, occurs as quickly as 24 hours after the start of exposure. In order to extend these findings, we hope to determine the dose response and timing of these effects. Our results begin to explain how atrazine can affect processes that are important for organ morphogenesis during amphibian development which have not been thoroughly examined in previous studies. Importantly, our studies further demonstrate the importance of characterizing teratogenic effects of environmental chemicals at many stages of development using multiple experimental strategies

52.3 LENTINK, David*; DICKSON, William B.; VAN LEEUWEN, Johan L.; DICKINSON, Michael H.; Wageningen University, California Institute of Technology; *david.lentink@wur.nl*

Leading edge vortices elevate lift of autorotating plant seeds

As they descend, the autorotating seeds of maples and some other tree species generate exceptionally high lift, but how they attain this elevated performance is unknown. To elucidate the mechanisms responsible, we measured the three-dimensional flow around dynamically-scaled models of maple and hornbeam seeds. We show that these seeds attain high lift by generating a stable leading edge vortex (LEV) as they slowly descend. The compact LEV of maple seeds allows them to remain in the air more effectively than do a variety of non-autorotating seeds. LEVs also explain the high lift generated by hovering insects, bats, and possibly, hummingbirds. This suggests that the use of LEVs represents a convergent aerodynamic solution in the evolution of flight performance in both animals and plants.

5.6 LETTIERI, Liliana*; STREELMAN, J. Todd; Georgia Institute of Technology; *liliana@gatech.edu*

Colorful stripes send mixed signals from cleaner gobies to risky reef fish clients

Parasite cleaning mutualisms may be risky for cleaners because many visitors to cleaning stations are predators. We have shown, using visual models, that blue stripes of cleaner gobies increase contrast and attractiveness against typical coral reef microhabitats. Here we demonstrate in laboratory experiments that cleaner gobies possess chemical defenses against predation and that higher contrast colors correlate with increased chemical deterrence. We therefore predicted that blue striped gobies would both attract more potential clients and deter predation attempts. We used video monitoring of painted goby models to test whether approach frequency, risk of attack, and stylized client posing differed between non-striped, yellow- and blue-striped patterns. Blue-striped models elicit more approaches and induce posing more frequently than yellow-striped models. This increase in visitation does not result in higher numbers of attacks as striped models are attacked less frequently than non-striped. Obligate mutualists must attract partners and may use multiple sensory cues and modalities to signal cooperative status while avoiding predation. Our data suggest that colorful stripes in cleaner gobies send the dual signals of cooperation and defense. Cheating by predators in such mutualistic partnerships may be actively deterred by chemical defenses in a wide variety of systems.

S5.3 LEYS, SP; University of Alberta; *sleys@ualberta.ca*

Evolution of animal body plans evidence for early sophistication in sponge physiology and morphology

One of the most dramatic transitions in the evolution of animals was becoming multicellular. Multicellularity required coordination among cells for feeding, growth and reproduction, which may initially have been via the secretion of signaling molecules. Multicellular fungi signal to organize polarity and structure, both with local messenger molecules and with molecules acting over longer distances. Responsiveness via electrical signaling was invented multiple times in protists (e.g., the bright flash emitted by Noticula or the avoidance response of Paramecium or Stentor). But in the evolution of multicellular animals cells presumably needed to retain their identity and position relative to one another to enable a unified (whole organism) response. This entailed evolution of an epithelium that regulated the internal ionic milieu, and permitted cell-cell signaling both during development and homeostasis. This level of organization is seen in modern sponges (Porifera). An evaluation of sponge integrity shows that during embryogenesis cells are organized by signaling molecules into differentiated tissues, the outermost of which form functional epithelia and is essential to the animals physiology. Sponges are specialized suspension feeders, superbly designed to extract minute particles (bacteria and flagellates) from a three dimensional environment. Despite this apparently simple lifestyle, the sponge body plan reflects innovations that are found in other filtration and gas exchange systems such as the kidney and lung, including alveolar-like extensions of the canal system, primary cilia that likely play a role in sensing water flow, and one-way valves that prevent backflushing during contractions to expel waste. Thus studies from sponges show that physiological and morphological integration arose early during the evolution of multicellular animals.

86.5 LI, C.*; UMBANHOWAR, P.; KOMSUOGLU, H.; KODITSCHEK, D.E.; GOLDMAN, D.I.; Georgia Insitute of Technology, University of Pennsylvania, University of Pennsylvania; *chen.li@gatech.edu*

Enhancement of legged robot speed on granular media using kinematics which promote solidification

Model locomotors (e.g. legged robots) have begun to achieve mobility comparable to organisms on hard ground but suffer significant performance loss on granular media (e.g. sand). Based on observations of lizards and crabs running on both hard ground and granular media, we hypothesize that organisms modify their gaits on granular media to take advantage of its solidification properties to achieve high performance. We test this hypothesis in laboratory experiments on a model locomotor, a six-legged 2.3 kg robot, SandBot, on a controlled trackway of granular media (poppy seeds) as a function of limb rotation frequency $4 <$ < 30 rad/sec and material preparation (packing fraction $0.58 <$ < 0.63). A fluidized bed sets the initial via repeated pulses of air through the granular media. Kinematic parameters which generate a bouncing alternating tripod gait yield average speeds (v_a) up to 50 cm/sec on hard ground but result in a slow swimming motion in granular media (~ 1 cm/sec). With proper adjustment of the limb kinematics, SandBot achieves v_a of up to 30 cm/sec on granular media using a pendulum-like walking gait. A model of Sandbot's motion based on balancing inertial and granular forces indicates that properly tuned kinematics minimize inertial stress and simultaneously maximize grain stress. Systematic variation of and reveal that v_a of the robot is a sensitive function of both parameters. For fixed > 0.6 and increasing , v_a displays a maximum at a frequency *( ), beyond which v_a decreases rapidly with increasing . For < *, the robot walks using a pendulum-like gait and for > * it swims using a paddling motion.

90.6 LIANG, Haiyi*; MAHADEVAN, L; Harvard University;
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The undulating shape of growing surfaces

The undulating morphology of leaves and petals is now accepted as a consequence of differential growth of the underlying tissue. Various qualitative and quantitative aspects of the buckling patterns seen in both vascular and avascular leaves may thus be ascribed to the distribution of non-uniform growth in the lamina, and have been demonstrated in normal and mutant leaves, as well as in physical models thereof. To understand the different modalities that arise quantitatively, we construct a mathematical model for the stability of an initially flat elastic ribbon with excess growth along its edges, directly motivated by observations of kelp that are capable of phenotypic plasticity in different environments. Using a combination of analysis and numerical simulation, we map out the phase space of possible shapes for these growing ribbons. We find that are two generic buckling modes that arise: a global catenoid-like structure and a more localized periodically-rippled structure. In general, we find that as the relative growth strain is increased, the flat ribbon-like structure switches to a catenoidal shape before developing undulating edges that can develop on the catenoid's edges. Our theoretical and numerical framework allows us to delineate the few macroscopic parameters that control the morphology of leaves and captures a large variety of observed shapes in elongated blade-like leaves.

86.2 LIEBERMAN, DE*; WERBEL, W; DAOUD, A; Harvard University;
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Biomechanics of foot strike in habitually barefoot versus shod runners

Hominins evolved to run long distances, possibly as much as 2 million years ago, and until recently, humans ran either barefoot or in soft sandals with minimal cushioning or arch support. Here we investigate whether heel strikes, characteristic of approximately 80% of modern shod runners, are typical of habitually barefoot runners. We also investigated how the foots initial contact with the ground influences the rate and magnitude of the heel strike transient (HST), an impulse several times body weight that travels from the ground to the head in less than 10 ms, and which is thought to be a major cause of injury among distance runners. Leg kinematics, HST ground reaction forces, and foot strike patterns were recorded in habitually shod runners, habitual barefoot runners, and in a group of habitually shod runners training to run in Vibram FiveFingers (VFF, a shoe that protects the sole of the foot but provides no arch support or cushioning). We found that habitual barefoot runners while running barefoot avoid heel strikes, and tend to exhibit lower rates of HST loading than do habitually shod subjects in the same condition. In addition, after several weeks of training in VFF, runners transitioned to a higher percentage of midfoot strikes. For all groups in the barefoot condition, decreased HST loading rates were significantly correlated with a lower angle of incidence of the foot at heel strike and with greater limb compliance during the initial part of the stance phase. Although running shoes with large cushioned heels decrease the magnitude and rate of loading from the HST, habitual barefoot runners face different HST loading regimes than habitually shod runners.

54.11 LIGHTON, JRB; Univ. of Nevada, Las Vegas; *lighton@sablesys.com*

FM, not AM: Gas exchange during rest and activity in non-flying insects

Using the xeric tenebrionid beetle *Cryptoglossa verrucosa* as a model animal, and using a very fast-responding flow-through respirometry system, I show that the kinetics of gas exchange during activity are practically identical to those during the V (Ventilation) phase of the discontinuous gas exchange cycle or DGC, which is expressed only when the insect is completely inactive. This re-purposing of a fixed component of the DGC for use during locomotion has not previously been described. That maximal rates and frequencies of gas exchange during the cyclic bouts of convective ventilation characterizing the V phase of the DGC do not differ significantly from those found during activity has implications on the evolutionary origins of different gas exchange strategies among insects that will be explored.

49.5 LOH, Y.-H.E.*; STREELMAN, J.T.; Georgia Institute of Technology;
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MicroRNAs from cichlid genomes

MicroRNAs are small RNA molecules of approximately 22 nucleotides known to hybridize to 3' untranslated regions (3' UTRs) of target messenger RNAs (mRNAs), thereby effecting gene silencing through translation inhibition or targeted mRNA degradation. They are an integral class of regulatory molecules, with each microRNA having the potential to regulate many genes (200 on average), while each gene may in turn be regulated by numerous different microRNAs. While microRNA regulation has been implicated in a diverse range of biological processes and diseases, such as development, cell proliferation and differentiation, neurogeneration and neurodegeneration, and many forms of cancer, the complex interplay between microRNAs and their target genes also provides fertile grounds on which regulatory mutations might produce phenotypic differentiation without adverse pleiotropic consequences. Cichlid fishes from the East African Rift lakes Victoria, Tanganyika and Malawi display a compendium of diverse and replicated morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years. Has the evolution of diversity in cichlids been driven by genetic changes in microRNAs or their target sequences? We used computational methods to predict microRNAs from a growing collection of cichlid genomic resources. We also identified thousands of corresponding putative target sequences in 3' UTRs of cichlid genes. We aim to integrate variation in microRNA and/or target sequences with differential expression of microRNAs and their target genes to explore the role of these molecules in rapid phenotypic diversification.

101.1 LOPEZ-DUARTE, P.C.*; TANKERSLEY, R.A.; Scripps Institution of Oceanography, Florida Institute of Technology; *plopezduarte@ucsd.edu*

Where Did You Get That Rhythm? Plasticity in the Circatidal Swimming Behavior of Fiddler Crab Larvae

Fiddler crab *Uca pugilator* larvae (zoeae) possess an ebb-phased circatidal rhythm in vertical swimming that matches the period of the local tidal regime (~12.4 or 24.8 h) and facilitates export from estuaries to offshore development areas. We tested the hypothesis that the rhythm exhibited by *U. pugilator* zoeae is phenotypically plastic and entrained in embryos prior to hatching. To test whether developing embryos receive tidal information from cues associated with the adult habitat, ovigerous females were reciprocally translocated between beaches with diurnal and mixed tides. To test the alternative hypothesis that tidal information is communicated from mother to embryos during incubation, egg clusters were exchanged between crabs from areas with semidiurnal and diurnal tides. Swimming activity of transplanted zoeae was compared to that of larvae from the original (donor) and recipient (surrogate) egg masses. Vertical swimming activity was monitored under constant conditions for 72 h using a time-lapse video system. Larvae from female crabs translocated between beaches possessed ebb-phased circatidal rhythms that matched the dominant period of the tides at the original (native) beach. However, larvae from egg clusters exchanged between crabs from different beaches possessed circatidal rhythms that differed significantly from those exhibited by larvae from the original (donor) egg mass. These results suggest that the period and phase of the circatidal rhythms exhibited by *U. pugilator* zoeae are not influenced by environmental conditions prior to hatching, but instead are the result of some unknown interaction or communication between the female and embryo during brooding.

S3.4 LORENZ, M.W.*; GAEDE, G.; University of Bayreuth, University of Cape Town; *matthias.lorenz@uni-bayreuth.de*

The role of insect adipokinetic hormones in locomotion, development and reproduction

Many insect hormones have a direct or indirect influence on metabolic events in insects. One of the true metabolic hormones is the adipokinetic hormone (AKH) which has been compared in some of its actions with vertebrate hormones such as glucagon or adrenalin. In addition to the well-established glucagon-like effects, many additional functions of this small neuropeptide have been established. The present paper briefly summarises the multiple actions of AKH and focuses on three situations where the energy demand is high: locomotion, reproduction, and moulting. During flight, aerobic metabolism is increased up to 100-fold; substrates such as lipids, carbohydrates or proline are mobilised from the fat body. Mobilisation, transport, and uptake of these substrates are specifically regulated by AKH. Recent work on other locomotory behaviour such as swimming or walking, clearly demonstrates a regulatory function of AKH. Females of flying insects are faced with the problem of energy allocation during vitellogenesis. Some species produce huge numbers of eggs that are rich in energetic substrates at the cost of reduced flight ability (oogenesis-flight syndrome). We show that AKH is involved in the control of egg production and evaluate the role of AKH in regulating energy allocation. Finally, larval development is characterised by phases of starvation due to the necessity to empty the gut prior to moulting. Thus, starvation coincides with increased energy demand for the synthesis of the new cuticle and the emergence of the insect from the old cuticle. On the basis of these events, we discuss the significance of AKH in larval insects.

64.3 LOSOS, J.B.; Harvard University; *jlosos@oeb.harvard.edu*

Is Adaptive Radiation an island phenomenon? Comparison of Mainland and West Indian Anolis Lizard Evolution

West Indian anoles have radiated independently on each island in the Greater Antilles, producing in each case species morphologically and behaviorally adapted to use a wide variety of different ecological niches. Less well known is the fact that the diversity of anoles in mainland Central and South America is equally rich, both in terms of species number and ecomorphological disparity. In this study, we compare the extent of morphological variation. We demonstrate that mainland anoles occupy different parts of morphological space than that occupied by West Indian anoles; mainland anoles belong to two clades and have convergently evolved to occupy overlapping portions of morphological space. Comparison between mainland and island anoles indicates that the habitat specialiststermed ecomorphsthat have evolved repeatedly in the West Indies have not, for the most part, evolved in the mainland. Moreover, the relationship between morphology and habitat use differs between mainland and island forms. Greater predator richness and diversity in the mainland than on the islands may account for the different evolutionary trajectories experienced in these two areas.

63.3 LUND, R.*; GROGAN, E.D.; Carnegie Museum, Saint Joseph's University; *rlund@sju.edu*

Tooth Whorls in Chondrichthyes: The Edestoids, Helicoprion, and other Nightmarish Sharks of the Past

Tooth arches or whorls of the Edestoid and Helicoprionid Chondrichthyes (Euchondrocephali) of the Upper Paleozoic are borne upon calcified cartilage and bear triangular serrated teeth like those of *Carcharodon megalodon*. Virtually no head or postcranial information accompanies these specimens. The sizes of these arches or whorls approach 1 meter in length or diameter. Past restorations have placed these on the snout, anterior to the dorsal or/and anal fins, and at the tip of the dorsal lobe of the tail before settling in the mouth. Most recently they have been theorized to be part of a pharyngeal apparatus. Data from new taxa shed broader light on the question of what and where these structures are found. Tooth whorls mounted on parasymphysial and symphysial cartilages are found in most basal Chondrichthyes and virtually all known Euchondrocephali (Holocephali); they are absent in Elasmobranchii. Tooth whorls are also found in basal chondrichthyan taxa that lack mandibular arch teeth. Analyses suggest they are under the control of separate developmental fields from that of mandibular arch teeth. Thus, even the anterior upper dental positions of the cochliodont Holocephali, which are also under control of separate developmental fields, are hypothesized to be parasymphysial elements fused to the neurocranium. While multiple upper and lower whorls or families are found in some Iniopterygians, the basic euchondrichthyan pattern of tooth whorls is for paired uppers and a median lower whorl. This is also the condition in the few known edestoids, including *Edestus mirus*. There is no evidence for large tooth whorls in any chondrichthyan pharynx. A two foot diameter *Helicoprion* symphysial tooth whorl translates into an approximately 50 foot long fish.

29.4 LUTTERSCHMIDT, D.I.*; MASON, R.T.; Georgia State University, Atlanta, Oregon State University, Corvallis; *lutterschmidt@gsu.edu*

Endocrine mechanisms mediating temperature-induced reproductive behavior in garter snakes (Thamnophis sirtalis).

In many hibernating ectotherms, photoperiod cues likely have little or no influence on the initiation of spring reproductive behavior. Rather, temperature may be the most important environmental cue for synchronizing seasonal rhythms. We investigated the mechanisms by which temperature induces seasonal reproductive behavior in red-sided garter snakes (*Thamnophis sirtalis parietalis*). Specifically, we addressed whether elevated environmental temperatures during winter dormancy influence (1) patterns of sex steroid hormones; (2) diel melatonin and corticosterone rhythms; and (3) the expression of courtship behavior following emergence. Elevated hibernation temperatures (i.e., 10C versus 5C) significantly decreased androgen concentrations of male snakes during winter dormancy, presumably via increased metabolic clearance. In contrast, estradiol concentrations of female snakes increased significantly during winter dormancy and were not affected by hibernation temperature. Elevated hibernation temperatures also significantly increased melatonin and decreased corticosterone concentrations of snakes. The cold temperature-induced differences in melatonin rhythms between the 5C and 10C hibernation temperature groups persisted even after both groups were again acclimated to 10C, indicating that cold temperature exposure has a lasting influence on melatonin rhythms. Following winter dormancy, we observed robust courtship behavior in all treatment groups. However, males maintained at 10C during winter dormancy exhibited delayed onset of courtship behavior. Our results suggest that environmental temperatures induce reproductive behavior, in part, via changes in melatonin and/or corticosterone rhythms in this seasonally breeding reptile.

19.1 LYNCH, Kathleen S.*; BALL, Gregory F.; Johns Hopkins University; *lynchks@jhu.edu*

Noradrenaline, Receiver Error and the Cocktail Party Effect

In humans, the ability to attend to important signals while simultaneously rejecting intrusion from other sources is termed the 'cocktail party effect'. This task is relevant to the study of animal communication because animals often communicate within a cacophonous background of noise, which may result in signal detection errors. We examined the role of the noradrenergic (NA) system during signal reception. The NA system simultaneously regulates selective attention and sensory processing thus, it is possible that it is involved in signal detection. We degraded the noradrenergic system in female canaries (Serinus canaria) by administering N-(2-chloroethyl)-N-2-bromobenzyl-amine hydrochloride (DSP-4), a noradrenergic-specific neurotoxin. We measured auditory responses to conspecific and heterospecific songs using ZENK protein expression within the caudomedial nidopallium (NCM) and the mesopallium caudomedial (CMM). ZENK expression in these regions is typically higher in birds exposed to conspecific songs as compared to heterospecific songs. We found that that this differential ZENK induction is abolished specifically within dNCM and CMM in female canaries treated with DSP-4. Furthermore, in DSP-4 treated birds, conspecific song-induced ZENK expression is significantly reduced as compared to saline treated birds. This suggests that the noradrenergic system modifies auditory processing by enhancing neuronal responses to conspecific songs rather than inhibiting neuronal responses to signals that are less relevant, such as heterospecific songs. Together, our results reveal that noradrenaline regulates auditory processing in such a way that facilitates the females ability to assess communication signals.

26.10 LYNCH, Vincent/J*; WAGNER, Gunter/P; Yale University; *vincent.j.lynch@yale.edu*

Domestication and adaptation of a transposable element in to a tissue-specific enhancer of prolactin (PRL) was an essential step in the origin of pregnancy in placental mammals

The evolution of gene regulation, particularly through cis-regulatory element and transcription factor change, is widely thought to be the molecular basis developmental evolution. Classic early studies suggested that repetitive elements may have played an important role in reorganizing genomes and regulatory networks promoting the origin of novel gene regulatory links, but clear examples of transposable elements conferring positive effects on gene regulation are still rare. Here, were show that a transposable element (MER20) integrated upstream of prolactin (PRL), a multifunctional gene essential for implantation and pregnancy, in the stem-lineage of placental mammals and generated a novel tissue-specific enhancer that drives PRL expression in the uterus and placenta. Molecular evolutionary analysis of the MER20-derived enhancer indicates that some binding sites are ancient and likely were function upon insertion while other binding-sites for several transcription factors that regulate PRL have statistical signatures of adaptive evolution coincident with the origin of PRL expression in the female reproductive tract. Remarkably, many of the nucleotide substitutions in the MER20-derived PRL enhancer mutated pre binding-sites into consensus binding sites for transcription factors that regulate uterine PRL expression. These results show that transposable elements can contribute to evolutionarily important changes in gene regulation, potentially generating novel regulons and facilitating developmental evolution.

14.5 LYNN, S. E.*; PRINCE, L. E. ; SCHOOK, D. E. ; MOORE, I. T. ; The College of Wooster, Virginia Tech; *slynn@wooster.edu*

Interactions of testosterone and paternal care in a tropically breeding sparrow

In most male birds that exhibit paternal care, elevated testosterone (T) reduces nestling provisioning, which can be detrimental to offspring survival. Two mechanisms may enable some males to avoid this potentially detrimental effect of responding to elevated T: (1) decreased sensitivity to Ts effects on behavior, and/or (2) decoupling of T secretion from territorial challenges. Both mechanisms have been documented, however whether selection for them is correlated or independent is unknown. We investigated the relationship of elevated T and paternal care in a tropical bird, the rufous-collared sparrow (*Zonotrichia capensis*). *Z. capensis* have a flexible breeding season and smaller clutch size than temperate congeners. Males also do not increase plasma T in response to territorial challenges. We implanted males with T or empty implants, and later observed paternal behavior 2-3 and 6-7 days post-hatch. During both observation periods, control males fed chicks significantly more often than T-implanted males. In fact, 100% of control males fed chicks during both observation periods, whereas 22% and 0% of T-implanted males fed chicks on days 2-3 and 6-7, respectively. Chicks of T-implanted males weighed less than control chicks, but tarsus growth, wing growth, and fledging success did not differ. Thus, we demonstrate a robust negative effect of T on nestling provisioning that may not impact reproductive success. Some of the differences we describe between this tropical bird and previous studies on higher latitude species may relate to life history characteristics of tropical breeders, including extreme flexibility in breeding schedule and small clutch size. Our data also suggest selection for mechanisms to avoid the costs of elevated T during the parental phase occurs independently.

95.5 LYONS, P.J.; Stony Brook Univ.; *plyons@life.bio.sunysb.edu*
Dynamics of Shrimp Goby Mutualism in the Caribbean
In the mutualism between burrowing alpheid shrimp and gobies, the goby gains shelter and the shrimp benefits from the alarm against predators generated by flutters of the gobys caudal fin. In the Caribbean, the shrimp, *Alpheus floridanus*, associates with three gobies; *Nes longus*, is an obligate mutualist, while two others, *Ctenogobius saepepallens* and *Bathygobius curacao*, are facultative mutualists. I studied dynamics of the *N. longus* and *C. saepepallens* association with *A. floridanus* in the Bahamas. *N. longus* density was positively correlated with *A. floridanus* density but *C. saepepallens* density showed no trend. *N. longus* individuals are always associated with a single burrow often positioned to best relay warning to their shrimp partner (proximal to the entrance and with the caudal tail pointing toward the entrance); *C. saepepallens* are nomadic and rarely positioned as such. *N. longus*, the obligate mutualist seek shrimp partners, while *C. saepepallens* only seek shelter. *A. floridanus* prefer entrances guarded by *N. longus* rather than the facultative mutualist *C. saepepallens*. *N. longus* individuals compete for shrimp partners, the outcome which is determined by the size of the competitors. Our results demonstrate the dimensions of the facultative and obligate states of *C. saepepallens* and *N. longus*, respectively. *N. longus* and *A. floridanus* are seemingly well co-evolved. Reportedly, the third goby *B. curacao* often remain associated with one shrimp (as *N. longus* does) but do not provide a warning signal (as *C. saepepallens* doesnt). We speculate that *C. saepepallens* represents a first step toward obligate mutualism, *B. curacao* a second step, and *N. longus* the final step.

S10.1 MABRY, Karen E; Miami University; *mabryk@muohio.edu*
Ecological influences on seasonal (and aseasonal) breeding in brush mice
The timing of breeding may be influenced by both seasonal and aseasonal factors, particularly for animals living in seasonal but relatively temperate environments. The brush mouse (*Peromyscus boylii*) is a generalist small mammal that lives under a variety of environmental conditions across western North America. The timing of breeding in this species appears to vary across the range, and there is some indication that these mice may breed opportunistically when conditions are favorable. Over three years, I monitored the reproductive status of brush mice in the Northern Coast Ranges of California, an area that experiences predictable seasonal variation in weather, with cool, wet winters and hot, dry summers. However, ecological factors which may influence reproduction, such as population density and the availability of food resources, are less predictable. From June 2004-2007, I live-trapped individually-marked mice monthly, and recorded the reproductive status of each animal on every capture. I used a model-selection approach to determine the relative influence of the following factors on breeding: season (wet/dry), population density, and food (acorn mast) availability. I found that both season and acorn mast had a substantial impact on the probability of breeding. Brush mice reproduced primarily during the summer dry season, but also responded opportunistically to favorable conditions during other parts of the year. Up to 100% of adults were in reproductive condition between May and July each year, with only 0-25% of adults in breeding condition during a typical winter. However, after a relatively large acorn mast crop in fall 2004, brush mice reproduced continuously through the following winter. These results suggest that both seasonal and aseasonal factors affect the timing of breeding in this species.

S10.11 MACDOUGALL-SHACKLETON, S.A.*; STEVENSON, T.J.; WATTS, H.E.; PEREYRA, M.E.; HAHN, T.P.; Univ. Western Ontario, Johns Hopkins Univ., Univ. of California, Davis, Univ. of Tulsa, Univ. of California, Davis; *smacdou2@uwo.ca*
The evolution of photoperiod response systems and seasonal GnRH plasticity in birds
Many birds use lengthening photoperiod as an initial predictive cue to time gonadal recrudescence in preparation for the onset of seasonal breeding. In addition, in many species long days result in an eventual decrease in sensitivity to their own stimulatory effects: photorefractoriness. Thus, photorefractoriness can terminate reproduction and lead to gonadal involution while days are still long. Photorefractoriness is often associated with down-regulation of the entire HPG axis, including a cessation of GnRH-I production and release. Opportunistically breeding birds, on the other hand, may never become photorefractory and have only minimal seasonal changes in GnRH-I. Here we review the distribution of different forms of photorefractoriness among birds and test hypotheses regarding the evolution of photorefractoriness and GnRH plasticity. Our conclusions include that spontaneous regression of the gonads while experiencing long days is an ancestral trait, and is associated with down regulation of the GnRH system. Both GnRH-I and GnRH-II exhibit seasonal plasticity. Only four species tested fail to spontaneously regress their gonads while on long days, and all of them are opportunistic breeders. Other aspects of the photoperiod response system appear more evolutionarily labile. For example, several species of cardueline finches retain responsiveness to very long days when putatively photorefractory, differing from other species in which photorefractoriness is absolute. Neural GnRH-I and GnRH-II have been found to respond rapidly to photic and non-photic cues in birds and other vertebrates. Thus, birds that appear to become photorefractory during their annual cycle may possess cryptic flexibility in their ability to respond to photoperiod and other cues.

S1.5 MACIVER, Malcolm A; SHIRGAONKAR, Anup A; PATANKAR, Neelesh A*; Northwestern University; *maciver@northwestern.edu*
Biomechanical constraints on sensory acquisition in weakly electric fish
The knifefish *Apteronotus albifrons* hunts for small water insects at night using a self-generated electric field to perceive its world. Using this unique sensory adaptation, the fish senses prey that are near its body with a detection volume that approximates a cylinder that has a length ten times its radius, similar to the fishs elongated body plan. If the fish swims straight, then the back portion of the actively generated detection volume is scanning fluid already scanned by the front portion, but the energy expended to overcome drag is minimized. If it swims with the body pitched, then the rate of volume scanned for prey is increased, but the energy needed to overcome body drag is also increased. We examine the compromise the fish makes between minimizing drag and maximizing scan rate. We use computational fluid dynamics simulations to assess the impact of changes in body pitch angle on drag, and how the thrust from the ribbon fin propulsor changes with pitch angle. These mechanical studies are combined with high-fidelity computational neuroscience simulations to assess the shape and size of the prey detection volume and how body angle changes the scan volume rate. We find that the observed body pitch angle of 30 degrees during prey search behavior results in 35% higher volume scan rate while doubling the body drag, and that increasing the body pitch angle decreases the forward thrust available with typically observed fin deformation kinematics. The combination of neural and mechanical modeling allows us to show how the conflicting demands of biomechanics and information acquisition are negotiated in a core behavior.

63.5 MAHLER, D.L.; Harvard University; *lmahler@oeb.harvard.edu*
Convergence and parallelism in the evolution of Anolis tail length
In *Anolis* lizards, similar environments have spurred the evolution of similar species numerous times. But have these species evolved to look the same via the same mechanisms (parallelism), or has similarity been achieved through different evolutionary pathways (convergence)? Using data on a broad diversity of neotropical anoles, I asked several questions about the relative roles of convergent and parallel processes in the evolution of long and short tails. Typically, in *Anolis*, grass dwelling lizards have relatively long tails whereas twig and branch specialists have short, but semi-prehensile tails. These repeated patterns are thought to reflect common locomotor solutions to similar ecological conditions. However, anole tail length may change as a result of two different developmental processes, namely serial addition (or subtraction) of vertebrae versus elongation (or shortening) of individual vertebrae (henceforth referred to as addition versus elongation). I generated radiographs from more than one hundred Caribbean and mainland anole species to determine whether relatively long and short-tailed species achieved their tail lengths via addition or elongation. I examined these traits in the context of the anole phylogeny to ask: 1.) Is tail length convergence achieved through developmental convergence or parallelism? 2.) Which mechanism of length change (elongation or addition) exhibits greater evolutionary lability? 3.) Are the strategies of addition versus elongation associated with particular clades? 4.) Do addition and elongation correspond with particular ecological or morphological specializations? This study has important implications for understanding the processes underlying the repeated evolution of ecomorphological similarity in anoles, and provides one assay of whether superficially convergent species have arrived at similar endpoints through similar or unique developmental means.

76.4 MAHON, A.R.*; SENAPATI, S.; FEDER, J.L.; CHANG, H-C.; LODGE, D.M.; Center for Aquatic Conservation, University of Notre Dame; *amahon@nd.edu*
Rapid detection of invasive species in ballast water using molecular methods
Invasive species have inflicted high levels of environmental and economic damage to the North American Great Lakes region. During recent decades, approximately 70% of Great Lakes invasives were introduced through transoceanic shipping. One vector for species introduction is ships ballast water. As treatment systems for ballast water are lacking, real-time monitoring of the biological contents of ballast tanks could inform decisions about ship movements and ballasting practices. We are currently developing a portable, real-time genetic probe for the detection of target invasive species in ships' ballast. By combining modern molecular methods with microfluidic chip-based technologies, ballast samples can be rapidly screened for multiple target organisms, allowing informed decisions about the risk of invasions to be made en route. Target species for our work include the green crab (*Carcinus maenas*), the golden mussel (*Limnoperna fortunei*), the zebra mussel (*Dreissena polymorpha*), the quagga mussel (*Dreissena bugensis*) and the Chinese mitten crab (*Eriocheir sinensis*). These species, excluding the green crab, have either already invaded the Great Lakes watershed or are potentially threatening to the region. In our work, we asymmetrically amplify a fragment of cytochrome c oxidase subunit I (COI) using species specific PCR primers for detection in our novel microfluidic chip-based system. We have also begun to analyze detection limits of the system and both artificial and real ballast samples for presence or absence of the target species. The results of our work show that we can rapidly and accurately detect target invasive species in samples of ships ballast. These data support the continued development of the portable real-time detection system that could be used on board a ship during transport, prior to discharging ballast.

23.4 MAIE, T*; SUMMERS, AP; Clemson Univ., Univ. of California, Irvine; *tmaie@clemson.edu*
THE ADHESIVE DISC AND ITS FUNCTIONAL CAPACITY IN NORTERN CLINGFISH Gobiesox maeandricus: Gobiesocidae) AND TIDEPOOL SNAILFISH (Liparis florae: Liparidae): SCALING OF MORPHOLOGY AND SUCTION FORCE
In the intertidal environment, Northern clingfish, *Gobiesox maeandricus*, and tidepool snailfish, *Liparis florae*, withstand waves that could potentially dislodge them from the substrate by adhering via suction discs. We measured the performance and scaling of these discs in these two species. Neither species was able to adhere to a surface in which a hole had been drilled, indicating that microstructure of the disc alone could not produce adhesion and that suction pressure must be generated by the fish. We measured the disc area and peak load to suction failure for clingfish ranging from 41.7-102.9 mm and snailfish from 92.5-167.9 mm. The disc area of both *G. maeandricus* and *L. florae* showed positive allometric scaling relative to body length and either positive allometry or isometry of dislodgement force relative to body length, indicating that adhesive capacity would be either maintained or enhanced as these fishes grow. The peak force measured for clingfish was 27.4 N for a 102.9 mm individual and 19.9 N for a 167.9 mm snailfish.

88.1 MAIN, R.P.*; LYNCH, M.E.; SCHMICKER, T.L.; VAN DER MEULEN, M.C.H.; Cornell University; *rpm74@cornell.edu*
Changes in cortical bone stiffness and geometry in response to applied load vary with age in female mice
A variety of vertebrate taxa maintain functional bone strain levels within a certain healthy range through bone modeling and remodeling. As humans age, our bones are believed to become less sensitive to the strains induced by mechanical loads, resulting in resorption to achieve what the osteocytes perceive as healthy strains. This process results in decreased bone stiffness, and hence increased strains and a greater likelihood of fracture during functional loading. To examine the sensitivity of the response of mammalian bone to functional strain levels with age and the effects of this response on bone stiffness, we applied non-invasive loads to the tibiae of 6wk, 10wk, 16wk, and 26wk old female C57Bl/6 mice for 2wks. The right tibiae served as non-loaded controls. Bone stiffness was measured as the relationship between applied load and bone strain at the medial tibial midshaft. Initial bone stiffness and changes in stiffness associated with the loading protocol were related to bone geometry and mineral content. Experimental load levels varied between groups but corresponded to +1200 microstrain tissue deformations at the medial midshaft. Following 2wks of loading, stiffness changed significantly between the loaded and control limbs in only the 10wk and 16wk old groups where, surprisingly, the control tibiae were stiffer than the loaded tibiae. Although no stiffness differences occurred with age in the control tibiae, the loaded tibiae of the 6wk old mice were significantly stiffer than the loaded tibiae in all older groups. Similarly, the loaded tibiae of the 10wk old mice were stiffer than those of the 26wk old mice. Thus, stiffness and, likely, geometric and mineral responses to applied load are age-dependent in female mouse tibiae.

104.4 MALADEN, R.D.*; GOLDMAN, D.I.; Georgia Institute of Technology; *rmaladen@gatech.edu*

X-ray study of subsurface locomotion of a sand swimming lizard: the effect of material preparation

Animals that move within desert sand contend with material that can display solid and fluid-like behavior and can exist in a range of packing fractions whose mechanical response to stress can govern ability to move through the material. We used high-speed x-ray imaging to reveal how a small (10 cm) desert dwelling lizard (the sandfish *Scincus scincus*) swims within a granular medium, and how the animal is affected by the preparation (packing fraction - of the media. We used a fluidized bed to prepare a system of glass beads (particle size: 0.3mm, similar in size range of desert sand) into naturally occurring loose and tight packing (represented by the packing fraction 58% and 63% by volume). Once below the surface, x-ray video revealed that the organism no longer used limbs for propulsion. It placed them against its sides and executed a large amplitude undulatory gait using its body to propel itself at speeds up to ~1 body-length/sec. For a given the animal increased swimming speed by increasing temporal frequency, while maintaining a single period traveling wave along its body and tail. Surprisingly, the sandfish was able to move at both a higher frequency and velocity in the more resistive tightly packed media. While the slope of the velocity frequency regression was not statistically different for different packings (P>0.05),the range was extended: maximum frequency and velocity of (2.9Hz,7.9cm/sec) in loosely packed material and (4Hz,10.2cm/sec) in tightly packed material. Since physics equations do not exist for granular media in the regime encountered by the sandfish, we developed a direct simulation of a model sandfish in granular media to reveal the how material preparation and oscillation frequency govern thrust and drag to determine swimming velocity.

9.10 MALISCH, J.L.*; SATTERLEE, D.G.; COCKREM, J.F.; WADA, H.; BREUNER, C.W.; University of Montana, Louisiana State University, Massey University, Virginia Polytechnic Institute ; *jbunk001@ucr.edu*

Corticosteroid-binding globulin levels decrease 24 hours after an acute stressor in Japanese quial

Corticosteroid-binding globulin (CBG) circulates in the blood and is thought to be a potent modulator of the stress response; changes in plasma CBG capacity can alter total plasma concentration and tissue availability of glucocorticoids (GCs). Hence, the time frame of CBG change in an organism is of interest, as these changes will alter the organismal output of a stress response. It is clear that chronic stress causes CBG decline while the stressor persists. Recent evidence also demonstrates that shorter acute stressors, such as capture and handling, can reduce CBG during the 30-60 minutes of the stressor. However, recent evidence in mammals indicates a delayed response to acute stressors as well, in that brief stressors can reduce CBG capacity from 6 to 24 hours after the stressor is over. We investigated CBG levels 24 hours after an acute stressor in a unique study system: Japanese quail that are divergently selected for GC reactivity to acute stress. Quail selected for high acute stress reactivity have a two-fold higher response to crush cage stress as compared to quail selected for low stress reactivity and both lines differ from a third line of randomly bred Japanese quail. Using this model, we examined the interaction of selected stress reactivity with CBG response to determine if CBG shows a delayed decline in response to an acute stressor. We found lowered CBG capacity 24 hours after acute stress in all three lines of quail, with similar reduction in capacity among all three lines of quail. These results suggest that acute stressors can have long-term physiological effects even after total GC levels have returned to pre-stress levels.

81.1 MANOR , R.*; WEIL, S.; ROSEN, O.; GAFNI, O.; GLAZER, L.; AFLALO, E.D.; VENTURA, T.; SAGI, A.; Ben-Gurion University of the Negev; *sagia@bgu.ac.il*

Identification of the Protein Product of an Insulin-Like Gene Uniquely Expressed in the Androgenic Gland of Crayfish

In crustaceans, sexual differentiation is controlled by the androgenic gland (AG), an organ unique to males. Using a subtractive cDNA library, an AG uniquely expressed gene was identified in the crayfish *Cherax quadricarinatus*. This gene was found to be a novel insulin-like factor, thus termed *Cq-IAG* (*C. quadricarinatus* insulin-like AG factor). The proposed protein sequence encompasses cysteine residues and putative cleaved peptide patterns whose linear and 3D organization are similar to those of members of the insulin/insulin-like growth factor/relaxin family and their receptor recognition surface. In order to identify the proteinacious product, an antibody raised against a short part of the A chain was developed. In an immunohistochemistry assay, a specific cross-reactivity was detected in the AG when using the Cq-IAG antibody. A recombinant Cq-IAG is now in the process of production. The identification of the protein product of *Cq-IAG* is important in order to prove that the gene indeed encodes the predicted protein and in order to investigate its function.

25.5 MARA, Kyle R.*; MOTTA, Philip J.; PFEIFFENBERGER, Janne A.; University of South Florida, Tampa; *kmara@mail.usf.edu*

Constructional Constraints In Sphyrnid Sharks: Shape Change And Space Utilization Through Phylogeny.

Constructional constraints are particularly important within spatially limited structures such as the head. The head must contain all structures associated with feeding, respiration, neural integration, sensory reception, and musculoskeletal support. Sphyrnid sharks present an excellent study system for investigating the potential functional trade-offs within the head. *Rhizoprionodon terraenovae*, *Eusphyra blochii*, *Sphyrna lewini*, *S. mokarran* and *S. tiburo* were chosen to represent differences in head form through phylogeny. A combination of surface based geometric morphometrics and computed tomography volumetric analysis was utilized to investigate the implications of change in head form. The more basal, *E. blochii*, has relatively small anteriorly positioned eyes. Through phylogeny the relative size and position of the eyes changes, such that *S. lewini* and *S. tiburo* have larger more medially positioned eyes. Mouth size and position remain largely unchanged, however *S. tiburo* has relatively larger upper jaws. The position of the external nares is highly variable, but shows no phylogenetic trend. Interestingly, the volume of the brain is variable through phylogeny and the internal volume of the nasal capsule is increased in the most derived *S. tiburo*. These data indicate that the neurocranium and jaws are morphologically conserved whereas the laterally expanded cephalofoil and its consituent sensory components account for much of the morphological diversity within the clade. Therefore, there is little support for constructional constraints playing a role in the evolution of the sphyrnid cephalofoil.

11.7 MARKO, P.B.*; MCGOVERN, T.M.; EMME, S.A.; COX, L.N.; HOFFMAN, J.M.; Clemson University; *pmarko@clemson.edu*

Demographic history of the northeastern Pacific rocky shore community

Rocky shores have provided many insights into the responses of organisms to their biotic and abiotic environments, engendering some of the most important conceptual advances in the field of community ecology. Our understanding of the benthic and pelagic processes shaping patterns of contemporary community structure on rocky shores is fairly deep, but considerably less is known about the long-term persistence and stability of these model ecological communities over time scales longer than ~30 years. From a macroecological perspective, the relatively sharp zoogeographic boundaries between near-shore marine biogeographic regions indicate that rocky shore communities respond to spatial environmental factors as discrete co-evolved units. However, the fossil record has shown that some of these same species respond to temporal environmental change in a more individualistic manner. To compare the recent demographic histories of co-distributed and interacting species on rocky shores in the Northeastern Pacific, we conducted a multi-species survey of mitochondrial DNA diversity across 2500 km of coastline. Our study focuses on the northern two-thirds of these species' ranges, where the impacts of Pleistocene climate change on population dynamics are expected to be greatest. All species examined to date show a similar mixed population history of recent rapid growth combined with the persistent signal of ancient haplotypes from earlier eras. The persistence of high haplotype diversity across most species suggests the long-term endurance of the entire community at relatively high latitudes despite enormous demographic change.

13.5 MARKS,, C.; MICHELSON,, A.V.*; BAGATTO,, B.; MOORE, , F. B.-G.; University of Akron; *andy.michelson@gmail.com*

GxExE Whiz!: The influence of genotype and multiple environments on the developing zebrafish cardiovascular system

Genetics and environment are known to interact to influence phenotype. In quantitative genetics this is represented by a significant GxE interaction. However, while environments are known to vary over the ontogeny of an individual, the traditional quantitative genetic paradigm does not incorporate variation in ontogenetic environment. Recently, we have found interactions between developmental and adult environment (ExE interactions) in zebrafish developmental physiology and behavior. In this study, we tested for genetic variation in the extent to which these ontogenetic oxygen environments interact (GxExE) in the early development of the zebrafish cardiovascular system. We reared full and half-sibs for 48 hours of development that was divided into two, 24 hour ontogenetic periods (E_{early} and E_{test}). Utilizing a split clutch design, individuals were exposed to hypoxia, normoxia or a combination of the two environments for E_{early} and E_{test}. We measured cardiac output, and its component traits, stroke volume and heart rate, for all individuals. While we found that cardiac output increased significantly in hypoxic test environments as anticipated, we also found that cardiac output showed genetic variation for responses across the developmental environments ($GxE_{early}xE_{test}$) while the component traits did not. These results indicate that genotypes differ in the extent to which ontogenetic environments interact in determining phenotype.

26.1 MARLOW, Heather Q.*; SPEISER, Daniel I.; SEAVER, Elaine C.; MARTINDALE, Mark Q.; University of Hawaii at Manoa, Duke University; *marlow@hawaii.edu*

Opsin diversity and extra-ocular photorecepion in the Metazoa

Bilaterian animals (protostomes and deuterostomes) sense light through the use of visual opsins, seven-pass transmembrane receptors of the Rhodopsin superfamily. It has been long hypothesized that two families of visual opsin molecules, the rhabdomeric and the ciliary families, were present in the urbilaterian ancestor. These molecules, and their corresponding morphological cell types, assumed independent functions in protostome, and deuterostome photoreception, where protostome eyes have been largely found with rhabdomeric opsins and deuterostome eyes are associated with ciliary opsins. Our examination of the visual opsins in the basal metazoa (cnidarians, trichoplax and sponges) confirm previously published reports which show that cnidarians were the earliest phyla to possess putative light sensitive opsin molecules. We find that a large diversity of visual opsin genes are found in the *Nematostella vectensis* (anthozoan cnidarian) genome and that these genes are expressed in different subsets of minimally differentiated *N. vectensis neurons* in the adult (polyp) and larval (planula) stages which lack the large membrane elaborations of rhabdomeric and ciliary photoreceptor cells. In addition, we find previously undescribed opsin diversity in the lophotrochozoan *Capitella* sp.I (polychaete annelid), which is expressed outside of the adult and larval eyes. These data, as well as our examination of the developmental eye gene regulatory network (PSEDN) in *N. vectensis* (anthozoan cnidarian) implies that opsins evolved and diversified in light sensitive extra-ocular neurons prior to the emergence of the bilateria and have been co-opted for use in non-homologous visual structures (eyes) many times in the bilateria.

66.1 MARLOW, H. Q.; ROETTINGER, E.; MARTINDALE, M.Q.*; Univ. Hawaii, Kewalo Marine Lab; *mqmartin@hawaii.edu*

Notch signaling during embryogenesis in the cnidarian Nematostella vectensis

Nematostella vectensis, the startlet sea anemone, is an anthozoan cnidarian and early branching member of the metazoa. As a morphologically simple early metazoan it possesses only two tissue layers (endoderm and ectoderm) and a nerve net and is ideal for investigating the role of many developmental pathways in the evolution of conserved features such as the nervous system and gut. The notch pathway has been implicated in a number of developmental processes including segmentation, neurogenesis and gastrulation. The notch receptor, delta ligand and a number of downstream targets including the basic helix-loop-helix genes are present in the *N. vectensis* genome and are shown to be expressed prior to gastrulation and throughout the planula (larval) stage by in situ hybridization studies. Inhibition of notch signaling the by the gamma-secretase inhibitor DAPT induces marked morphological defects in global processes such as cell proliferation as well as cell-type specific abnormalities (absence of cnidocyte stinging cells). Diverse roles of this pathway in *N. vectensis* development is consistent with its many roles in bilaterian animals. We are currently functionally testing the role of specific pathway members in *N. vectensis* through the expression of dominant negative forms of the ligand delta and the transcription factor suppressor of hairless in early embryos. Determining the role of Notch signaling in early metazoans such as *N. vectensis* provides insight into the ancestral role of this pathway and additional data for its more general role in cell proliferation.

98.5 MARSH, Richard L.*; HITCHCOCK, Amanda C.; TRUONG, Rosemary; PROPERT, Matthew W.G.; Northeastern University; *r.marsh@neu.edu*
Cost of muscle force production during legged locomotion in guinea fowl.
We combined measures of joint moments, joint angles, and instantaneous effective moment arms at the ankle and tarsometatarsal-phalangeal joints with previous measures of muscle energy use by the stance muscles acting at these joints to estimate the cost of muscle force production by the ankle extensors and digital flexors. The resulting values were expressed in W/N (similar to organismal level cost coefficients). Preliminary data indicates that the cost of force production by the digital flexors rises at low speeds and then is relatively constant at higher speeds. However, the cost of force production by the pure ankle extensors (largely the gastrocnemius) increases at higher speeds. One hypothesis that might explain this difference is the production of larger amounts of net positive work by the gastrocnemius with increases in speed, because force per active muscle volume is expected to be reduced during shortening. Supported by NIH AR47337 and NSF IOB-0542795.

BART.1 MARTIN, L.M.; University of South Florida
Ecological immunology: an adaptationist perspective on the vertebrate immune system
TBA

5.2 MARTIN, Shannon B.*; LEBERG, Paul L.; University of Louisiana at Lafayette; *sbm@louisiana.edu*
Comparing two life history strategies in a changing environment
As the Earth's climate changes and sea level rises, more saline waters will encroach into traditionally freshwater coastal habitats with greater frequency. These environmental changes stress resident organisms affecting their reproductive fitness. To evaluate the effects of increasing salinity on reproductive allocation, *Gambusia affinis* and *Heterandria formosa* were collected from populations along a salinity gradient and maintained in a common freshwater environment for six generations. We performed an experiment on pregnant F6 females using a factorial design of historical and contemporary salinity treatments to examine the influence of salinity on offspring size and number in these two livebearing fish species that have different strategies of offspring provisioning. In the primarily lecithotrophic *G. affinis*, we found that the historical salinity influenced the number of offspring while the contemporary gestational salinity impacted offspring size. In support of the Trexler-DeAngelis model, we detected plasticity in post-zygotic offspring provisioning under an *ad libitum* feeding regime. Our results suggest that *G. affinis* from fresh and intermediate marshes were facultatively matrotrophic by increasing offspring size after fertilization while females from brackish marshes were lecithotrophic. Contrasting results were obtained for the highly matrotrophic *H. formosa*. Both species, however, exhibited genetic variation in phenotypic plasticity and utilized maternal effects to vary the number and size of their offspring in an attempt to maximize their fitness (i.e., fecundity and offspring quality) in environments with different salinity levels.

68.2 MARTIN, Christopher H.*; WAINWRIGHT, Peter C.; University of California, Davis; *chmartin@ucdavis.edu*
Divergence in trophic morphology and diet within a young radiation of Cyprinodon pupfishes on San Salvador Island, Bahamas
Evolutionary transitions to new adaptive peaks, such as the invasion of a new niche or the origination of a key innovation, are still poorly understood. Unfortunately, very few clades containing novel traits are sufficiently young to observe the context in which these transitions occur. One exception is a radiation of four sympatric *Cyprinodon* pupfish species inhabiting inland saline lakes on San Salvador Island. This may be the youngest known radiation (< 6,000 years old, the age of the lakes) and, in contrast to the algivorous diet of almost all other *Cyprinodon* species, it contains at least two species which have invaded novel trophic niches. A specialized scale-biter and a large piscivore each exhibit distinct morphology, diet, behavior, and breeding coloration from their putative sister species *C. variegatus*. Furthermore, a third species exhibits a unique swelling of the anterior nasal and lacrimal tissues overgrowing the premaxilla, which may function in species recognition. Here I will compare the jaw morphology of these four species from cleared and stained specimens, including differences in adductor mandibulae mass. I will also quantify dietary breadth and diversity among species. These results will be contrasted with the only other known *Cyprinodon* radiation from Laguna Chichancanab, Mexico.

8.8 MARTIN, K.L.*; MCCLURE, M.; BLANK, T.; VANDERGON, T.; RUMBLE, J.; SLEDGE, J.; Pepperdine Univ., Univ. of North Texas; *kmartin@pepperdine.edu*

Instant Fish: Environmentally Triggered Hatching in Beach Spawning California Grunion

A coastal marine silverside, the California Grunion *Leuresthes tenuis* emerges from water to spawn on sandy beaches. During oviposition at lunar high tides, grunion eggs are buried in damp sand in the high intertidal zone. There they will be above the water line for over a week, emerged until the wave wash of a subsequent lunar rising tide reaches them on shore. Oviposition in damp sand is beneficial for clutches of chorion-encased fish embryos, providing high oxygen, suitable temperatures, and protection from desiccation. However this terrestrial incubation habitat is fatal to a delicate hatchling. Thus hatching must occur only when the embryo is submerged in water. The release of the hatchlings from their surrounding membranes into their new aquatic habitat must occur very quickly, within seconds as waves sweep over the oviposition site. However, release must not occur too soon, because hatching under a layer of sand is lethal. The California Grunion has several unique behavioral and physiological adaptations for this dramatic life history switch point. These include the ability to delay hatching for more than double the original incubation period, extremely rapid emergence from the chorion once the process has been initiated, and a unique environmental trigger for initiation of hatching. The environmental trigger provides a means for synchronization of hatching. Hatching is a two-stage process involving action of chorionase and muscular exertion by the embryo to break free of the weakened egg membranes. The physiological and behavioral adaptations for hatching of *L. tenuis* are characterized through a series of experiments, and compared to other fish and amphibians with aquatic and terrestrial incubation. Supported by NOAA, CA SeaGrant R/CZ195.

4.4 MARTIN, R.A.*; PFENNIG, D.W.; Univ. of North Carolina, Chapel Hill; *martinra@email.unc.edu*

Disruptive selection and the evolution of variation within species

What evolutionary and ecological factors account for the amazing diversity seen within most natural populations? A long-standing hypothesis is that disruptive selection promotes the evolution of such diversity by favoring extreme phenotypes. Two distinct mechanisms can cause disruptive selection. First, disruptive selection can occur when extreme phenotypes specialize on separate resources, for which intermediate phenotypes are competitively inferior. Second, disruptive selection can occur when competition is more intense between phenotypically similar individuals, because of shared resource use. This results in the most common phenotypes experiencing intense competition and rare phenotypes experience reduced competition. By the first mechanism, fitness is *frequency-independent*, meaning that fitness is not expected to vary with the proportion of intermediate and extreme phenotypes in a population. By the second mechanism, however, fitness is *frequency-dependent*. Although recent theory has emphasized the role of frequency-dependent interactions as the primary cause of disruptive selection, frequency-dependent and frequency-independent competitive interactions are not mutually exclusive. We show that disruptive selection is acting on tadpoles of the spadefoot toad tadpole, *Spea multiplicata*. We also show that both frequency-dependent and frequency-independent effects drive this disruptive selection. In particular, we show that intermediate phenotypes are less well adapted for handling the available resources than are extreme phenotypes. We also show that competition is more intense between phenotypically similar individuals. In general, disruptive selection may be common in nature, and both frequency-dependent and frequency-independent effects may drive such selection.

32.2 MASON, R.T.*; ERICKSON, S. M.; HALPERN, M.; Oregon State University, SUNY Downstate Medical Center, Brooklyn; *masonr@science.oregonstate.edu*

Sexual Dimorphism and Seasonal Variation in the Harderian Gland of the Red-sided Garter Snake

The Harderian gland of the red-sided garter snake, *Thamnophis sirtalis parietalis*, is a secretory structure that plays a role in the vomeronasal system by solubilizing semiochemicals, such as the otherwise insoluble female garter snake sexual attractiveness pheromone. Detection of the pheromone by the vomeronasal system is essential for male courtship of female garter snakes. Feeding, which occurs only in the summer, involves detection of prey chemicals by the vomeronasal system as well, and may require carrier molecules (binding proteins) to deliver prey proteins to the vomeronasal organ. Because only male snakes respond to the female pheromone and breeding occurs primarily in the spring and feeding in the summer, the morphology of the Harderian gland was expected to be sexually dimorphic and seasonally variable. We found this to be true. Harderian glands were larger, cell heights were greater, and lumen diameters larger in the summer than in the winter or spring. Whereas the acinar cell heights and lumen diameters of males increased significantly from winter to spring, those of females did not. Sexual dimorphism was most evident in the acinar cell heights and lumen diameters in the spring, with males having significantly greater cell heights and lumen diameters than females.

31.1 MATSON, K.D.*; HORROCKS, N.P.C.; VERSTEEGH, M.A.; TIELEMAN, B.I.; University of Groningen; *k.d.matson@rug.nl*

Understanding the role of lysozyme in birds: physiological interactions between experimental immune enhancement and challenge.

In pigeons, we examined the interactions between experimental immune enhancement and challenge. Immune enhancement took the form of a six day course of oral lysozyme supplementation (180 mg/bird/day); a non-specific immune challenge was presented as a single injection of lipopolysaccaride (LPS, 2.5 mg/kg) on day six. Lysozyme is a naturally-occurring antibacterial protein in birds; it functions by hydrolyzing cell-wall peptidoglycan, making Gram-positive bacteria particularly susceptible to its effects. In contrast, LPS is a building block of Gram-negative bacterial cell membranes and is a classic endotoxin. In all birds, a range of immunological indices and physiological parameters were measured twice: before and after LPS challenge. These measures included body temperature, metabolic rate, blood glucose and ketone levels, plasma haptoglobin concentration, and bacteria-killing abilities. We compared the pre-challenge baseline levels of these measures in lysozyme and control birds. We also compared the LPS-induced within-individual changes in these measures in all birds. Since lysozyme can bind with LPS and is thought to have anti-inflammatory properties, we hypothesized that supplementing birds with lysozyme would mitigate the energetically-expensive inflammatory effects of an LPS challenge. We also hypothesized that baseline comparisons, reflecting the effects of lysozyme alone, would show greater impacts on immunological indices than on other physiological parameters (e.g. metabolic rate). Initial analyses suggest larger than expected effects of lysozyme treatment. With some measures, it appears as if the effects of LPS in lysozyme birds are the result of both slightly depressed baseline levels and greater response levels compared to control birds.

101.11 MCALISTER, J/S*; MORAN, A/L; Clemson University; *jmcalis@clemson.edu*

Unscrambling the relationship between egg size and egg composition using geminate species pairs

Egg size is one of the most important life-history parameters in marine organisms. Among species with a planktonic larval stage, egg size is strongly associated with developmental mode (planktotrophy or lecithotrophy) and is linked to numerous fundamental traits, i.e. larval form, the length of larval development and fertilization success. Among planktotrophic species however, egg size can be a poor predictor of energetic content. To examine the evolutionary association between egg size and egg energetic composition, we are analyzing the protein, carbohydrate, and lipid content of eggs of echinoid geminate species pairs from tropical America, which have known differences in egg size between geminates. Geminates are closely related species that formed when the Panamanian Isthmus raised 2-4 mya and split previously continuous populations of marine organisms. Geminates inhabit two different larval food-level environments: high in the eastern Pacific (EP) vs. low in the western Atlantic (WA). These environments are associated with the differences in egg size, which have been attributed to changes in maternal investment per egg: an increase in the WA and/or a decrease in the EP. Our results indicate that per-egg protein content is similar between members of each geminate pair. When corrected for volume, however, the EP species have significantly and substantially higher protein densities than their WA geminates. Analyses of carbohydrate and lipid content are ongoing. The results from this study, the first to be conducted in a rigorous, phylogenetically-controlled, comparative context, will increase our understanding of the evolutionary association between egg size and egg composition.

11.10 MCCARTNEY, Michael A.*; LIMA, Thiago G.; YUND, Philip O.; Univ of North Carolina, Wilmington, University of New England; *mccartneym@uncw.edu*

Results from hybrid genotypes question the role of M7 lysin in blue mussel gamete recognition

M7 lysin is a sperm protein that dissolves the egg vitelline coat, prior to fertilization, in blue mussels in the *Mytilus* species complex. As in abalone lysin, DNA sequences of M7 lysin show an excess of nonsynonymous substitutions indicative of positive selection. These results have been used to conclude that M7 lysin is a gamete recognition protein; that is, that it controls species-specific fertilization. We tested this hypothesis in the Gulf of Maine hybrid zone between *M. edulis* and *M. trossulus*. We predicted that introgression at a gamete recognition locus should be reduced compared to marker loci not involved in species recognition. Results were to the contrary: we found a much higher rate of introgression of M7 lysin alleles into *M. trossulus* genetic backgrounds compared to alleles at marker loci. Introgression at M7 lysin is biased, and does not occur into *M. edulis* backgrounds. Sequencing of cloned alleles showed multiple amino acid substitutions within the fifth exon, confirming that hybrid lysin heterozygotes carry one *M. edulis* and one *M. trossulus* allele. We have found no consistent differences between the compatibility of sperm from male lysin heterozygotes with eggs from pure *M. edulis* females, compared to homozygous males. Both the pattern of introgression and these fertilization results question the role of M7 lysin in species-specific gamete recognition. However, evidence for positive selection indicates that the gene is under selection, and the high rate of retention of introgressed alleles in highly backcrossed hybrids suggests that alleles contributed through hybridization provide some advantage. Selection within species (e.g. under sperm competition) may favor these divergent lysin alleles, and may help drive adaptive evolution of *Mytilus* lysin.

13.2 MCCAULEY, DW; University of Oklahoma, Norman; *dwmccauley@ou.edu*

Evolution of vertebrate chondrogenesis: Lessons from lampreys

The appearance of neural crest cells in early vertebrates has been suggested to have been a key event critical to vertebrate complexity. Gene duplication has also been suggested to play a crucial role in increased vertebrate diversity and complexity. The presence of an internal supporting skeleton was important to the evolution of vertebrates and aspects of the vertebrate skeleton are derived from cranial neural crest. Chondrogenic neural crest cells emigrate from the dorsal neural tube in the hindbrain region and form the branchial skeletal elements that support the pharynx and gills in basal vertebrates. Lampreys are the basal-most extant vertebrates and are useful for understanding the origin of novel vertebrate traits in the context of gene duplication. The branchial skeleton in lampreys is comprised of fused cartilage bars that form a basket and previous studies have suggested a neural crest origin of lamprey cartilage. Here we use DiI lineage tracing to confirm the neural crest origin of chondrocytes within the branchial basket. We have found that lamprey cartilage can be stained with the commonly used cartilage stain Alcian Blue. Interestingly, we observe that lamprey cartilage can be induced to fluoresce, facilitating high-resolution whole-mount imaging of the intact branchial basket. Normal development of whole-mount branchial cartilage is compared to cartilage in lamprey embryos following morpholino knockdown of duplicated SoxE genes, shown previously to play a chondrogenic role in lamprey. Following morpholino-induced knockdown of SoxE1 and SoxE2 proteins, cartilages that would form the branchial basket do not develop. Our results demonstrate that duplicated transcription factors SoxE1 and SoxE2 regulate cartilage development at the base of the vertebrates and further suggest the chondrogenic function of Sox9 is a gnathostome synapomorphy.

S3.6 MCCORMICK, Stephen D.; USGS, Conte Anadromous Fish Research Center, Turners Falls, MA USA; *mccormick@umext.umass.edu*

The hormonal control of seawater performance in anadromous fish

Anadromy is a life history strategy in which fish move from fresh water to seawater as juveniles and then return to fresh water to breed. Anadromy developed early in vertebrate evolution and is a feature of many basal fishes such as lamprey, sturgeon and salmonids. Downstream migration and seawater entry of juvenile anadromous fish generally occurs during a particular season and developmental stage. Morphological changes such as silvering and physiological changes such as increased salinity tolerance and scope for growth increase performance and fitness in seawater. The endocrine changes that control seawater performance are best known for salmonids. Cortisol and the growth hormone/insulin-like growth factor I act synergistically to increase osmoregulatory ability in seawater. Prolactin is thought to play an inhibitory role, though direct evidence for this is limited. The thyroid axis promotes morphological changes in salmonids, whereas thyroid hormones inhibit metamorphosis in lamprey. The ability of sex steroids (and estrogenic endocrine disruptors) to inhibit seawater performance may be related to their role in promoting movement of adults into fresh water. Photoperiod and temperature regulate these hormones, and inappropriate rearing conditions such as those that may occur in hatcheries can lower seawater performance. Relaxed selection in land-locked populations has resulted in lower levels of growth hormone and cortisol and dampening of traits associated with seawater performance. By integrating developmental and environmental information, the endocrine system induces behavioral and physiological changes that increase seawater performance of juvenile anadromous fish.

101.5 MCCOY, M W*; WARKENTIN, K; VONESH, J R; Boston University, Virginia Commonwealth University; *mwmccoy@bu.edu*

Phenotypic plasticity in metamorphic timing: Understanding the roles of size- and density-dependent processes

For organisms with complex life histories, environments encountered early in ontogeny may substantially alter densities or phenotypes transitioning into subsequent habitats. These differences in initial conditions could arise via a number of processes, including differences in maternal investment or habitat selection, abiotic factors, or the lethal and phenotypic effects of predators earlier in ontogeny. In this study we employ a simulation based approach to extend the minimize mortality (μ)/growth (g) framework of Werner and Gilliam (1984) to understand how effects early in ontogeny shape survival and subsequent switch point phenotypes. While previous models predict optimal switch points as a function of size-specific growth and mortality in each stage or habitat, for many taxa, these vital rates depend upon density, as well as size. Here, we incorporate both density-dependent processes and variation in initial phenotypic and density conditions to elucidate the relative importance of density- and size dependence in vital rates on survival and size and timing of subsequent life history switch points. We show that initial cohort density and phenotype can affect how size- and density-specific processes in later stages magnify or reduce variation earlier in ontogeny. Our results highlight the importance of density dependence for determining both survival and the timing of life history switch points.

64.5 MCCUE, M.D.; Blaustein Institutes for Desert Research, Ben Gurion University; *mmccue@bgu.ac.il*

Hyperoxia reduces the costs of digestion in snakes: Investigating the energetic consequences of the paleoatmosphere

Oxygen levels in the Earths atmosphere have fluctuated dramatically during the Phranerozoic eon, and may have reached concentrations at 60% greater than current levels. These atmospheric changes have engendered much speculation about the relationship between O_2 availability and major evolutionary events among animals (*e.g.* insect gigantism, flapping flight, endothermy, *etc.*). With the exception of studies on exercising humans, a limited number of investigations have examined the effects that hyperoxic conditions can have on physiological performance variables. Given that energetic costs of maintenance and digestion can account for a majority of the total energy budget of snakes, this study was conducted to determine the effect of simulated paleoatmospheric O_2 levels on the metabolic requirements (*i.e.* VO_2 and VCO_2) of postabsorptive and postprandial snakes. A series of three repeated measures experiments conducted on western diamondback rattlesnakes, (*Crotalus atrox*, (n = 20) under O_2 concentrations ranging from 21% to 50% demonstrated that hyperoxia did not influence resting metabolic rates, but that 35% O_2 was sufficient to reduce metabolic costs of digestion (*i.e.* specific dynamic action; SDA) by an average of 11%. It is impossible to determine whether or not extinct snakes would have shown similar responses, and to quantify the precise evolutionary significance of such responses. However, given our current understanding about the degree to which extent extant snakes are energy limited, such an energetic benefit could have had enormous implications to the life histories and feeding behaviors of ancient snakes as they radiated from their lizard ancestors.

41.6 MCDERMOTT, J.J.; Franklin and Marshall College; *jmcdermo@fandm.edu*

Hypersymbioses in the pinnotherid crabs (Decapoda: Brachyura: Pinnotheridae): a review

Members of the brachyuran family Pinnotheridae are nearly all symbionts of other invertebrates; some crabs are subtly parasitic and others commensalistic. Most live inside bivalve mollusks or in the tubes or burrows of polychaetes and other marine crustaceans. Animals living on or in pinnotherid crabs are considered hypersymbiotic. Hypersymbionts are poorly represented within 26 members (8.6%) of the Pinnotheridae (20 species in the subfamily Pinnotherinae and 6 species in the Pinnothereliinae). Parasitic hypersymbionts are as follows: 3 species of fungi; 1 unidentified cestode (Trypanorhyncha); 1 unidentified trematode (Microphallidae); nematode cysts; 3 species of Nemertea (Carcinonemertidae); 2 species of rhizocephalans (Sacculinidae; plus 5 or more unidentified species); epicaridean Isopoda (13 species of Bopyridae and 1 species of Entoniscidae, plus 3 unidentified). Preliminary biological information on unidentified entoniscids is presented. A variety of mainly incidental hypersymbioses involving ectosymbionts is known primarily from *Pinnixa chaetopterana*, a symbiont of polychaete burrows. The ctenostome bryozoan *Triticella elongata*, the only known obligate symbiont of *P. chaetopterana*, infests five other species of pinnotherids. Some other ectosymbionts are stalked ciliates, hydroids, polychaetes, bivalve mollusks, balanomorphan barnacles, harpacticoid copepods, and urochordates. Factors influencing our meager knowledge of hypersymbioses in the Pinnotheridae are discussed, among them the inaccessibility of crab hosts and research emphasis on taxonomy within the family

101.3 MCFARLANE, W.J.*; DEBLASIO, H.; Manhattanville College, Purchase, NY; *mcfarlanew@mville.edu*

Turbidity May Provide a Protective Barrier Against Ultraviolet (UV) Light Exposure in Zebrafish (Danio rerio) Embryos

Exposure to ultraviolet (UV) light has been correlated to cellular damage in both human and animal models. Although UV radiation is both absorbed and scattered in the upper surface of water, shallow areas may be vulnerable to significant radiation, possibly leading to developmental effects on early life stages. Turbidity in water is influenced by many factors including rainfall, which washes excess organic matter, soil and sand particles into water bodies. Suspended particles enhance the scattering of light, which may serve to decrease the amount of UV radiation that can penetrate into shallow water and be available for absorption by organisms. Water with high turbidity may therefore have a protective function against UV damage. In this study, zebrafish embryos were exposed to three levels of light: a high UV (UV-B) light, a medium UV (UV-A and UV-B) light, and an incandescent light (control; negligible UV). Developmental lag in UV exposed embryos was assessed by comparing the expected stage of development to the observed stage (compared to controls). Results of this preliminary study showed that the greatest developmental delay occurred in the low UV light source, containing both UV-A and UV-B. Mortality rates were highest in embryos that were held in water with no turbidity. Turbidity appeared to serve a protective function. It is possible that the shielding effect of turbidity could serve as protection for organisms that are constantly exposed to UV radiation in shallow aquatic habitats.

39.1 MCGEE, M.D.; Univ. of California, Davis; *mcgee@ucdavis.edu*

Gravidity degrades escape performance in threespine stickleback

Traits that increase reproductive success while increasing predation risk have been well documented in males, but a similar phenomenon may also exist in females. Just as males with sexually selected ornaments may experience an increased predation rate, females may experience increased predation because gravidity impedes escape performance. To test this, I used wild-caught marine threespine stickleback, *Gasterosteus aculeatus*. I divided the fish into two groups, 12 gravid females and 7 nonsexual individuals, which were defined as fish with no obvious gravidity or male nuptial coloration. I filmed fast-starts for both groups at 250 frames per second using a mirror placed at a 45 degree angle below the tank to generate a ventral image. I triggered fast-start responses by rapidly bringing a dipnet handle down near the vicinity of the fish. I filmed at least 5 escape responses per fish, and used the trial with the best overall escape performance for statistical analysis. Both groups were then massed, subjected to an egg removal procedure, and massed again. Each individual was allowed to recover for at least 24 hours, then filmed for fast-starts again. Measures of fast-start performance included net distance traveled, maximum velocity, maximum acceleration, and the bending coefficient. Gravid female stickleback exhibited poorer overall escape performance than both nongravid stickleback and gravid females after eggs had been manually removed. Other studies on fast-starts suggest that a decrease in escape performance of this magnitude is likely to strongly affect the ability of a gravid female stickleback to avoid capture during a predation event. These results, combined with observed variation in clutch mass between females, suggest a potential tradeoff between high fecundity and the ability to effectively evade predators.

28.1 MCGOVERN, TM*; KEEVER, CC; HART, MW; SASKI, CA; COX, LN; EMME, SA; HOFFMAN, JM; MARKO, PB; Clemson Univ., Simon Fraser Univ.; *tmcgove@clemson.edu*

Vicariance or pseudocongruence? Evidence from a multi-species break in the northeastern Pacific

Comparative phylogeography often reveals the existence of shared phylogeographic breaks across multiple, co-distributed species, a pattern consistent with a hypothesis of vicariance, in which a single event simultaneously disrupted the geographic ranges of many species. The hypothesis of vicariance, however, not only requires geographic concordance, but also temporal congruence with respect to the disruption of gene flow. Recently, several multi-species breaks have been shown to represent cases of pseudo-congruence, in which a geographically concordant break resulted at different times in different taxa. Pinpointing the timing of divergence therefore not only contributes to our understanding of the historical processes shaping spatial patterns of genetic variation, but also has great significance to community ecology given the potential for testing hypotheses about the geographic responses of groups of interacting species to environmental change. We have employed Bayesian/Markov chain Monte Carlo methods to compare mtDNA-based estimates of divergence time in multiple species in an area of the northeastern Pacific in which a phlyogeographic break has previously been documented. For two of these species a benthic brooder and a free-spawner with planktonic larvae - we refine our estimates of divergence time by adding six anonymous nuclear loci. We use these analyses to discuss broader issues of phylogeographic congruence as well as implications for the impact of life histories and species interactions on responses to environmental change.

73.4 MCGOWAN, C.P.; Univ. of Texas at Austin; *cpmcgowan@mail.utexas.edu*

Could Giant Kangaroos Hop? Scaling of tendon geometry and skeletal features.

Large species of Macropodoidea, the superfamily containing kangaroos and wallabies, have the amazing ability to decouple oxygen consumption from speed. This is largely due to the capacity to store and return increasing amounts of elastic energy in the ankle extensor tendons. However, elastic energy storage in tendons is proportional to tendon strain and as elastic energy storage increases, tendon safety factor decreases. Recent scaling studies of macropodoids have shown that the capacity for elastic energy return increases with body size, while tendon safety factor decreases and may limit maximal body size (~140 kg). Yet fossil evidence suggests that several species of extinct macropodoids likely reached 150 kg and the largest, Procoptodon goliah, may have been 250 kg or more. Clearly, if these animals followed the same scaling relationship as extant species, they would have had safety factors well below one, and thus would have been very limited in their ability to hop. In this study, we examined the scaling of morphological features on the calcaneus and tendon cross-sectional area in extant macropodoids (n=15, size range: 0.8 to 27 kg). The results of this analysis showed that the area of the tendon attachment site on the calcaneus is highly correlated with gastrocnemius tendon area (r^2=0.91), plantaris tendon area (r^2=0.91) and combined tendon area (r^2=0.93). We then measured the same morphological features from fossilized calcanei of extinct giant kangaroo species (n=4). The relationship between tendon attachment area and tendon cross-sectional area was used to estimate the tendon cross-sectional area for these extinct species. Our results suggest that extinct giant kangaroos did not follow the same scaling patterns as smaller extant species, but rather had much larger ankle extensor tendons for their size and therefor could likely hop in a similar manner to modern kangaroos.

16.3 MCGUIRE, L.P.*; FENTON, M.B.; GUGLIELMO, C.G.; University of Western Ontario, London; *lmcguir5@uwo.ca*

The effects of age on energy storage during pre-hibernation swarming of little brown bats (Myotis lucifugus)

Little brown bats (*Myotis lucifugus*) gather in large numbers at hibernacula in autumn to mate and prepare for hibernation. This period is known as swarming. In eastern Ontario, bats arrive in early August, and mating begins at the end of August. Mating occurs inside the hibernacula, while foraging occurs outside. Consequently bats must manage the tradeoff between foraging to build fat stores for hibernation and spending time in the mine for mating. Minimizing energy expenditure by using daily torpor may result in a net energy gain, despite decreasing energy input. In captivity, first year bats are not as effective at using torpor and therefore may not experience the same energy savings. In natural conditions, increased feeding may compensate. We estimated the energy stores of adults and first year bats throughout swarming and used plasma metabolite analysis to assess feeding performance. Size corrected body mass increased throughout swarming for adults and decreased for first year bats. Plasma metabolite analysis indicated there was no difference in the feeding of adult and first year bats. All bats foraged hyperphagically early in the swarming period, with feeding decreasing approximately co-incidentally with the first observed mating. With no difference in nutrient intake, our results suggest that first year bats suffer from increased energy costs, either through increased costs of torpor, or through increased foraging costs due to lower foraging efficiency.

S1.8 MCHENRY, MJ*; STROTHER, JA; VAN TRUMP, WJ; Univ. of California, Irvine; *mmchenry@uci.edu*

Fluid-structure interaction in lateral line receptors

Many aquatic animals are exquisitely sensitive to water flow through the deflections of ciliated receptor organs. The sensitivity of these organs is governed by the fluid forces that act to create deflections and their structural resistance to these forces. In order to understand the fluid-structure interactions that govern flow sensing, we have developed mathematical models based on mechanical testing of the lateral line receptors in larval zebrafish (*Danio rerio*). Our findings suggest that these receptors encode the velocity of flow at the surface of the body and their resonant properties serve to attenuate high-frequency stimuli. Their sensitivity is largely determined by the height of the cupula and the height and number of hair cell kinocilia. The boundary layer over the body's surface acts as a high-pass filter of flow stimuli. Therefore, the both the boundary layer and morphology of the cupula contribute layers of filtering to a superficial neuromast that have substantive effects on it the sensitivity of the lateral line system.

42.5 MCMILLAN, D.M.*; REES, B; IRSCHICK, D; UMass Amherst, University of New Orleans; *mcmillan@bio.umass.edu*

The role of HSP70 expression in locomotion - Reduced sprint speeds after heat stress in Sceloporus occidentalis.

The Western fence lizard, *Sceloporus occidentalis* is a geographically widespread lizard occurring throughout the western United States across many diverse thermal environments, and can experience potentially stressful temperatures in these natural habitats. During these periods of temperature stress, metabolic enzymes become completely or partially denatured, losing the ability to function and limiting the energy production capabilities of the cell. The production of molecular chaperones, specifically heat shock proteins (Hsps) can aid in the recovery from periods of thermal stress by repairing denatured proteins to their functional state. However, this protection consumes metabolic energy which may be diverted from other organismal functions such as locomotion. Locomotor ability, especially sprint speed, is an important determinant of predator escape ability in lizards and is greatly affected by body temperature. The production of Hsps during periods of thermal stress may reduce the metabolic energy available for locomotion and therefore may increase the susceptibility of an individual to predation. For this study, we measured sprint speeds in recently captured *S. occidentalis* individuals from four populations during June 2007 and June 2008 before and after exposure to a thermal stress (or control temperature). After sprint trials we collected muscle tissue to quantify expression levels of Hsp70, one of the heat shock proteins. Lizard from all sites showed a decrease in sprint speed as a result of the heat stress and sprint speed was inversely related to Hsp70 expression. These results, along with the environmental variation in temperature at our sites indicate the potential for natural selection to act within these populations and may lead to populations of *S. occidentalis* becoming locally adapted to environmental temperature.

77.1 MEDINA, J.M.*; TANKERSLEY, R.A.; Florida Institute of Technology; *jmedina@fit.edu*

Role of chemical cues in the visual orientation of horseshoe crab larvae and juveniles.

Adult horseshoe crabs (*Limulus polyphemus*) have long served as models for the study of vision in marine arthropods. Yet, little is known about the visual responses of early life history stages. We examined the visually directed movements and orientation of larvae and first stage (tail-stage) juveniles to horizons containing dark visual targets of different sizes. The study tested the hypotheses that (1) early life history stages use visual cues to avoid predators or locate potential refuge areas and (2) responses to visual targets depends upon ontogentic stage and the presence or absence of chemical cues from potential nursery habitats. Visual orientation of larval and juvenile crabs to horizontal rectangles subtending angles from 30-330 was tested in a circular arena containing water that either lacked estuarine chemical cues (offshore water) or contained odors from aquatic vegetation or predators. In offshore water, larvae oriented toward dark horizons subtending angles > 60. In contrast, juveniles moved in the opposite direction when exposed to similar horizontal rectangles. When placed in water containing chemical odors from potential predators and nursery habitats, including manatee grass *Syringodium filiforme*, shoal grass *Haloduli wrightii*, drift algae *Acanthophora sp.*, mummichug *Fundulus grandis*, and blue crab *Callinectes sapidus*, both larvae and juveniles crabs reversed their direction of orientation (approx. 180 phase shift) relative to their responses to similar targets in offshore water. Results support the hypotheses that the visual orientation of larval and juvenile horseshoe crabs changes dramatically upon exposure to habitat and predator cues and that the direction of the response undergoes an ontogenetic shift following metamorphosis to the juvenile stage.

42.4 MEEK, T.H.*; EISENMANN, J.C.; KEENEY, B.K.; HANNON, R.M.; GARLAND, T., Jr.; University of California, Riverside, Michigan State University; *tmeek001@ucr.edu*

High Fat Diet Increases Wheel Running in Mice Selectively Bred for High Voluntary Wheel Running

Energy balance plays a key role in the ontogenetic development of many complex diseases, e.g., obesity, type II diabetes, and the metabolic syndrome. Mice from a long-term selection experiment for high voluntary wheel running offer a unique model to examine the contributions of genetic and environmental factors in determining relevant aspects of behavior and metabolism. Since generation 16 and continuing through 50, mice from the 4 replicate selected lines have been running 2.5-3-fold more revolutions/day as compared with 4 non-selected control lines, but the nature of this apparent selection limit is not yet understood. Wheel running, food consumption (Teklad Rodent Diet (W) 8604 or Harlan Teklad TD.88137 Western Diet, 42% kcal from fat), and body mass were measured regularly in 200 males for two months starting at weaning (21 days of age). As expected from previous studies of rodents, wheel access reduced body size (both mass and length). With body length as a covariate, ANCOVA indicated that the high-fat diet (HFD) increased body mass and retroperitoneal fat pad mass, but this effect was ameliorated by wheel access (diet * wheel access interaction $P < 0.05$). HFD had little or no effect on wheel running in control lines, but resulted in a nearly 50% increase in the selected lines. No other pharmacological or environmental agent has increased running to this extent in the selected lines. Future studies will be required to determine the mechanism of this remarkable stimulation, which may involve fuel usage during prolonged (~ 8 hours/day) endurance exercise and/or direct behavioral effects on motivation or the hypothesized "activitystat." Supported by Michigan State Univ. Seed Grant to JCE and NSF IOB-0543429 to TG.

72.4 MEHTA, Rita/S*; ALFARO, Mike/E; WAINWRIGHT, Peter/C; Univ. of California, Davis, Univ. of California, Los Angeles; *rsmehta@ucdavis.edu*

Cranial diversity in Anguilliform fishes: does morphological disparity lead to lower levels of modular integration?

Fish skulls are highly complex musculoskeletal systems that have been used as a model for numerous biomechanical studies. Historically, the teleost skull has been broken down into the following functional units or modules: the oral jaws, hyobranchial complex, and opercular series. These modules are functionally integrated to perform important survival behaviors such as capturing, transporting (swallowing) and processing prey, and respiration. Although it is sometimes suggested that functional integration constrains evolutionary diversification, there are relatively few systems where this relationship has been quantitatively examined. Here we examine the design of the cranial system of a diverse group of teleosts, Anguilliform fishes. We propose to study the evolution of correlated trait evolution across different modules comprising the visceral skeleton of Anguilliforms as a means for understanding the evolution of functional integration. Specifically, we investigate the relationship between disparity within modules and how this affects the strength of their trait associations. Our preliminary analyses suggest that increased disparity in the lower jaw module appears to be correlated with morphological disparity of the hyobranchial complex. The length of the oral jaws and the cross-sectional area of the hyoid apparatus, not only appear to be strongly and inversely correlated, but attributed to the evolution of suction as a prey capture strategy. These and other planned analyses will be ultimately used to test whether the evolutionary innovation of biting as a prey capture strategy has increased cranial diversity in anguilliform fishes.

14.4 MENG, Yanling; ZOU, Enmin*; Nicholls State University, Thibodaux, LA; *em.zou@nicholls.edu*

Impacts of molt-inhibiting organochlorines on epidermal ecdysteroid signaling in the fiddler crab, Uca pugilator, in vitro

Organochlorine compounds (OCs) are widely used as industrial and agricultural chemicals. Because of their lipophilicity, these chemicals can readily accumulate in fatty tissues of crustaceans. Several OCs have been reported to have molt-inhibiting effects in Crustacea. To determine whether the molt-inhibition caused by these OCs involves interference with intracellular ecdysteroid signaling in epidermal tissues, the impacts of various molt-inhibiting OCs on N-acetyl-beta-glucosaminidase (NAG) mRNA level in cultured epidermal tissues from the fiddler crab, *Uca pugilator*, were investigated using quantitative real-time PCR. NAG mRNA was found to be inducible by 20-hydroxyecdysone in cultured epidermal tissues. The results show that, of the six molt-inhibiting OCs tested, methoxychlor is the only one that inhibited the NAG mRNA level, suggesting this OC can suppress epidermal ecdysteroid signaling. Arochlor 1242, PCB29, endosulfan and kepone were found to upregulate the NAG mRNA level in epidermal tissues, suggesting these OCs can stimulate epidermal ecdysteroid signaling, while heptachlor had no effect on NAG mRNA expression in cultured epidermal tissues.

S4.8 MERLIN, C.*; REPPERT, S.M.; UMass Medical School; *Steven.Reppert@umassmed.edu*

The Evolution of Circadian Clocks in Insects

The molecular mechanism of circadian clocks has evolved independently several times over the course of evolution. However, within insects, in which circadian clocks regulate key daily and seasonal aspects of physiology and behavior, it appears that a single clockwork mechanism evolved that has undergone specialized changes in various lineages, through the processes of gene duplication and loss. The intracellular clockwork mechanism involves transcriptional feedback loops that drive persistent rhythms in mRNA and protein levels of key clock components. Within holometabolous insects, a molecular clock mechanism has been most extensively studied in the fruit fly *Drosophila melanogaster*, the housefly *Musca domestica*, the monarch butterfly *Danaus plexippus*, and the Chinese oak silk moth *Antheraea pernyi*, with more limited studies in the commercial silkworm *Bombyx mori*, the honeybee *Apis mellifera*, and the beetle *Tribolium castaneum*. Hemimetabolous insects, like cockroaches, locusts and crickets, have been the subjects of intensive behavioral studies of the circadian clock, but less in known about its molecular control, because genetic resources in these species are not yet available. Studies in the monarch butterfly have expanded our knowledge of the diversity of clockwork mechanisms within insects with the discovery of two functionally distinct, clock-relevant cryptochrome proteins. The ancestral clock of the butterfly provides a model for comparison of clockwork mechanisms among insects, and between insects and mammals.

9.9 MERRILL, L.*; ROTHSTEIN, S.I.; O'LOGHLEN, A.; Univ. of California, Santa Barbara; *lmerrill@lifesci.ucsb.edu*

Divergent Response of the Innate Immune System to Acute Stress in Male and Female Brown-headed Cowbirds (Molothrus ater)

Researchers have found substantial evidence linking stress and immunosuppression in numerous animals. There are few studies, however, documenting the duration and degree of stress response in wild animals as manifested by changes in innate immunity. In this talk we present data on the bacteria-killing ability of a captive but wild-caught group of male and female Brown-headed Cowbirds exposed to an acute stressor. We measured the bacteria-killing levels of the birds blood at different intervals to obtain a time series profile of the immune response post stressor. We conducted two experimental sessions for each sex. For the first male session, we stressed the birds by aggressively chasing them around their cages for 15 second. In the second male, and both female sessions we stressed the birds by catching them and collecting blood to obtain baseline bacteria-killing levels. Males and females exhibited opposite responses to the stressor; male bacteria-killing levels declined before recovering, while female levels increased before returning to baseline. In the first experiment, male bacteria-killing levels declined at least 15% at 90 minutes post stressor and had begun to recover at two hours. In the second experiment, male levels declined eight percent between 30 and 60 minutes post stressor, and had recovered to baseline at two hours. Female bacteria-killing peaked 90 minutes post stressor approximately 20% above baseline, and returned to baseline three hours post stressor. These results show a sex-specific difference in immune response to acute stress. In addition, they demonstrate the speed with which the innate immune system responds to an acute stressor, and subsequently the length of time it takes to return to baseline levels.

61.3 MERRY, J.W.*; RUTOWSKI, R.L.; Arizona State University; *jmerry@francis.edu*

Does body size limit eye size in Drosophila melanogaster?

We tested the hypothesis that body size constrains the evolution of eye size in insects. We subjected flies to antagonistic artificial selection on eye height and thorax length in an effort to disrupt the relationship between these two variables. We predicted that body size-induced limits on maximum eye size would result in a smaller response among lines selected for proportionally large eyes and a greater response among lines selected for proportionally small eyes. Instead, there was an immediate and equivalent response to selection in both directions, with complete separation of both experimental lines from control lines within three generations. Realized heritability (h^2) was 0.16 in "Large Eye" lines and 0.18 in "Small Eye" lines, which matches broad-sense heritability estimates (H^2) from a previous experiment. Nevertheless, the specific morphological changes that produced these responses differed among treatments. Selection favoring proportionally larger eyes resulted in a large decline in thorax length and only a small increase in eye height. On the other hand, selection in lines favoring proportionally smaller eyes responded entirely via a decline in eye size. Finally, we subjected animals from each of the selection treatments to diets of varying nutritional quality to test the hypothesis that lines with proportionally large eyes were more resource limited than lines with proportionally small eyes. The dietary restriction affected all lines equally. Nevertheless, Large Eye animals showed a decline in eye size during the diet experiment across all diet treatments, which may indicate that natural selection operated against proportionally large eyes following relaxation of artificial selection.

10.9 METZGER, KA*; BAIER , DB; LIN, A; HARPER, CJ; HERRING , SW; BRAINERD, EL; Touro University College of Medicine, Brown University, University of Washington; *Keith.Metzger@touro.edu*

XROMM analysis of mastication in miniature pigs

XROMM (X-ray Reconstruction of Moving Morphology) is a newly developed technique for visualization and analysis of 3D skeletal kinematics. In XROMM, accurate animations of skeletal movement are generated by combining 3D morphological data from CT scans with biplanar videofluoroscopy. The goals of this study are to: (1) assess precision of radiopaque marker-based XROMM under typical in vivo experimental conditions, and (2) compare results of XROMM analysis of the kinematics of minipig mastication with previously published studies. Precision of XROMM is assessed through analysis of inter-marker distances between pairs of markers implanted in the same bone and recorded under typical experimental conditions at 250 Hz. The mean standard deviation of inter-marker distance for 13 chewing sequences is 0.084 mm, and there is no significant difference between manual and automatic tracking methods for marker centroids (p=0.82). Results of the XROMM analysis of minipig mastication are consistent with previous studies (*e.g.* Herring, 1976, *Arch. Oral. Biol.* 21: 473), including bilateral grinding and frequent reversal of grinding direction with each stroke. The 3D rigid body kinematics of the mandible confirm the importance of lateral grinding, and show for the first time that grinding results primarily from rotation of the mandible about a dorsoventrally oriented axis, with little contribution from lateral translation of the whole jaw. Substantial dorsoventral and rostrocaudal translations were found, resulting from jaw protrusion and retrusion. Rotation about a rostrocaudally oriented axis was negligible, likely due to soft tissue constraints and low amounts of tensile strain at the TMJ.

S5.5 MEZENTSEVA, Nadejda/V*; KUMARTILAKE, Jaliya; NEWMAN, Stuart; New York Medical College, Valhalla, The university of Adelaide, Adelaide, Australia; *mesen2000@gmail.com*

Brown adipocyte differentiation pathway in birds: an evolutionary road not taken

The adipose organ of mammals consists of white (WAT) and brown (BAT) adipose tissue. The main function of WAT is to store energy; in contrast, BAT dissipates energy for heat production. BAT thermogenic function is possible due to uncoupling protein 1 (UCP1). Thermogenic BAT has been considered to be an evolutionary novelty in mammals. In contrast to BAT, UCP1 is not a new gene because it is present in fish and amphibians. In both: mammals and fish, UCP1 expression is under the control of temperature. In mammalian BAT, temperature control is achieved via activation of the beta-adrenergic receptors (beta-ARs). We have demonstrated that avian brown adipocyte-like cells (ABALC) can be induced from embryonic limb bud mesenchymal cells under in vitro conditions. We have also shown that avian and lizard species lack the gene for UCP1 and, therefore, ABALC are not functional brown adipocytes. Nevertheless ABALC are generated by a developmental pathway virtually identical to brown fat differentiation in mammals. Furthermore, ABALC induction resulted in strong transcription from a transfected mouse UCP1 promoter. Treatment with beta-AR agonists activated lipolysis in ABALC. Activation of the exogenous UCP1 promoter in these cells is also under control of beta-ARs, as is the endogenous one in mammals. These findings strongly suggest that the brown fat differentiation and thermoregulation pathways evolved in a common ancestor of birds and mammals, and that its thermogenicity was lost in the avian lineage, with the degradation of UCP1, after it separated from the mammalian lineage. Since this event occurred no later than the saurian ancestor of birds and lizards, an implication of this work is that dinosaurs had neither UCP1 nor canonically thermogenic brown fat.

15.2 MIKLASZ, K.A.; Hopkins Marine Station; *kmiklasz@stanford.edu*

Solving a low-Reynolds number conundrum: How fast should diatoms sink?

Diatoms are one of the oceans primary producers. We would like to understand the movement and flux of diatoms through the water column, or how fast diatoms of different sizes should sink. Fluid dynamic theory (Stokes law) predicts that for small objects such as diatoms, the relationship between size (r) and sinking speed (V) should be $V \sim r^2$. Unfortunately, empirical data collected for diatoms over the last fifty years suggests an exponent much lower (between 1 and 1.5). This discrepancy can be solved if one realizes two facts: first, most of the diatom's mass is in its frustrule, and second, the frustrule scales like a surface area. Through expressing these two ideas mathematically, a modification can be made to Stokes law such that it agrees with the empirical data. This modification solves a problem that has persisted for over fifty years and finally allows accurate modeling and prediction of diatom sinking speeds for oceanographic nutrient flux.

80.6 MILLER, Christine W.*; FLETCHER, Robert J.; University of Florida; *cwmiller@ufl.edu*

The type and timing of social information alters offspring production in the cactus bug, Chelinidea vittiger (Hemiptera: Coreidae)

The acquisition and use of information is essential for decision-making in an uncertain world. The use of social information, or information from the behavior of others, may be a common and efficient mechanism to improve estimates of resource quality by animals. According to theory, social information cues with higher information content should have a greater influence on decision-making, and current information should be weighed more than prior information. However, experimental tests of these hypotheses remain scarce. We exposed female cactus bugs (*Chelinidea vittiger*) to different types of social information (the presence of conspecific eggs or nymphs) presented at different times (current or prior to egg laying) to determine the influence of social information on offspring production. We found that the presence of conspecific eggs or nymphs increased egg production by females. In particular, the presence of eggs, regardless of when they were presented, consistently increased egg production, whereas nymphs only increased egg production when presented during egg-laying. We conclude that the type and timing of social information may be an important, yet unappreciated, influence on reproductive allocation.

8.3 MILLER, L.P.*; DENNY, M.W.; HARLEY, C.D.G; Hopkins Marine Station, Stanford University, University of British Columbia; *millerlp@gmail.com*

Long-term reconstructions of limpet body temperatures allow estimation of the frequency and severity of stress events, and reveal potential consequences for small scale distributions on a rocky shore

The distribution of species within microhabitats at a site may be driven by a variety of factors, both biotic and abiotic. To examine the potential role of high temperature and desiccation stress on the small-scale distribution of the limpet *Lottia gigantea*, we used a combination of physiological assays and biomechanical modeling techniques to hindcast the occurrence of sub-lethal and lethal stress events in a population. Sub-lethal and lethal stress exposures were conducted using an environmental chamber designed to recreate stressful field conditions in the laboratory. Heat-shock protein 70 expression was used as a metric of sub-lethal stress, and median lethal temperatures were calculated. These physiological parameters were combined with the output of a bio-physical heat-budget model to predict conditions under which *L. gigantea* would experience significant sub-lethal stress or mortality. Within a subset of the microhabitats at our site, we predict that the vertical distribution of limpets could be set by rare high temperature and desiccation events. The synthesis of these techniques has the potential to help inform ecologists about the role of physical and physiological constraints in shaping communities and their responses to future environmental changes.

15.4 MILLER, LA*; SANTHANAKRISHNAN, A; University of North Carolina at Chapel Hill; *lam9@email.unc.edu*

Diving wasps: swimming and flying at very low Reynolds numbers

The family Mymaridae (fairyflies) is comprised of tiny parasitoid wasps that include the smallest of all insects. The females of several species in this family are known to dive into the water and swim with their wings and hind legs in order to parasitize the eggs of larger insects. Fairyflies also represent some of the smallest organisms that use flapping appendages to generate lift and thrust, in both swimming and flying. The forewings of the insect have reduced venation and a marginal fringe of hairs. The hind wings are extremely narrow and contain setae along the entire margin. In this study, we used computational fluid dynamics and particle image velocimetry (PIV) to characterize the flow around simplified models of fairyfly flapping wings and hind legs. We described the net thrust in water and lift in air produced over a range of Reynolds numbers and relate the magnitude of these forces to the behavior of the wake behind the flapping appendages. The assumption that the fringed wings act as solid plates in both air and water was also examined. At these scales, both swimming and flying become relatively inefficient, and these insects are likely pushing the lower limits of locomotion with flapping appendages.

50.4 MINEO, PM*; ROBERTS, ME; SCHAEFFER, PJ; Miami University; *mineopm@muohio.edu*

Skeletal muscle energetics following cold acclimation in a brown adipose tissue deficient mouse.

We are interested in muscle plasticity in response to cold challenge. To remove the influence of brown adipose tissue (BAT) and non-shivering thermogenesis, we use the UCP-dta mouse, a transgenic line lacking BAT. When presented with an acute cold challenge, summit VO_2 in UCP-dta mice were significantly lower than wild type controls. These results show that the lack of functional BAT in these mice greatly reduces their ability to produce heat during an acute cold challenge as shivering in skeletal muscle is not able to compensate for the absence of BAT. Further, we present data on the skeletal muscle mitochondrial respiration in these mice. Future experiments will investigate the effects of cold acclimation on the aerobic capacity of skeletal muscle following sustained shivering and how the increased activity due to shivering affects mitochondrial energetics.

5.4 MINER, B.E.*; KERR, B.; University of Washington; *miner@u.washington.edu*

Adaptation to Variable Ultraviolet Radiation Threats in Alpine Daphnia Populations

How do organisms evolve to tolerate environmental stresses that vary in space and time? This simple question is of critical importance in the current era of global climate change. In particular, one can study the relative importance of induced (acclimation) responses versus local (fixed) adaptation among populations with different environmental histories. In aquatic systems, organisms must frequently cope with exposure to harmful ultraviolet radiation (UVR) in habitats that exhibit high water clarity, such as those at high altitude. The evolutionary processes responsible for adaptations to high UVR habitats in zooplankton have received little attention to date, yet knowledge of such processes will be valuable in the near future, as some freshwater habitats are expected to exhibit increases in UVR transparency due to indirect effects of global climate change and other anthropogenic factors. We investigate the evolutionary history of adaptation to high and variable UVR exposure in multiple interconnected populations of the zooplankton *Daphnia pulex* in the Olympic Mountains of western Washington. Because these organisms inhabit ponds that are located in a forest-to-alpine transition zone, the UVR transparency of the ponds spans a wide range, such that some populations receive considerable UVR exposure while others receive almost none. We find that a populations tolerance to UVR in the laboratory mirrors the UVR threat in their natal pond. In addition, we find that local adaptation to UVR conditions outweighs acclimation effects in determining UVR tolerance. Finally, we evaluate differentiation for UVR tolerance in the context of neutral genetic differentiation among populations to gain insight into the evolutionary history of these adaptations.

7.2 MINER, BG*; MULLER, E; PORTER, S; MORGAN, SG; Western Washinton University, Univ. of California, Davis; *benjamin.miner@wwu.edu*

Factors that Influence the Strength of Indirect Interactions Mediated by Phenotypic Plasticity

For several decades ecologists have been interested in comparing the relative importance of direct and indirect interactions. In recent years, research has focused on comparing different types of indirect effects. This is especially the case for trophic cascades. The classic density-mediated or non-consumptive indirect effects are mediated through predators consuming and reducing prey population sizes. In contrast, trait-mediated or non-consumptive indirect effects are mediated through plasticity of prey in response to a predator. Which one is more important depends on the system, and thus the question becomes what aspects of a system determine the relative strength of these two types of interactions. We present the results from several laboratory experiments on an intertidal marine trophic cascade. A seastar is the predator (*Pycnopodia helianthoides*, or *Pisaster ochraceus*), a snail (*Chlorostoma funebralis*) is the prey, and algae (unidentified species of diatoms, or *Macrocystis* sp.) are the resource. We determined that the strength of non-consumptive effects is altered with cue concentration, and degradation of cue. Additionally, results suggest that prey condition and density also influence the strength of non-consumptive effects. These results have important implications for comparing the relative strengths of consumptive vs. non-consumptive indirect effects.

47.3 MIRANDA, R.A.*; SEARCY, B.T.; PROPPER, C.R.; Northern Arizona University; *ram257@nau.edu*

Arginine Vasotocin Induces Calling Behavior in Xenopus tropicalis

The non-mammalian neurohormone arginine vasotocin (AVT) and its mammalian homologue, arginine vasopressin (AVP), influence a variety of social and sexual behaviors across vertebrate taxa. The AVT/AVP peptide and receptor structures are conserved throughout vertebrate evolution as are the endocrine, neuroendocrine, and behavioral effects. Vocal modulation is the most widely established behavioral role for AVT/AVP and has been documented from fish through mammals. We investigated whether AVT induces calling behavior in male *Xenopus tropicalis*, the Western clawed frog. Ten adult males received three different doses of AVT (0 ug, 1 ug, 10 ug) in 50 ul saline Ringers solution. The injections were given in random order with at least three days between injections. Frogs were kept in separate tanks with six liters of salt-conditioned RO water and recorded using a hydrophone under four different contexts (no stimulus, with male call playback, with an untreated adult female, and with male call playback and an untreated female) for 15 minutes per context over the course of six hours. The following number of frogs was observed calling at some point during the experiment: one injected with 0 ug AVT; three with 1 ug; six with 10 ug. The difference between treatments is significant (G-test, $p=0.0495$). Furthermore, all calling males from the three treatments were observed calling when a female was present while no males called when a female was absent (G-test, $p<0.001$). Male calls were identified as one of four types: a fast (>25 Hz), long (> 1 s) trill; a fast, short (<1 s) trill; a slow (5-25 Hz) trill; a click. Future work will determine if calling is, indeed, female-dependent and, if it is female-dependent, whether this contextual element is a result of tactile, visual, and/or pheromonal cues.

13.1 MITGUTSCH, Christian*; WONG, Benita; SCHNEIDER, Richard A; University of Zurich, Zurich, Switzerland, University of California at San Francisco, San Francisco, USA; *christian.mitgutsch@gmail.com*

The role of the cranial neural crest during species-specific morphogenesis in quail, duck, and quail-duck chimeras

We investigated species specific morphogenesis in Japanese quail, *Coturnix coturnix japonica* (Aves: Galli) and in White Pekin duck, a domestic race of the mallard, *Anas platyrhynchos* (Aves: Anatidae). Species specific developmental characters concerning timing, size, and shape can easily be recognized from earliest stages onward. For example, species specific head morphologies are already manifested during neurulation when notable proportional differences in the fore- and midbrain region become apparent. Furthermore we found a slight relative delay in neural tube closure when compared to somitogenesis in the duck relative to the quail. Distinctive size, shape, and proportions of the mandible could be observed throughout development. As an example of an inner morphological structure, the trigeminal ganglion develops a species-specific morphology early during its development, particularly obvious is the more robust maxillary-mandibular ganglionic part in duck embryos. Utilizing the developmental differences in these two bird species, we assessed the influence of the cranial neural crest on the development of species-specific ganglionic shape by grafting cranial neural crest populations unilaterally from quail donors to stage matched duck hosts. We found donor (quail) specific traits on the donor side in contrast to the duck specific development on the quail side. In particular the mandible shape was found quail like and the donor sides developed a less robust trigeminal ganglion also indicating donor specific development. This is in accordance with observations on connective tissue development described from similar experiments.

16.6 MODRALL, J.T.*; KEATING, J.H.; MILLER, E.A.; POKRAS, M.A.; Tufts University, Grafton, MA, Tri-State Bird Rescue and Research, Newark, DE ; *jmodrall@verizon.net*

Syrinx of Northern Gannets (Morus bassanus): What are those lumps?

The avian syrinx is located at the bifurcation of the trachea and is considered the vocal organ of birds. Variations in avian syringeal anatomy are vast and have been used for taxonomic purposes. However, scant documentation exists of the syringeal morphology and unusual syringeal appendages of Northern Gannets. They are sexually monomorphic, highly social, breed in dense colonies and use their voice for many purposes including pair bonding, individual recognition and territoriality. This study provides an anatomic and histologic description of the Northern Gannet syrinx and associated appendages. The gannet syrinx is tracheobronchial, with well developed tympana on the ventral and dorsal aspects, medial tympaniform membranes, pessulus and interbronchial ligament. The gannet syrinx is sparsely muscled. Most unusually, the gannet syrinx has bilateral appendages covering lateral tympaniform membranes (ltm), hereafter called syringeal nodules. The nodules span the ltm and adjacent interannular membranes, but are not attached to the ltm itself. The well vascularized nodules are composed mainly of adipocytes. They grow during development and appear to undergo atrophy during emaciation. Similarly sized nodules are present in both sexes. Nodule growth may explain vocal development of chicks. Given that the syrinx and associated membranes play a role in voice production, it is our hypothesis that syringeal nodules may modify vocal quality. Further, since these nodules change in size during maturation and with body condition, the nodules may provide a mechanism, or "truthful signal", by which gannets could assess the body condition or maturity of mates or competitors.

S2.7 MOELLER, O. S.; University of Rostock; *ole.moeller@uni-rostock.de*

Branchiura, -parasitic crustaceans with a sting

The Branchiura are fascinating parasitic crustaceans not only able to attach to the slippery sides of freshwater fish, but also able to detach at will and swim freely to find another host. The Branchiura display two different ways of attachment to the fish surface as adults: the Mx1s are either hooks (*Dolops*) or suction discs (*Argulus, Chonopeltis*, and *Dipteropeltis*). In larval *A. foliaceus* the first maxillae are hooks. During larval development, the proximal part of the first maxilla increases in size to form a large disc/cup. Specific homologies exist between the larval hooks of *Argulus* and the adult hooks of *Do. ranarum*: The Mx1 distal segment terminating in a double structure: a distal two-part hook (in *Argulus*) or one hook and an associate spine-like structure (in *Dolops*). In the phylogenetic reconstruction based on mt16S rRNA, 18S and 28S rRNA), Do. ranarum is found to be a sister group to all other Branchiura, which here comprise six *Argulus* and one *Chonopeltis* species. Based on the molecular phylogeny a likely evolutionary scenario is that the ancestral branchiuran used hooks for attachment, as seen in *Dolops*, of which the proximal part was then modified into suction discs in *Argulus* and *Chonopeltis* (and *Dipteropeltis*). Based on previously overlooked papers and a re-investigation of paratype material, the presence of a pre-oral spine in *D. hirundo* was finally confirmed. As this character could possibly support a *Argulus+Dipteropeltis* clade and the molecular data suggest *Argulus* as paraphyletic with respect to *Chonopeltis*, (no *Dipteropeltis* seqs are available), the internal topology of the branchiuran genera remains open. Our phylogenetic reconstructions confirm the sister group relationship of the Branchiura and Pentastomida with the most comprehensive taxon sampling until now. No evidence supports a branchiuran in-group position of the Pentastomida.

61.2 MOOI, R.*; DAVID, B.; California Academy of Sciences, Centre National de la Recherche Scientifique, Dijon; *rmooi@calacademy.org*

Axes of evol: Anterior-posterior body patterning is congruent with a disordered Hox cluster in echinoderms

Recent advances in echinoderm evo-devo include acquisition of the genome sequence for *Strongylocentrotus purpuratus*. The echinoid Hox cluster is disordered. Genes of the anterior class (*Hox1* to *Hox3*) are translocated in reverse order to the 5' end of the cluster (*Hox4* is missing). Prior to such discoveries, the Extraxial-Axial Theory (EAT) was introduced. The EAT is a reappraisal of body homologies based on embryological and anatomical criteria in all echinoderms, recognizing two main body wall components. The extraxial part is related to somatocoels and develops in the non-rudiment region of the larva. The axial part is associated with the hydrocoel and is derived from a rudiment that develops on the left side of the larva. The merger of EAT and evo-devo datasets permits comprehension of echinoderms in a single framework. Genes of the central (*Hox7* and *Hox8*) and posterior classes (*Hox9/10* to *Hox11/13b*) express first along a somatocoelar "hox vector" in the extraxial domain. *Hox5* expresses later and anteriorly near hydrocoelar derivatives in the axial domain. *Hox3* expresses still later. Expression of *Hox2* and *Hox1* remains unknown. Temporal colinearity is strongly upheld, and spatial colinearity is split into divergent vectors congruent with the axial-extraxial distinction of the EAT. Disorder of the Hox cluster does NOT mean incomprehensible disarray. It represents innovations allowing dominant adult expression of the most anterior domain (axial) over the posterior (extraxial). Hox "disorder" is correlated with the 2-part developmental trajectory of echinoderms leading to prevalence of rudiment derivatives (axial elements), thereby superimposing radial symmetry on the anterior-posterior axis.

S3.8 MOORE, Ignacio/T*; HOPKINS, William/A; Virginia Tech; *itmoore@vt.edu*

Interactions between hormones and energetics as mediators of performance and reproductive success

How an animal performs in its natural environment ultimately determines its reproductive success. Thus, performance traits are often a target of selection, both natural and sexual. While many studies have investigated how selection acts on performance-related traits, fewer studies have examined how hormones are related to performance and ultimately reproductive success. The paucity of information on hormones, performance, and reproductive success is partially because the relationships are rarely simple. Performance traits are often mediated or influenced by multiple hormones and selection that is acting directly on the performance trait is often acting indirectly on the underlying endocrine mechanisms. We propose that, from a physiological perspective, performance and ultimately reproductive success are strongly influenced by interactions among glucocorticoid stress hormones, sex steroids, and energetics. These interactions are often two-way and may be positive or negative. For example, while reproduction is often suppressed during a stress response, baseline stress hormone levels are often elevated during the breeding season and appear to facilitate energetically expensive processes and behaviors. Here we discuss what is known about the interactions among glucocorticoid stress hormones, sex steroids, energetics, and performance traits. We emphasize that if investigators are interested in fully understanding how hormones and energetics influence performance traits and ultimately reproductive success, then investigating the complex relationships and interactions is necessary.

55.6 MOORE, M.S.*; JACKSON, F.R.; TURMELLE, A.S.; PANASUK, B.J.; MENDONCA, M.T.; RUPPRECHT, C.E.; KUNZ, T.H.; MCCRACKEN, G.F.; Boston University, Boston, Centers for Disease Control and Prevention, Atlanta, University of Tennessee, Knoxville, Auburn University, Auburn, University of Tennessee, Knoxville; *mmoore@bu.edu*

Rabies Exposure, Relative Immune Function and Life-history Traits in the Big Brown Bat, Eptesicus fuscus

This study characterized immune responses in the big brown bat, *Eptesicus fuscus*, and how variation in immune function relate to population differences, life-history traits and exposure to rabies virus. We used a bactericidal assay with *Escherichia coli* to test innate immune responses and subcutaneous injections of phytohemagglutinin (PHA) to test cell-mediated adaptive immune responses. To assess pathogen exposure, we used the rapid fluorescent focus inhibition test (RFFIT) to measure rabies virus-neutralizing antibodies (VNA). We estimated infection status from oropharyngeal swabs using nested RT-PCR and sequencing. The proportion of bats exposed to rabies virus was 2% in 2005, 17% in 2006 and 6% in 2007. Rabies viral amplicons were generated from only three of 515 individual bats. Pregnant and lactating females were more likely to exhibit VNA compared to postlactating individuals. Bactericidal ability of bat blood was significantly related to colony-level effects, reproductive stage, and sex. Specifically, postlactating bats showed greater bacterial killing compared to lactating bats and females demonstrated an ~13% greater killing ability compared to males. PHA index was significantly related to date and year. Results suggest that sex, reproductive status, colony site, and seasonal and annual variation may influence the ability of bats to respond immunologically. Moreover, our results suggest that pregnant and lactating females, which exhibit increased gregarious behavior compared to bats in other reproductive stages, have greater pathogen exposure.

28.5 MORAN, A.L.*; WOODS, H.A.; Clemson Univ., SC, Univ. of Montana, Missoula; *moran@clemson.edu*

Polar Gigantism in Antarctic Invertebrates: Sizing up the Role of Temperature-Oxygen Interactions

Polar gigantism, the trend among some marine invertebrates towards large body sizes at high latitudes, is not clearly understood in ecological or evolutionary terms. One hypothesis is that in cold environments, ectotherms have low metabolic oxygen demands and thus are released from constraints placed on body size by the challenges of O2 transport and diffusion at higher temperatures. We tested this hypothesis in the Southern Ocean using a metabolically simple, diffusion-driven system, nudibranch egg masses. We developed biophysical models that predicted O2 dynamics and maximum possible sizes at different environmental temperatures. These models accurately described radial O2 profiles in the lab and field, and predicted that in the Antarctic, egg masses can reach larger sizes and/or higher densities of embryos without experiencing greater internal hypoxia. We measured the size of egg masses from 6 Antarctic species and compared them to masses of temperate relatives, and showed that Antarctic nudibranchs indeed lay significantly larger masses. However, Antarctic egg masses contained substantially fewer embryos per unit volume than temperate masses. Low embryo density was due to the unusually large size of Antarctic embryos, which averaged 10x larger than embryos of their temperate relatives. This, along with direct observations of hatching in some taxa, suggests the majority of Antarctic species in our study are nonplanktotrophic. Thus, predictions of the temperature-oxygen model must be considered in the light of dramatic differences in life histories between polar and temperate oceans.

69.3 MORENO, C.A.*; BIEWENER, A.A.; Harvard University; *cmoreno@oeb.harvard.edu*

Quadrupedal Turning Behaviors: Mechanics and Gait Preference

Turning behaviors are critically important for many terrestrial animals and have been studied in a variety of taxa. Recent work in our lab has described the functional roles the limbs of cursorial quadrupeds in terms of the linear impulses produced during each stride of a 90 turn as well as how each limb contributes to the overall roll, pitch and yaw moments about the center of mass (COM). We found that both the forelimbs and hindlimbs contribute substantially to the production of lateral impulse in the turn direction, but that the outside limb produces more vertical and more lateral impulse than the corresponding inside limb. We also found that during trotting there was very little overall moment produced about the COM, whereas in galloping, there were large, alternating pitching moments, as well as substantial roll and yaw moments produced by all four limbs. With this foundation, we are developing a model to predict how upright animals initiate and execute turns while maintaining traction and stability. This work suggests a continuum between a continuous turning gait on one hand, where each stride is functionally similar to the previous stride, versus a discrete maneuver on the other, where the behavior is performed over a much shorter time scale resulting in differences in limb function from one stride to the next. It seems likely that during predator-prey interactions animals would use a combination of continuous, high-speed steady turning along with discrete, quick changes of direction to elude their predator or capture their prey. Because it has been frequently observed that racing animals such as dogs and horses prefer an inside lead gallop to an outside lead gallop, in this study we also address the mechanical consequences of lead preference and handedness during high-speed locomotion.

S7.11 MORGAN, EF*; SALISBURY PALOMARES, KT; MASON, ZD; LEONG, PL; HAYWARD, LNM; GLEASON, RE; BELLIN, D; Boston University; *efmorgan@bu.edu*

Mechanical Regulation of Skeletal Healing

An intimate relationship exists among the structure, mechanical function, and mechanical environment of skeletal tissues. The ability of these tissueswhich include bone, cartilage, tendon, and ligamentto withstand the forces placed upon them during activities of daily living is derived largely from their hierarchical, composite microstructure. Moreover, compelling evidence has continued to emerge that these tissues can respond to their mechanical environment through adaptive changes in structure and mechanical function. A powerful example of the close correspondence among structure, function, and mechanical cues in skeletal tissues is that of bone repair. Bone fracture healing involves a dynamic interplay of biological processes that ultimately restore form and function to injured bone. Our laboratory and others have demonstrated that altering the mechanical environment of a healing bone fracture can dramatically change the course of healing. These findings indicate that it may be possible to use mechanical stimulation not only to accelerate bone repair but also to promote repair and regeneration of other types of skeletal tissues. This talk will present our recent work on manipulating the mechanical environment of a healing bone defect in order to promote the formation of cartilaginous tissues that have many microstructural and molecular similarities to hyaline cartilage. Special emphasis will be given to the experiments that have sought to elucidate relationships between local mechanical stimuli and the micro- and macroscale structure of the healing tissues.

98.3 MORITZ, S.; Friedrich-Schiller-Universitaet Jena; *sabine.moritz@uni-jena.de*

Adaptations of the perivertebral musculature to different locomotor behaviours in lizards.

Although the trunk and its associated musculature play an important role during locomotion in lizards, studies on the locomotor apparatus are biased towards legs and only very few studies on the axial musculature exist. One feature determining muscular properties is the fibre type composition. Generally, oxidative muscles contract slow but are fatigue-resistant, while glycolytic muscles contract fast but fatigue quickly. Locomotor behaviour in lizard species ranges from slow exploratory walking, fast prey-ambushing or escape behaviours (burst locomotion) to pursuit hunting over longer distances. In order to investigate how the musculature meets the demands of these different locomotor strategies, the three-dimensional fibre type distribution of the perivertebral muscles in three distantly related lizard species (*Varanus exanthematicus, Dipsosaurus dorsalis, Acanthodactylus maculatus*) was studied using enzyme-histochemistry on frozen serial sections. Despite the highly comparable axial movements among the species, the fibre type distribution differed strikingly. The results are consistent with their different locomotor strategies. While the axial muscles were highly oxidative in the pursuit hunter *Varanus*, they were highly glycolytic in the ambush hunter *Dipsosaurus*. Thus, the metabolic profile reflects the functional trade-off between respiration (e.g. oxygen availability) and locomotion. Species that can not ventilate while running show a highly glycolytic profile and exhibit burst locomotion, whereas *Varanus* with its accessory gular pump and thus slower oxygen depletion is capable of sustained locomotion and shows highly oxidative muscles.

42.1 MOSTMAN-LIWANAG, H.E.*; BERTA, A.; COSTA, D.P.; BUDGE, S.M.; ABNEY, M.; ARNOULD, J.P.Y.; WILLIAMS, T.M.; UC Santa Cruz, San Diego State Univ., California, Dalhousie Univ., Halifax, Nova Scotia, UC Santa Barbara, Deakin Univ., Victoria, Australia; *mostman@biology.ucsc.edu*

Morphological and thermal properties of mammalian insulation: implications for the evolutionary transition to an aquatic lifestyle

Over the course of their evolutionary history, several mammalian lineages secondarily invaded the aquatic environment. With aquatic specialization came an evolutionary change from reliance on external insulation provided by fur to internal insulation provided by blubber. The Carnivora includes three independent transitions to the marine environment; among these, pinnipeds retain both types of insulation, providing an ideal model for investigating factors that drove the convergent evolution of blubber across lineages. We compared fur and blubber characteristics among carnivores, determining quality of the insulation from gross morphology, molecular composition of fat, and thermal conductivity. We found that marine carnivores have significantly flatter, shorter, and more dense hairs than terrestrial carnivores ($P<0.001$ for each). Sea lions and phocids have thicker blubber layers ($P<0.001$) and lower fur densities than fur seals ($P<0.001$). Comparisons of lipid, water and fatty acid content indicated differences in the composition of the inner and outer regions of the blubber among groups ($P<0.05$), suggesting phocids and sea lions utilize the outer layer for insulation and the inner layer for energy storage. Fur seals, in contrast, rely on fur for insulation and blubber for energy storage. Comparisons of thermal conductivity revealed decreases in the insulative quality of fur in aquatic specialists, and concomitant increases in the insulative quality of blubber. Overall, these results indicate consistent changes in the insulation of mammals and evidence for convergent evolution of thermal traits across lineages.

21.6 MOUNTCASTLE, A.M.*; TULL, C.; DANIEL, T.L.; University of Washington; *mtcastle@u.washington.edu*

Wing stiffness affects mean advective flows of Manduca sexta, with wing overlap a potential contributor

Many insects have wings that bend and twist during flight, often with dramatic deformations. The pattern and extent of deformation are dependent on wing flexural stiffness and the boundary conditions that govern actuation. Prior work has shown that the extent of deformation during hovering in *Manduca* can vary between strokes. The aerodynamic consequences of wing compliance, however, remain largely unknown. In this study, we examined the effects of wing stiffness on the overall induced flow in the wings of the hawkmoth, *Manduca sexta*. We subjected moth wings to robotic actuation in their dominant plane of rotation at the natural wing beat frequency of 25 Hz. We used digital particle image velocimetry at high temporal resolution (2,100 fps) to assess the influence of wing stiffness on the mean advective flows of three wings, each tested in a fresh, flexible state and a desiccated, stiff state (overall spanwise flexural stiffness increased 2-2.5x). We find that flexible wings yield mean advective flows with total magnitudes 2-4x those of their stiff wing counterparts, and vertical (lift-favorable) components that are 7-31x those of stiff wings. If flight forces are sensitive to wing deformation, then any mechanism that alters deformation is a potential source of flight control. We show that the overlap between forewing and hindwing can vary by 15% during ventral stroke reversals in *Manduca*. Flexural stiffness tests on extracted wing pairs reveal that overall spanwise stiffness can increase by a factor of 1.3 for a similar change from min. to max. wing overlap. Our results show that wing compliance may play a critical role in the production of insect flight forces, and suggest the possibility that wing overlap may affect compliance.

79.3 MUKAI, M.*; REPLOGLE, K.; WANG, G.; WACKER, D.; CLAYTON, D. F.; WINGFIELD, J. C.; Univ. of California, Davis, Univ. of Illinois, Urbana-Champaign, Univ. of Washington, Seattle, Univ. of Washington, Seattle; *momukai@ucdavis.edu*

Effect of season and territorial aggression on hypothalamic gene expression in song sparrows

Male song sparrows (*Melospiza melodia morphna*) are territorial year-round with two peaks of aggression in spring and fall. Neuroendocrine responses to a simulated territorial intrusion (STI) differ between breeding (spring) and non-breeding seasons (fall). In spring, STI is followed by increases in luteinizing hormone and testosterone, whereas these hormone inductions are not observed in fall. These observations suggest that there are fundamental differences in mechanisms driving neuroendrocrine responses to STI between seasons. We used spotted cDNA microarrays (SoNG 20K array) to test the hypothesis that gene expression profiles in the hypothalamus after territorial aggression would differ between the seasons. In this study, hypothalami were collected from free-ranging male song sparrows in western Washington after STI experiments, in which a sparrow was exposed to either a conspecific or a control (white-crowned sparrow) male. Our comparisons showed 152 genes that were differentially expressed between spring and fall in the control birds. There were 59 genes that were significantly different between control and STI birds in fall. However, only 14 genes were significantly different between control and STI birds in spring. These results suggest that the regulatory circuit underlying the neuroendocrine response during the breeding season requires fewer genes to be triggered by social interactions. Moreover, the genes identified in this study and their functional analyses significantly advance our basic understanding of the mechanisms that lead to differential neuroendocrine responses to aggressive interactions.

96.2 MUNOZ, Martha/M*; HERREL, Anthony; SASA, Mahmood; LOSOS, Jonathan; Harvard University; *mmunoz@fas.harvard.edu*

How similar are aquatic Anolis lizards: a detailed ecological and behavioral analysis of two Costa Rican species (A. oxylophus and A. aquaticus).

Anolis lizards of the Greater Antilles have become a model system for the study of adaptive radiations as species living in ecologically similar habitats have convergently evolved similar morphologies. However, some ecologically similar species such as aquatic anoles appear not to converge upon a single morphology. Yet, it remains currently unclear to what the degree these aquatic species utilize similar microhabitats within their stream-side habitat. As convergence can only be expected if selective pressures are similar, detailed ecological, behavioral and performance data are crucial to understand the lack of convergence among these aquatic species. Here we provide such data for two aquatic Anolis lizards from Costa Rica, A. oxylophus and A. aquaticus which have independently radiated into stream-side habitats. Preliminary analyses suggest that both species are morphologically distinct, behave differently, and use different structural microhabitats with A. aquaticus showing a clear preference for rocky substrates. Species also differ in locomotor performance (sprint speed) and bite force capacity and forage in different microhabitats. Future studies incorporating quantitative ecological and behavioral data for additional species living in stream-side habitats are clearly needed to gain better insights into the lack of convergence in the aquatic anoles.

42.3 MUNOZ-GARCIA, Agusti*; WILLIAMS, Joseph B.; Ohio State University, Columbus; *munoz-garcia.1@osu.edu*

Developmental plasticity of cutaneous water loss and lipid composition in stratum corneum of desert and mesic nestling house sparrows

Intercellular lipids of the stratum corneum (SC), the outer layer of the epidermis, form a barrier to water vapor diffusion through the skin. Previously, we measured cutaneous water loss (CWL) and lipid composition of the SC of adult house sparrows from two populations, one living in the deserts of Saudi Arabia, another living in mesic Ohio. Adult desert house sparrows had a lower CWL, a lower proportion of free fatty acids, and a higher proportion of ceramides and cerebrosides in the SC compared with mesic sparrows. In this study, we investigated developmental plasticity of CWL and lipid composition of the SC in desert and mesic nestling house sparrows reared in low and high humidity, and compared our results with previous work on adults. We measured CWL of nestlings and analyzed the lipid composition of the SC using thin layer chromatography. We showed that nestling house sparrows from both localities had higher CWL than adults in their natural environment, a result of major modifications of the lipid composition of the SC. The expression of plasticity in CWL seems to be a response to opposed selection pressures, thermoregulation and water conservation, at different life stages, on which regulation of CWL plays a crucial role. Desert nestlings showed a greater degree of plasticity in CWL and lipid composition of the SC than did mesic nestlings, a finding consistent with the idea that organisms exposed to more environmental stress ought to be more plastic than individuals living in more benign environments.

15.3 MURPHY, D. W.*; WEBSTER, D. R.; KAWAGUCHI, S.; KING, R.; YEN, J.; Georgia Institute of Technology, Australian Antarctic Division, Australian Antarctic Division; *dwmurphy@gatech.edu*

Locomotory Biomechanics of Antarctic Krill

Antarctic krill (*Euphausia superba*) are the keystone species of the Antarctic food web, yet little is known about the biomechanics of their behavior and, in particular, their locomotion. Although it has been noted that these animals swim via a metachronal wave moving along their pleopods from posterior to anterior, the kinematics of these swimming appendages have not been characterized. Determining the kinematics of krill in various swimming modes will shed light on the fluid mechanics of krill locomotion and thereby deepen our understanding of krill sensing and schooling. High speed footage (250 fps) of freely swimming juvenile and adult Antarctic krill was acquired at the Australian Antarctic Division in Hobart, Tasmania. Various swimming modes were identified and two-dimensional kinematic parameters such as pleopod stroke frequency, amplitude, and tail position were examined as a function of these swimming modes. The effect of body length on the stroke frequency of hovering krill was also investigated by comparing the kinematics of adult and juvenile animals, and it was found that the stroke frequency decreased linearly from 6 Hz for a juvenile krill (11 mm body length) to 3 Hz for adult krill (45 mm body length). For comparision, Pacific krill (*Euphausia pacifica*), which live in warmer seawater with lower kinematic viscosity, have been shown to exhibit a higher stroke frequency of 9.5 Hz (~20 mm body length). The swimming kinematics data will be used to address hypotheses regarding low Reynolds number locomotion of krill.

55.9 MURRAY, I.W.*; WOLF, B.O.; Univ. of New Mexico, Albuquerque; *imurray@unm.edu*

Exploring the nutritional ecology of the ornate box turtle in New Mexico via stable isotope analyses

We report on the stable isotope ecology of ornate box turtles, *Terrapene ornata*, in geographically distinct populations across New Mexico. The ornate box turtle is widespread in New Mexico, occupying a diverse array of habitats, from shin-oak dunes in the southeast, to Chihuahuan-desert grasslands in the central part of the state. Stable isotopes of carbon (^{13}C) and nitrogen (^{15}N) can be used to explore the plant photosynthetic pathway type used as a nutrient source (i.e. C_4 grasses and cacti versus C_3 annuals) as well as look at trophic shifts between individuals and across populations. We measured the ^{13}C and ^{15}N values of blood and growth ring scute keratin from box turtles in New Mexico. These tissues have different turnover rates, which means we can integrate dietary history over short and long periods of time over the course of an animal's life. Here we report on the long and short-term dietary history of a long-lived reptilian omnivore from several populations across New Mexico.

58.4 MUSCEDERE, M.L.*; SEID, M.; JOHNSON, N.; WILLEY, T.; GILLIS, B.; TRANIELLO, J.F.A.; Boston University, Smithsonian Tropical Research Institute, Northwestern University, Chicago, IL; *mario@bu.edu*

Brains, neurotransmitters, nursing, and foraging in the ant Pheidole dentata

Temporal polyethism, or age-correlated task performance, is a near universal feature of labor organization in social insects. Typically, young workers engage in within-nest work (nursing immatures), while older workers perform outside-nest work (foraging). In the ant *Pheidole dentata*, the number of tasks workers perform, and their task competence, increases as they age. This behavioral maturation is accompanied by marked neurological changes, including synaptic pruning, proliferation of serotonergic neurons, and increased dopamine and serotonin titres in the brain. Here we present novel evidence that worker brood-rearing efficiency also increases with age and that older workers are efficient nurses. This result contrasts with the traditional view that young workers form a discrete age caste that specializes on nursing. We next describe an additional neural correlate of temporal polyethism in *P. dentata*: expansion of the mushroom bodies, paired neuropils involved in learning and sensory integration. Finally, we provide the first experimental demonstration causally linking increased serotonin titre to two distinct components of foraging behavior: outside nest activity and responsiveness to trail pheromone. Workers fed the serotonin precursor 5-hydroxytryptophan had increased serotonin levels (verified by HPLC), were more likely to leave the nest, and followed trails longer than controls or workers whose serotonin levels were reduced by the serotonin synthesis blocker alpha-methyltryptophan. These results further our understanding of the social organization of labor by focusing on neural development and the aminergic control of polyethism in *P. dentata*.

S1.1 NARINS, P.M.; Univ. of California, Los Angeles; *pnarins@ucla.edu*

Influence of environmental noise on the evolution of communication systems

Many species of animals, including man, face the formidable task of communicating in naturally noisy environments. In this talk, I shall emphasize the effects of noise on both the calling behavior of anurans (frogs and toads) and the temporal and spectral filtering ability of the amphibian auditory pathway. Moreover, the role of spectral, temporal and spatial separation in minimizing masking by background noise will be examined. I shall review the evidence for the remarkable ability of amphibians to shift their call timing in response to both high-level interfering tones or to small intensity shifts in the background noise. Finally, I shall present behavioral evidence that broadband environmental noise may act as a strong selective force in sculpting the acoustic communication systems of two species of Old World arboreal frogs. The dramatic frequency shift into the ultrasonic range of the harmonic content of the advertisement calls likely represents an adaptation that minimizes signal masking by the intense broadband background noise from local streams. Supported by NIH Grant no. DC-00222.

69.1 NAUWELAERTS, S*; MALONE, S; CLAYTON, HM; Michigan State University, East Lansing; *nauwelae@msu.edu*

Development of interlimb coordination in young horses

Motor control development is the sequential, continuous age-related process whereby neurological control of skilled and coordinated movements changes. The process involves changes in coordination of locomotion, development of strength, posture control, balance, and perceptual skills. Young horses are able to stand and walk around within hours after birth despite their relatively small muscle mass and immature motor control. This study analyzes the development of interlimb coordination in young horses using timing between the footfalls of all four limbs. It was hypothesized that early locomotion would be geared towards maintaining dynamic stability while efficiency of locomotion would become important in more mature locomotion. Horses were videotaped at 60 Hz while moving freely out in the pasture, starting from the first time they went outside (usually the second day after birth). They were observed daily during the first week, and weekly until the foals reached one month of age. Footfall diagrams were obtained from the videos. Duty factor for each hoof, diagonality and ipsilaterality for both sides, and front and hind limb lag were calculated for a random selection of 50 strides. Based on similar data for adult horses, specific regions in the gait plots were appointed to known gaits. Results show that young horses have higher duty factors, indicating the importance of stability during locomotion. In addition, their interlimb repertoire was larger and less restricted to specific gaits. There was considerable inter-individual variation between foals. This study is part of a larger project that will test whether the development of dynamic and static stability is linked in horses.

24.2 NGUYEN, NHI / P.*; MILLER, LAURA; SANTHANAKRISHNAN, ARVIND; GUNDERSON, JENNIFER; Univ. of North Carolina, Chapel Hill; *en08nicki@gmail.com*

Flow within Physical Models of the Vertebrate Embryonic Heart

Vertebrate cardiogenesis is believed to be partially regulated by fluid forces imposed by blood flow in addition to myocardial activity and other epigenetic factors. Recent *in vitro* studies in embryonic cardiogenesis (see Hove et al., *Nature* , 2003) show that blood flowing through the embryonic heart tube creates shear forces necessary for the formation and development of the heart valves. It is suggested that these flow driven forces interact with the core proteins (e.g. proteoglycans, heparin sulfate glycosaminoglycans (GAGs), glycoproteins, and plasma proteins) making up the glycocalyx and endothelial surface layer (ESL). The shear and pressure forces from these flows provide a mechanical stimulus that is transmitted through the various proteins and the cytoskeleton, resulting in a biomechanical cascade within the ESL that might initiate intracellular processes leading to heart looping, chamber ballooning and valve formation. To understand the flow field within the embryonic heart, flow visualization experiments were performed on a series of physical models that represent the different morphological stages of early heart development. The chamber and valve depths of the models as well as the Reynolds numbers were varied in this study. Different compositions of solutions consisting of corn syrup and water were used as the fluid media to examine Reynolds numbers from 0.01 to 1000, corresponding to a scale of the early heart tube to the adult heart. The observed results showed that vortex formation within the chambers occurred for Reynolds numbers in the range of 1-10. This transition to vortical flow appears to be highly sensitive to the chamber and valve depths within the model. The sensitivity of this transition in flow ultimately affects the mechanotransduction ability of the ESL.

S5.4 NICHOLS, Scott A.; University of California, Berkeley; *nichols1@berkeley.edu*

The ancestry of animal cell signaling genes

The evolution of cell signaling mechanisms is thought to have been a pre-requisite to the evolution of multicellularity and the diversification of animal body plans. Reconstructing the ancestry of these mechanisms is complicated by their complexity and by the functional diversity of their molecular components. With more than 20 known binding partners, beta-catenin is a prototype of a multifunctional signaling molecule. Among other functions, beta-catenin plays critical roles in canonical Wnt signaling and cadherin-mediated cell adhesion. By exploiting the phylogenetic position of sponges, I have employed comparative and functional genomic approaches to explore the ancestry of beta-catenin function in animals. Specifically, the comparative analysis of beta-catenin orthologs in sponges, placozoans, cnidarians, and bilaterians suggests that structural aspects of beta-catenin are more highly conserved than functionally important amino acid motifs in the unstructured N- and C-terminal regions. Nevertheless, this comparative sequence analysis suggests that the signaling and adhesive functions of beta-catenin (at least) evolved prior to the radiation of modern animals. To test this prediction I have employed a yeast two-hybrid screen to identify candidate binding partners of beta-catenin in the sponge *Oscarella carmela*. Here, I discuss the outcomes of this analysis and use *in situ* hybridization and immunohistochemical techniques to further explore the timing of expression and subcellular localization of beta-catenin and key binding partners throughout sponge development.

8.7 NISHIZAKI, MT*; GRUNBAUM, D; CATTOLICO, RA; University of Washington; *mikenish@u.washington.edu*

Predicting bloom-formation from cell-level swimming, stability & gyrotaxis in a marine alga.

Heterosigma akashiwo is an actively motile marine alga that forms localized, dense aggregations known as harmful algal blooms (HABs). *Heterosigma* HABs have significant ecological and economic consequences in the marine environment and their formation is variable in both time and space. These HABs are often characterized by rapid increases in cell density in the surface layer of the ocean that cannot be accounted for by changes in population growth alone. An alternative explanation is that previously-dispersed cells become rapidly concentrated through swimming behavior and/or passive physical transport. A current challenge is predicting spatial distributions of these algae in realistic, moving flow environments. Because cells interact biomechanically and behaviorally with ambient flows, algal distributions cannot be predicted by simple addition of still-water swimming and flow. To measure swimming-flow interactions, we used a computerized video-based particle tracking system that quantifies the location and swimming orientation of large numbers of individual cells with high levels of spatial and temporal resolution. Still-water observations were made of cells (diameter ~ 10 microns) swimming freely within a stably-stratified 1.5 L tank. Observations were also made of cells swimming in a cylindrical tank in pure vorticity (solid-body rotation around its horizontal axis). Reconstructed cell trajectories from these experiments provided parameters for a turbulence model predicting the spatial distribution of cells during HAB formation in an estuary environment.

85.2 NOH, S; University of Connecticut, Storrs; *suegene.noh@uconn.edu*

Geographical variation in female and male song preference in Chrysoperla lucasina

Green lacewings in the *Chrysoperla carnea* species group are morphologically cryptic but clearly distinguishable via substrate-borne vibrational mating signals that both sexes produce. These species-specific mating signals are important in species recognition. Sexual selection upon these signals may have contributed to rapid speciation in the species group, where mating signal evolution seems to have outpaced that of DNA sequences. My objective was to test for evidence of sexual selection within *C. lucasina*, a member of the *carnea* group widespread across southern Europe. *C. lucasina* produces multi-volley signals and responds well to synthesized signals. First generation offspring were reared from individuals collected from three geographical localities (Switzerland, Italy, Slovenia). Individual preferences were measured for synthesized playback signals varying either in volley period or duration. Because both sexes sing, with females typically producing longer calls, I investigated the possibility of mutual mate choice by measuring both male and female preference. The following questions were addressed: (1) is there geographical variation in song preference, and (2) are the selective pressures from male vs. female preference similar in direction? Geographical localities showed different preferences for period but not for duration, with Slovene females preferring signals with slower periods compared to Swiss and Italian females. Male preferences were not different across localities. Overall, females preferred signals with slower periods whereas males preferred signals with faster periods. Males preferred signals with longer durations while female preference was not significant. When compared to measurements of song characters, the correlation or mismatch of preference and song for each sex from different localities could provide insight into the interactions of evolutionary forces acting upon the mating signals.

98.8 NOYES, N*; GILLIS, GB; Mount Holyoke College; *ggillis@mtholyoke.edu*

Flexor vs. extensor activity during jumping and swimming in Rana pipiens

Despite widespread study of jumping and swimming in anurans, little is known about the functional roles of limb flexor muscles in these animals. Work in toads demonstrates some overlap in extensor and flexor activity bursts during propulsion. To further explore flexor function in relation to extensors, we characterized activity patterns in antagonistic muscle pairs acting at the knee and ankle during jumping and swimming in *Rana pipiens*. Specifically, we implanted electrodes in the cruralis (CR) and semitendinosus (ST) to characterize EMG activity at the knee, and in the plantaris (PL) and tibialis anterior (TA) to characterize activity at the ankle. Our results indicate that all four muscles exhibit some coactivation during jumping and swimming. During jumping, all muscles exhibit nearly simultaneous EMG bursts lasting throughout much of takeoff. Intensities of bursts correlate positively between muscles, but negatively with the duration of the takeoff phase. During swimming, extensor activity is characterized by a single burst at the onset of limb extension. Flexor activity is more complex. The ST exhibits two EMG bursts per cycle. Burst 1 is closely aligned with activity in the extensors, and its intensity is positively correlated with extensor activity. Burst 2 is present later during limb retraction (~60-90% of swim cycle), and exhibits relatively little variation in intensity. The TA exhibits one long activity burst that begins late in limb retraction (~90% through the swim cycle) and lasts into limb extension, where its timing overlaps with extensor bursts. TA intensities correlate positively with intensities in both the PL and CR. In summary, major flexors and extensors are coactive during the propulsive phase of jumping and swimming, but flexor activity patterns shift considerably between the two locomotor modes.

S10.3 NUSSEY, D.H.; Institute of Evolutionary Biology, University of Edinburgh; *dan.nussey@ed.ac.uk*

Plasticity in breeding time in wild vertebrates: a quantitative genetic approach

There is abundant evidence from wild vertebrate populations for strong relationships between climatic variation and the timing of breeding, but these effects are typically assessed only at the population level. Such effects are usually presumed to be the result of individual altering their breeding phenology in response to climate conditions (i.e. phenotypic plasticity). In iteroparous species, individuals breed repeatedly across their lifetimes and may vary in the way they respond to climate variation. We currently know little about the prevalence, and evolutionary and ecological causes and consequences of variation in phenotypic plasticity in the wild. In this talk, I will briefly outline an analytical framework to assess the between-individual variation in life history plasticity that may underlie population-level responses to the environment at both phenotypic and genetic levels. This framework utilizes the reaction norm concept and random regression statistical models. Using examples of recent applications of the framework, from long-term individual-based studies of wild vertebrate populations, I will illustrate how both natural selection and ecological constraint may alter a population's response to the environment over time. These examples highlight the need consider variation in breeding time at the individual level in studies of natural populations.

41.3 O'BRIEN, J.J.; University of South Alabama; *jobrien@jaguar1.usouthal.edu*

Factors Affecting the Distribution and Infection Success of Two North American Sacculinids (Rhizocephala)

Heterosaccus californicus parasitizes majid crabs along the western coast of North America south of Bodega Bay while *Loxothylacus texanus* is endemic on species of portunids in the Gulf of Mexico. For reasons incompletely understood, both species of rhizocephalans are restricted to the southern portions of host ranges. Laboratory and field studies have revealed how physical (*e.g.* temperature and salinity) and biological (*e.g.* phototaxis and host molt-stage) factors affect adult fecundity as well as the ability of larvae to disperse, locate and infect vulnerable hosts. For example, 1) brooding time of embryos is negatively correlated with temperature, which may reduce densities of infective larvae in cold water habitats; 2) *L. texanus* naupliar stages do not survive to the infective cypris stage in low (less than 20 ppt) water suggesting that infection occurs in lower reaches of estuaries and bays and 3) naupliar larvae of *L. texanus* exhibited positive phototropism which could concentrate them in surface waters during daylight hours and augment dispersion on windy days. A summary of factors possibly influencing parasite prevalence of the parasite will be presented.

9.4 O'CONNOR, Constance/M*; YICK, Claire/Y; GILMOUR, Kathleen/M; VAN DER KRAAK, Glen; COOKE, Steven/J; Carleton University, Ottawa, University of Ottawa, Ottawa, University of Guelph, Guelph; *coconno4@connect.carleton.ca*

Brood value affects the endocrine response of a wild teleost fish to a standard stressor during parental care

For animals with multiple lifetime reproductive opportunities, the value of a current brood will influence optimal trade-off decisions between the current brood and future reproductive opportunities. One of the key mechanisms underlying these trade-offs decisions is the endocrine system. There is evidence that the endocrine state required for the maintenance of parental care is incompatible with the endocrine state associated with a stress response. When faced with a challenge during parental care, brood value should therefore influence whether an animal responds with an acute stress response at the expense of the current brood, or attenuates the stress response at the potential expense of survival and future reproduction. We tested this hypothesis in a wild teleost fish. The smallmouth bass, *Micropterus salmoides*, is a long-lived species that provides annual male-only parental care. Parental males show differences in energy expenditure and parental investment both in relation to brood size and brood age. In an initial set of experiments, we manipulated brood size at the onset of parental care, and subsequently measured the cortisol and testosterone levels of the parental males after a standard restraint stressor. In a second set of experiments, we measured the cortisol and testosterone levels of the parents after a standard restraint stressor across the parental care period. This is the first study that examines differential stress responses in relation to life-history trade-offs in a fish.

75.1 O'CONNOR, M.P.*; HONARVAR, S.; SOTHERLAND, P.R.; SPOTILA, J.R.; Drexel Univ., Kalamazoo Coll.; *mike.oconnor@drexel.edu*

Biophysical factors affecting gas exchange in sea turtle nests

The sandy environment of developing sea turtle eggs creates a significant resistance to both diffusive and convective exchanges of respiratory gases. Data suggest that the resulting relative hypoxia and hypercarbia affect egg metabolism, development times, and hatching success. Unfortunately, the magnitudes of the induced resistances are not clear and quantiative dependences on nest depth and density or tidal convection are unknown. We modeled the effects of several environmental factors on concentrations and fluxes of O_2 and CO_2 by numerically solving the Stokes equations for creeping flow in a porous substrate. Models argue that: 1) Convection caused by metabolism with a low RQ will slightly increase both O_2 and CO_2 concentrations. 2) Forced convection due to tidal fluctuation in the underlying water table can provide moderate increases in mean O_2 and decreases in CO_2 levels, but that gas concentrations will vary cyclically with trough O_2 concentrations approximating those without tidal forcing. 3) Hypoxia and hypercarbia vary approximately linearly with egg metabolism. 4) Crowding of nests in arribada nesting species could limit O_2 concentrations and nesting success. 5) The deeper nests constructed by larger sea turtle species provide larger resistances to gas exchange. 6) Time constants for approach to equilibrium can be long enough to prevent thermal (and to a lesser extent, gaseous) equilibrium in developing nests with metabolic rates that increase with weekly half times. Such models are computationally intensive, but can be used to predict under which circumstances gaseous exchanges might limit metabolism and development.

101.10 O'DONNELL, M.J.*; TODGHAM, A.E.; SEWELL, M.A.; HAMMOND, L.M.; RUGGIERO, K.; FANGUE, N.A.; ZIPPAY, M.L.; HOFMANN, G.E.; Univ. of Wash. Friday Harbor Labs, Univ. of California, Santa Barbara, Univ. of Aukland, Univ. of Aukland; *mooseo@moosecraft.org*

Ocean acidification alters skeletogenisis in larvae of the sea urchin Lytechinus pictus: evidence from morphometric and microarray data

Ocean acidification, the reduction of ocean pH via the absorption of anthropogenic atmospheric CO_2, is expected to impact marine ecosystems through effects on marine calcifying organisms. These impacts are not well understood at the community and ecosystem levels. A current focus in ocean acidification research is to understand the resilience organisms possess to withstand such changes, and to extend these investigations beyond calcification, addressing impacts on other vulnerable physiological processes. Using morphometric methods and gene expression profiling with a DNA microarray, we explore the impacts of high CO_2 conditions on development of the sea urchin, *Lytechinus pictus*, a pelagic larvae that forms a calcium carbonate endoskeleton. Larvae were raised from fertilization to pluteus stage in seawater with elevated CO_2 conditions based upon IPCC emissions scenarios. Morphometric analysis showed significant effects of enhanced CO_2 on both size and shape of larvae; those grown in a high CO_2 environment were smaller, and with a more triangular body than those raised in normal CO_2 conditions. Gene expression profiling showed that numerous genes central to energy metabolism and biomineralization were down-regulated in the larvae in response to elevated CO_2, whereas only a few genes in ion regulation and acid-base balance pathways were induced. These results suggest that, although larvae are able to form an endoskeleton, development at elevated CO_2 levels has consequences for physiological function as shown by changes in the larval transcriptome.

30.1 O'NEAL, DM*; SWANGER, L; KETTERSON, ED; Indiana University; *daoneal@indiana.edu*

Latitudinal Variation in Winter Immune Function in a Differential Migrant

Sex differences in migratory behavior (differential migration) can give rise to sexual segregation during the non-breeding season. The dark-eyed junco (*Junco hyemalis*) is one such differential migrant with females moving farther south in the winter than males. Northern latitudes are traditionally characterized by extreme temperature drops and unpredictable food resources due to snow cover, and both these conditions may increase metabolic needs and the frequency of potentially stressful competitive interactions. Additionally, disease prevalence is generally lower in northern locations, as colder temperatures restrict the growth, development, and persistence of parasites, mites, and vectors carrying disease. Combined, these factors suggest reduced immune function at northern latitudes. Recent winter warming, however, has reduced prolonged snow cover, and possibly increased available winter food resources and disease prevalence, possibly affecting latitudinal variation in immune function. In this study we evaluated innate immune function in free-living juncos during winter across a latitudinal gradient including Michigan, Indiana, and Mississippi. We asked whether immune function was correlated with climate factors associated with winter latitudes including average winter temperature, average snowfall, lowest temperature recorded, and maximum winter snow depth. Birds were captured at baited mist nets and potter traps between December 1st (the cessation of autumn migration) and March 1st (the start of spring migration). Upon capture birds were aged and sexed using morphological measures and a small blood sample was collected for innate immune measures. Preliminary results indicate latitudinal differences in immune function but the role of climate in these differences appears to be more complex than anticipated.

90.4 O'QUIN, C.T.*; HERNANDEZ, L.P.; The George Washington University; *ctoquin@gwu.edu*

Development of a functional complex: Ontogeny of the zebrafish pharyngeal jaw apparatus

The pharyngeal jaw apparatus of teleosts has long been of interest to both functional and descriptive morphologists alike. However, little to no work has been done to understand how this functional complex comes together during ontogeny. Fortunately, we have the opportunity to examine this by use of the popular model cypriniform, *Danio rerio*. Cypriniforms (cyprinids, balitorids, catostomids, and cobitids) posses a number of morphological novelties associated with their pharyngeal jaw apparatus (PJA). These include: (1) a muscular sling controlling movement of the lower pharyngeal jaws; (2) loss of the upper pharyngeal jaws; and (3) a pharyngeal pad on the basioccipital that has taken the place of the upper pharyngeal jaws. The cypriniform muscular sling originates on the neurocranium and inserts on ceratobranchial 5, and serves to adduct the pharyngeal jaws against a horny pad on the basioccipital. Here we present developmental data of musculoskeletal structures ranging from larvae to adult zebrafish. Morphological analyses following clearing and staining, histological processing, and immunohistochemistry revealed that the muscles of the PJA develop in larvae as early as 4 days post fertilization. However, some bony elements (epi- and pharyngobranchials) do not form until the fish is 4.4 mm in length, at which point larvae are approximately two weeks of age. These findings suggest that the musculature of the pharyngeal sling is established early on in development, well before the fish is feeding. As a result, we are provided with an understanding of how a functionally important trophic structure forms during ontogeny.

49.2 O'QUIN, Kelly E.*; MARSHALL, Justin; CRONIN, Thomas; CARLETON, Karen L.; Univ. of Maryland, College Park, Univ. of Queensland, Univ. of Maryland Baltimore County; *koquin@umd.edu*

Rapid visual system evolution within the cichlid species flock of Lake Malawi

Members of the cichlid species flock of Lake Malawi have evolved extensive morphological and behavioral diversity in only 1 -2 million years. We measured opsin gene expression in 56 cichlid species from Lake Malawi in order to estimate the diversity of retinal photoreceptor sensitivities in this group. Our results reveal significant divergence in visual sensitivities among many closely related cichlid species. We also show that the evolution of single cone photoreceptor sensitivities is significantly correlated with the evolution of both divergent foraging preferences and lens transmissivity. These correlated evolution of these traits suggest that the observed patterns of differential opsin gene expression among the cichlids species of Lake Malawi may be the result of natural selection to meet specific visual challenges. These changes could in turn have important implications for cichlid mate choice and speciation.

S3.7 OLIVEIRA, R.F.; ISPA, Lisboa, Portugal; *ruiol@ispa.pt*
Social behaviour in context: how animals adjust their behaviour to the social environment
Animals interact with each other frequently and these interactions modulate subsequent interactions among them and with other group members. Thus, animals must fine-tune the expression of their social behaviour to the social environment in which they live. Classically associative learning rules have been proposed to explain these effects of prior experience on the expression of social behaviour, whereas variations in the internal state (motivation) of the animal have not been taken into account. Here I propose that hormones (in particular androgens) may play a major role as physiological mediators of the modulation of social behaviour by social context; two types of evidence support this hypothesis: (1) social interactions elicit rapid responses in circulating levels of androgens; (2) androgens are known to have activational effects on the expression of social behaviour. We will review data demonstrating an involvement of androgens in the mediation of the following experiential (social) effects: anticipatory effect; bystander priming effect in bystanders; winner/loser effect (i.e. winners keep winning and losers keep losing); dear enemy (familiarity) effect. The possible mechanism involved in the translation of social information into an endocrine response will also be discussed. Together these results suggest an interrelationship between hormonal factors, that regulate the internal state of the animal, and cognitive and learning mechanisms in the regulation of social behaviour.

2.1 OLIVIER, T.J.*; MOON, B.R.; BAUER, R.T.; University of Louisiana at Lafayette; *tjo1457@louisiana.edu*
Nocturnal swimming patterns and speeds in the upstream juvenile migration of the amphidromous river shrimp Macrobrachium ohione and the potential for long distance migrations
In the river shrimp *Macrobrachium ohione*, larval development takes place in coastal estuaries after which postlarvae (juveniles) make a mass migration upriver into the adult freshwater habitat. To understand the timing and possible range of migration, we are studying swimming speed and duration in juveniles migrating up the Atchafalaya River, a distributary of the Mississippi river in Louisiana. We measured abundances and swimming speeds of juveniles at night using camcorders, infrared illumination, and motion analysis software. Preliminary data from 2007 showed ground speeds from 0.6-1.4 km/h measured at river velocities of 0.5-1.3 km/h. In 2008, we measured swimming patterns and velocities weekly throughout the summer migration to reveal the nocturnal patterns of movement and speeds as well as weekly relative abundances throughout the migration. These data can be used to estimate the time required for long distance migrations up the Mississippi River System (MRS). Various hypotheses are compared to explain the previously large populations of this amphidromous shrimp in the upper MRS and lower Ohio river, up to 2000 km from the coastal estuaries in which larval development occurs: (a) a long distance amphidromous migration to and from the Gulf of Mexico; (b) adaptation of northern populations to freshwater (abbreviated development); and (c) inland larval nurseries created by the formerly numerous saline springs and salt deposits in the upper Mississippi and lower Ohio Rivers. Supported by NOAA LA Sea Grant R/SA-04.

36.7 ORD, TJ*; STAMPS, JA; Harvard University / Univ. of California, Davis, Univ. of California, Davis; *tord@oeb.harvard.edu*
Studying cues for species identification using robotic lizards in the field
Theory suggests that territorial animals should recognize and selectively respond to species-specific components of displays used in territorial defense. We examined whether the territorial lizard, *Anolis gundlachi*, discriminate and respond differentially to conspecific versus novel territorial signals using robotic lizards to playback different displays to free-living lizards on Puerto Rico. The displays of *A. gundlachi* consist of stereotyped headbobs which are sometimes accompanied by the extension of a distinctly colored dewlap. The extent to which these lizards rely on headbob patterns, the dewlap, or both for species recognition is largely unknown. In our first set of playbacks, lizards were presented with a robot that extended the conspecific colored dewlap while performing either a conspecific or a novel display. In the second set of playbacks, the same conspecific or novel displays were presented, but the dewlap was not extended. When the display included the dewlap, lizards were equally aggressive and responded quickly to both the conspecific and novel display. When the dewlap was not extended, the level of aggression was again similar for both displays, but lizards took longer to respond to the novel headbob than to the conspecific headbob. This shows lizards are able to discriminate species using the headbob. The role of the dewlap is less clear. The dewlap may either provide species cues that override those conveyed by the headbob or function as an evocative threat signal irrespective of the headbob pattern that accompanies it. In either case, lizards responded equally aggressively to the conspecific and non-conspecific displays. A review of the literature suggests other animals are also less discriminatory of species-specific signals than predicted by theory.

63.1 ORGAN, Chris*; MEADE, Andrew; PAGEL, Mark; Harvard University; *corgan@oeb.harvard.edu*
Bayesian Inference of Discrete Character States
Most evidence for understanding the biology of extinct organisms is absent from the fossil record. For example, evidence for behavior, genetics, and physiology rarely fossilize. Yet, as a primary research goal, paleontologists endeavor to reconstruct the biology of extinct organisms. Two parsimony methods have been available to paleontologists: the concentrated change test and phylogenetic bracketing. Neither account for uncertainty (in reconstructions or trees) and neither use the statistical correlation of one variable with a second variable to inform us about the state of the first in taxa with missing data (extinct species). The lack of branch length information in these approaches is another drawback, especially with bracketing because this method only provides qualitative tests of inference localized within a tree. We have previously reported a Bayesian method for inferring continuous characters given a tree and a dataset, which will be reviewed here. We report a new method for inferring binary character states. Our approach starts with an extant-only tree and estimates rates of character change, automatically testing for character correlation by reversible jump Markov-chain Monte Carlo that selects the most-likely model(s). We then include the extinct taxa and use the rate model(s) from the first step to infer states in the first character using MCMC given known states for the second character in the extinct taxa. Our approach uses information within the dataset, phylogenetic position, branch lengths, and estimated rates of character change to produce a posterior probability distribution of inferred states for the first character. It accounts for the uncertainty we have in both reconstructions and trees. Here we demonstrate the method using sex determination data for amniotes.

80.5 ORR, Teri J*; LINDENFLORS, Patrick ; DALEN, Love ; ANGERBJOERN, Anders ; GARLAND, Theodore Jr.; Univ. of California, Riverside, Stockholm University; *teri.orr@email.ucr.edu*

Delayed implantation in carnivores, causes and consequences and reproductive effort.

The diversity of mammalian reproduction includes delayed implantation (DI), a period of diapause during which blastocysts formed after fertilization remain unattached to the female tract instead of immediately implanting. This unusual mode of reproduction seems limited to 9 of the 21 mammalian orders, and has been studied most thoroughly in the Carnivora, where 67 of 269 species are known to possess DI. The adaptive significance of DI is still unclear, and phylogenetic analyses have been limited to treating gestation length as a proxy for the presence or absence of DI. However, DI is appropriately treated as a binary dependant variable. Recently, A. R. Ives and Garland developed a method for performing phylogenetic logistic regression. We use this new method to evaluate two general questions. 1-Is DI associated with body mass, latitude, seasonality or mating system? 2-Do quantitative life history traits predict the occurrence of DI? For question 2, we examine several life history attributes, including age at first reproduction, litter size, litters per year, reproductive lifespan, weaning mass, and a newly developed emergent calculation of lifetime reproductive effort (LRE, Charnov et al. 2007), which approximates the energy females devote to reproduction in a lifetime and incorporates all of the aforementioned life history traits. Supported in part by NSF DEB-0416085.

S7.10 ORTIZ, Christine; Massachusetts Institute of Technology; *cortiz@mit.edu*

Nanotechnological Studies of Native and Regenerated Musculoskeletal Tissues

Biological materials, such as musculoskeletal tissues, have developed amazingly complex, hierarchical, heterogeneous nanostructures over millions of years of evolution in order to function properly under the mechanical loads they experience in their environment. In this talk, I will describe studies of these fascinating materials using "nanomechanics"; i.e. the measurement and prediction of extremely small forces within and between nanoscale constituents in order to provide a fundamental molecular-level understanding of the mechanical function, quality, and pathology of structural biological materials. Examples of materials under investigation to be discussed include; cartilage and bone. A quad-tiered approach is taken in order to achieve this goal which includes; nanomechanics of single cells and their pericellular matrix, individual extracellular matrix molecule imaging, biomimetic model systems, and tissue-level properties. Nanotechnological methods applied to the field of musculoskeletal tissues and regenerative medicine (e.g. stem-cell based tissue engineering) hold great promise for significant and rapid advancements towards tissue repair and/or replacement and improved treatments for people afflicted with diseases such as osteoarthritis.

25.4 OSBORN, M.L.*; HOMBERGER, D.G.; Louisana State Univ., Baton Rouge; *mosbor1@lsu.edu*

Asymmetry in the human cranio-cervico-omo-clavicular complex suggests connection with bipedalism

The mastoid process and clavicle are larger in humans than in other mammals and have been interpreted as having evolved in connection with upright posture and bipedalism. We hypothesize further that these features evolved in connection with the suspension of the shoulder girdle from the skull and the freeing of hands to carry loads. The mastoid process and clavicle are part of a cranio-cervico-omo-clavicular (CCOC) complex, whose elements are connected primarily by the paired upper trapezius and sternocleidomastoid (SCM) muscles. When loads are carried, the upper trapezius muscles counteract the additional weight, thereby stabilizing the shoulders. Simultaneously, the SCM muscles prevent the head from being retroflexed by the contracting upper trapezius muscles. We predicted that the preferential use of one limb would be expressed as asymmetries in the paired elements of the CCOC complex, thereby providing a natural experiment to test the corollary of our main hypothesis that the unique development of the mastoid process and clavicle in humans may have evolved in connection with increased muscular forces on them. In right-handed individuals, the dorsal border of the attachment of the upper trapezius muscle was often higher on the right side of the skull. This asymmetry in the attachment area results in a thicker muscle and a greater mechanical advantage. The mastoid process width was often greater on the right side, which provides a larger attachment area for a thicker right SCM muscle to counterbalance the larger right trapezius muscle. Hence, greater muscular forces and increased use of the CCOC complex result in a stronger development of some of its biomechanically relevant features. These observations support our hypothesis.

27.3 OSBORN, K. J.*; ROUSE, G. W.; Scripps Institution of Oceanography, UCSD; *kjosborn@ucsd.edu*

Fantastic pelagic diversity within Acrocirridae (Polychaeta)

At least seven new species of large, swimming polychaetes were collected while exploring the deep water-column with remotely operated vehicles since 2001. Deep bentho-pelagic animals are historically understudied due to their ability to escape benthic trawls, the difficulties of towing pelagic nets near the seafloor at great depths, and the fragility of many of these species. Animals from this habitat are of particular interest because they often possess unique morphological and ecological adaptations in comparison to their benthic relatives. The recently discovered worms belong to the polychaete family Acrocirridae, a group previously consisting of small, generally narrow-bodied worms with few chaetae. The new worms form a monophyletic clade with four distinct subclades and seven species. All are pelagic or bentho-pelagic, possess fantastic features (i.e. novel bioluminescent apparati, elongate branchiae, and complex sensory organs), and exhibit morphological adaptations assumed to be associated with their use of the water-column (i.e. numerous elongate, sometimes paddle-like chaetae and a thick gelatinous sheath). Phylogenetic relationships were reconstructed based on five genetic markers and morphological characters mapped on the resulting tree in order to assess character transitions. The discovery of this group strongly supports the assertion that continued exploration of the deep sea is necessary, as well as has broad implications for our understanding of evolution of pelagicism. Specifically, this project sheds light on the evolutionary history of the cirratuliform polychaetes and focuses on the morphological transformations observed during the transition from benthic to pelagic living.

57.3 OTA, K.G.*; KURATANI, S; RIKEN CDB; *ota_kinya@cdb.riken.jp*
Phylogeny of early vertebrates based on evidence from developmental study of hagfish
Hagfish is still located on the most basal position in the morphological phylogenetic tree of vertebrates, even though the monophyletic relationship between this animal and lamprey was confirmed by a large amount of molecular sequence data. This discrepancy between morphological and molecular data is mainly due to the apparently primitive features of this animal. To solve this problem, knowledge of the developmental and morphological study of hagfish is required. We attempted to collect the embryos from a shallow water hagfish, the Japanese inshore hagfish (*Eptatretus burgeri*), and succeeded to obtain several embryos. The result of our histological study implied the presence of the vertebrae in the hagfish embryo, although it is absent in the adult. The comparison between the embryo and the adult showed that the subcutaneous sinus, which is recognized as open blood-vascular system and representative primitive traits, evidently originate from the embryonic blood vessels. In addition, the morphology of the semicircular canal having two ampullars indicates that the degeneration has occurred in the inner ear of this animal during the evolution. These results suggested that most of primitive morphological traits could be regarded as derived condition. Based on these evidences, we will discuss the phylogenetic relationship of early vertebrates.

89.3 OUFIERO, Christopher E.*; GARLAND, JR., Theodore; Univ. of California, Riverside; *coufi001@student.ucr.edu*
The cost of bearing a sword: an examination of the locomotor costs associated with a sexually selected trait in Xiphophorus.
An underlying assumption of sexual selection theory is that while the secondary traits that arise increase reproductive fitness, they also impose costs of various types. One potential cost is a reduction in locomotor abilities caused by elaborate morphologies that arise through sexual selection (e.g., enlarged fish fins). These costs can be studied in various ways, including comparison of males, comparison of males with females, or by experimentally reducing the trait. Another way to examine locomotor costs is through a phylogenetic comparative approach with a group in which the species vary in their expression of the trait. The purpose of this study is to examine the locomotor costs and potential compensatory mechanisms of the sexually selected "sword" exhibited by males in species of *Xiphophorus* (swordtails and platyfish). This genus of fish is unique in that some species exhibit full expression of the trait (e.g., *X. helleri*), some have a reduced expression of the trait (e.g., *X. pygmaeus*), and some lack the trait completely (e.g. *X. variatus*). Therefore, through a phylogenetic comparative approach we can determine some of the evolutionary costs of the trait. To do this, we have been measuring the critical swimming speed, sprint speed, and c-start velocity of males and females of species within the genus. We have also been examining traits that may evolve to offset the cost, such as organ masses, enzyme activities, and maximum oxygen consumption. Here, we present preliminary findings on the potential cost of the sword on critical swimming speed and sprint speed from ~10 species. Supported by NSF DDIG IOS-0709788 to T.G. and C.E.O.

S2.11 OVERSTREET, RM*; JOVONOVICH, J; MA, H; University of Southern Mississippi; *robin.overstreet@usm.edu*
Parasitic Crustaceans as Vectors of Viruses
Parasitic crustaceans serve as both hosts and vectors of viruses as well as of parasites and other microbial pathogenic agents. Few of the presumably numerous associations are presently known. Recently, argulids and gnathopod isopods have been documented to host blood parasites. Because the agents can be observed with a microscope, they are better recognized than the smaller viral and other agents. Some agents, including viruses, are harmful to the crustacean parasites host and others are not. Many viruses that do not appear pathogenic are seen in ultrastructural images from a range of invertebrate hosts, including crustaceans. Some viruses have been implicated in causing disease in the host. For example, some lymphocystis viruses of fishes presumably are transmitted to the dermis by copepods and to the viscera by an isopod. Similarly, argulids seem to transmit the viral agent of spring viremia of carp, and copepods have been implicated in transmitting infectious hematopoietic necrosis, infectious salmon anaemia, and infectious pancreatic necrosis to salmon. Other viruses can be vectored to their hosts through an additional animal. We exposed three viruses, white spot syndrome virus, yellowhead virus, and Taura syndrome virus, which cause mortalities in wild and cultured commercial penaeid shrimps, to crustacean parasites on fish and crabs. Using real-time polymerase chain reaction analysis, we show that the viruses can occur in the crustacean parasites with a greater copy number per microgram of nucleic acid than that of its concurrently exposed host. The vector relationship indicates an additional potential means of transmitting and disseminating the disease-causing agents to the highly susceptible shrimp hosts. Funded by NSF award no. 0529684; USDA, CSREES, award no. 2006-38808-03589; and NOAA, award no. NA08NOS4730322 and subaward no. NA17FU2841.

90.9 OWERKOWICZ, T.*; TSAI, H.P.; BLANK, J.M.; EME, J.; GWALTHNEY, J.W.; HICKS, J.W.; UC Irvine; *towerkow@uci.edu*
Effects of exercise on skeletal growth and bone microstructure of the American alligator with and without the cardiac shunt
Exercise can affect the vertebrate skeleton via biomechanic or biochemical stress. Exercise-induced strains can elicit increased primary bone formation and/or secondary remodelling of limb bones. Strenuous exercise can result in high lactic acid loads, which may require buffering by bone mineral and perhaps influence bone remodelling. Cardiac shunting in crocodylians is thought to divert protons to the enteric circulation, and may thus reduce acidity of systemic arterial blood supplying bones of exercise-stressed animals. We subjected juvenile female American alligators (*Alligator mississippiensis*) to exhaustive exercise (running or swimming) every other day for 17 months, and compared their whole-body growth (mass, total and snout-to-vent lengths) and skeletal microstructure with those of sedentary controls. Prior to exercise training, half the animals in each group had their left aorta surgically occluded, thus rendering them incapable of cardiac shunting. Alligators were fed *ad libitum* twice weekly, and given injections of fluorescent dyes (calcein and alizarin) to determine bone deposition rate. Preliminary data (n=3 per group) show that bone formation rate at the femoral midshaft correlates with whole-body growth rate in all groups, but is significantly higher in treadmill runners. This suggests that terrestrial, but not aquatic, exercise stimulates periosteal bone formation. Neither exercise regime induced secondary remodelling in the femoral cortex. Loss of cardiac shunting did not reduce bone formation or accelerate resorption, which suggests cardiac shunting does not protect skeletal integrity in alligators. Funded by NSF IOB 04445680 to JWH. TO and JMB supported by NIH training grant 2T32AR047752 to V.J. Caiozzo.

S5.10 OWERKOWICZ, T.*; HICKS, J.W.; UC Irvine; *towerkow@uci.edu*
Evolution of the vertebrate cardiopulmonary system under varying atmospheric oxygen supply
Evolutionary history of the vertebrates has been subject to the vagaries of oxygen flux in Earths atmosphere. Cell-cell signalling in embryonic heart and lungs is highly sensitive to local oxygen tension. Changes in the atmospheric oxygen supply can alter tissue pO_2, and thus directly interfere with normal regulatory mechanisms (e.g., hypoxia-inducible factor, superoxides). Atmospheric oxygen can also affect cardiopulmonary development indirectly, as expression of mechanoreceptor proteins responds to a new mechanical milieu (stretch of lung parenchyma, shear in blood vessel walls). Altogether, this can produce viable novel morphologic and physiologic phenotypes, some of which may be adaptive to the changing environmental conditions. In order to better understand how the current diversity of cardiopulmonary Bauple arose, we argue it is necessary to study heart/lung development under appropriate atmospheric oxygen levels. We incubated eggs and raised hatchlings of the American alligator under chronic hyperoxia (30% O_2) and hypoxia (12% O_2) to resemble the atmospheric composition endured by early archosaurs in the oxygen-rich Permian and oxygen-poor Late Triassic. While hyperoxia does not appear to affect cardiopulmonary growth in alligators, hypoxia exerts a potent effect. Hypoxic alligators show persistent heart hypertrophy, driven mainly by right ventricular enlargement. Alligator lungs appear under-developed at hatching but exhibit strong compensatory growth after hatching. Unlike newborn mammals, hatchling alligators do not show a hypometabolic response to chronic hypoxia, but elevate their metabolism under hyperoxia. We discuss the potential cellular mechanisms, which may be responsible for the observed phenotypic plasticity. Funded by NSF IOB 04445680 to JWH.

27.1 PADILLA, Dianna K*; KARATAYEV, Alexander Y; BURLAKOVA, Lyubov E; MASTITSKY, Sergey; OLENIN, Sergej; Stony Brook University, Great Lakes Center, Buffalo State College, Belarusian State Universisty, Minsk, Belarus, Klaipeda University, Klaipeda, Lithuania; *dianna.padilla@sunysb.edu*
Are aquatic invertebrate invaders a random selection of species?
We assembled information on 119 species of freshwater macroinvertebrate invaders in North America and Europe, and compared them to all native freshwater species in North America and Europe. We tested whether the invaders were a random or selected group among taxa (phylum or class), water quality requirements, and feeding habit. We found that freshwater macroinvertebrate invaders are not a random selection of species, and are over-represented by molluscs and crustaceans, while taxa richness of native communities are dominated by insects. Over 35% of native species of aquatic invertebrates in North America are only able to live in areas with excellent or very good water quality, and are intolerant of organic pollution. In contrast, all invaders are tolerant of at least moderate amounts of organic pollution. There was a significant difference in the distribution of feeding habits between native species and invaders: collector-filterers (including suspension feeders) were 2.5 - 3 times more abundant, and predators were 3 - 4 times less abundant among invaders than among native invertebrates. The ongoing spread of exotic species affects the biodiversity of selected taxa, shifts communities toward greater tolerance of organic pollution and increases the numbers of suspension feeders, thereby enhancing benthic pelagic coupling in waterbodies with high densities of invaders. Because these processes are very similar in Europe and North America, we suggest that the observed patterns may have a common global effect

51.1 PAGE, J.L.*; DICKMAN, B.D.; WEBSTER, D.R.; WEISSBURG, M.J.; Georgia Institute of Technology, Atlanta; *jennifer.page82@gmail.com*
Simultaneous correlation of odor-plume structure and behavior: I. Three-dimensional plume structure at antennules affects speed and sensor height in tracking blue crabs
Little is known about specific aspects of plume structure that are important to facilitate ecologically important tracking behaviors, such as those involved in locating potential prey, mates or habitats. We used three-dimensional laser-induced fluorescence (3DLIF) to collect chemical concentration data simultaneously with behavior observations of actively tracking blue crabs (*Callinectes sapidus*) in a variety of plume types. This allows us to directly link chemical signal properties at the antennules to subsequent upstream motion. Initial data indicates that crabs in continuous plumes increase their speed to above average levels within 0.25s after receiving an odor burst at their antennules. Alternately, crabs in plumes with large-scale meander immediately decrease their speed for greater than ~1.5s following an odor burst if they were previously moving rapidly, but increase speed if they were previously moving slowly. Because meandering plumes expose animals to more intermittent signals, these observations suggest an endogenous timing mechanism that changes the state of the animal if it does not receive stimulation within a specific interval. In addition, crabs acquire chemical stimulus in a 3D volume by changing their height in response to plume concentration, standard deviation of concentration fluctuations, and intermittency of filaments. Height changes are preceded (0.25-0.5s) by periods of below average concentration that is less than 1% of the source concentration.

83.4 PAIG-TRAN, Misty EW*; STROTHER, James A; SUMMERS, Adam P; Univ. of California at Irvine; *epaig@uci.edu*
Estimating the ram suspension feeding efficiency of elasmobranchs
Filter feeding fishes consume vast numbers of tiny (5-3000 microns) prey by filtering immense quantities of water through their oropharyngeal cavity. Differential anatomies between cartilaginous and bony fishes suggest differences in suspension feeding mechanisms. Models of ram suspension feeders (e.g. herring, mobulas, etc) suggest that the gill rakers likely function either as a self cleaning sieve (cross-flow filtration) or as a sticky filter to separate food particles from the egressing water. To understand the role morphology and fluid flow play on particle retention in a typical ram suspension feeder, we measured the filtration efficiency in a simple physical model. We varied the buccal length, flow speed and the architecture of the gills slits; including the number, size, orientation and pore size/permeability of the model. Models were placed in a recirculating flow tank with plankton-like particles (40-2000 microns) collected at the esophagus and at the gill rakers to locate the highest density of particles accumulation. Changing the number of gills resulted in a change in the filtration mechanism of particles from a type of notch filtration, with mostly very small (less than 50 microns) and very large (above 1000 microns) particles collected, to a band pass type filter, with primarily intermediate sized particles (100-1000 microns) collected. Increased flow speed resulted in both an increase in number of particles collected on the gill rakers and a smaller size distribution of particles collected (40-500 microns). Gill orientation did not affect filtering efficiency. These results suggest that the filtration mechanics of suspension feeding is closely linked to the both the animals swimming speed and the structural design of the buccal cavity and gill slits.

99.2 PAITZ, RT*; BOWDEN, RM; Illinois St. Univ.; *rpaitz@ilstu.edu*
Characterizing the biological activity of estradiol sulfate during embryonic development: Inactive steroid metabolite or precursor for steroid production?
Steroids are known to play an important role in directing sexual differentiation of vertebrates. Traditionally, research has focused on the embryonic gonads as the primary source of these steroids, but more recent work has shown that steroids of maternal origin can also influence offspring development. In oviparous vertebrates, these maternal steroids can be present in relatively high concentrations in the yolk at oviposition and create a situation where embryos must begin development in an environment already rich with steroid signals. This may be especially important in some oviparous reptiles where it is has been shown that the sex of the developing embryo can be influenced by steroids. We recently demonstrated that estradiol present in the yolk of red-eared slider (*Trachemys scripta*) eggs is converted to a water-soluble form during the first 15 days of development and that estrogen sulfotransferase (an enzyme that converts estradiol to estradiol sulfate) activity significantly increases over this same period. At this point it is unknown what the biological activity of these conjugated metabolites may be, so the goal of this study was to test the effects of estradiol sulfate on embryonic development. We predicted that estradiol sulfate application would lead to an increased production of females, similar to what is seen following the application of estradiol. To test this, we applied varying doses of estradiol sulfate to *T. scripta* eggs at two different points of development. Hatchling sex will be determined to test for any effects estradiol sulfate may have on sex determination. If estradiol sulfate application does not influence sex ratios, it would suggest that embryos may be able to buffer themselves from maternal estradiol.

30.2 PALACIOS, M.G.*; WINKLER, D.W.; VLECK, C.M.; Iowa State University, Ames , Cornell University, Ithaca, NY; *mgp@iastate.edu*
Consequences of immunosenescence in the wild: A field experiment in tree swallows
Aging is a pervasive phenomenon in free-living organisms, but its consequences in the wild are remarkably understudied. We previously showed that free-living tree swallows experience immunosenescence. We investigated the consequences of this aging pattern by testing the hypothesis that older, immunosenescent individuals suffer higher costs of defense against pathogens than younger ones. We performed a field experiment to determine age-specific responses of adult female tree swallows to a simulated pathogenic insult (challenge with bacterial lipopolysaccharide, LPS) and carried out an integrated assessment of sickness behavior, hormonal changes, and immune function. In addition, we assessed the consequences of parental responses on current and future reproductive success and survival. Preliminary analyses indicate that in support of our hypothesis, when challenged with LPS, older, immunosenescent females suffered increased sickness behavior compared to younger ones, reflected by larger loss of body mass and decreased nest visitation rate. In contrast, bacterial killing capacity of plasma increased after LPS challenge but not in an age-specific manner. Moreover, baseline corticosterone was not affected by LPS nor did it differ with female age. Nestlings of LPS females showed increased corticosterone and reduced growth, but this was also independent of female age. Because some of these results are year-dependent we are assessing the influence of potential covariates (e.g., insect availability and weather) on observed responses. Additionally, we are currently analyzing other response variables of females (e.g., natural antibodies, complement-mediated lysis, specific antibodies against LPS, and H/L ratios), as well as reproductive and survival parameters.

46.4 PALENSKE, N.M.*; DZIALOWSKI, E.M.; University of North Texas, Denton; *npalenske@unt.edu*
Acute Effects of Triclosan and Triclocarban Exposure on the Physiology of Four Tadpole Species
The goal of this study was to determine acute effects of triclosan (TCS) and triclocarban (TCC), antimicrobials used in consumer products, on the development and physiology of four tadpole species. *Acris crepitans blanchardi*, *Rana sphenocephala*, and *Bufo woodhousii woodhousii* were collected locally in Denton and Tarrant County, Texas and *Xenopus laevis* was obtained from a commercial supplier. LC50 values were determined for TCS and TCC during Gosner stage 30 for native species and Nieuwkoop and Faber stage 41 for *X. laevis*. Heart rate and metabolic differences were also examined after 96 hour exposure to TCS and TCC. Nominal LC50 dilutions were used to determine LC50 values for TCS and TCC. A significant difference in LC50 concentration of both TCS and TCC was found between species. A significant increase in heart rate was observed with exposure to TCS, while exposure to TCC caused a significant decrease in heart rate. Metabolic rates of tadpoles exposed to TCS showed significant decreases only in *R. sphenocephala* and *X. laevis*. Exposure to TCC caused a significant decrease in metabolic rates of *X. laevis*. This study indicates that the toxicity of TCS and TCC in tadpoles is dependent upon species.

26.3 PANKEY, M.S.*; MCFALL-NGAI, M.N.; OAKLEY, T.H.; University of California, Santa Barbara, University of Wisconsin; *mpankey@lifesci.ucsb.edu*
Molecular evolution of light detection in a bioluminescent squid
Identifying the molecular bases of adaptive changes leading to novelty and increased complexity is one of the central goals of modern evolutionary biology. We approach this challenge by studying how existing molecular components underlying a certain trait may be modied following gene duplication or redeployed via co-option to give rise to novel phenotypes. Light-emitting organs are commonly found in pelagic sh and cephalopods for means of crypsis via counter-illumination. Recent physiological, immunocytochemical and transcriptome evidence suggests that the central core of the light organ in the squid *Euprymna* is equipped with photoreceptors responsive to light. While both eye and light organ share expression of some phototransduction genes, the physiological response to light differs greatly between these organs. Light organ tissues also express a duplicated G-protein and several vision genes previously undocumented in mollusk photoreceptors. To better understand how key phototransduction genes have played a role in the evolution of this morphological and behavioral trait we used Real Time PCR to quantify the relative expression of genes constituting this visual network from ocular and luminous tissues. We found that while the visual pigment opsin is shared between tissues, the downstream components of the signaling pathway differ between light organ and the eye photoreceptors. Our results provide molecular support for earlier physiological evidence of light-induced hyperpolarization in the light organ. Our findings also suggest a possible mechanism for novel phototransduction in the light organ in which an alternative signaling pathway may have been co-opted.

2.3 PARFREY, Laura Wegener*; KATZ, Laura A.; Univ. of Massachusetts - Amherst, Smith College; *lwegener@nsm.umass.edu*

Heterogeneity of genome content through the life cycle of Foraminifera

Genomes are dynamic across the tree of eukaryotes. Animals, plants, and numerous microbial lineages demonstrate widespread variation of genome content within individuals during a life cycle and within populations. Foraminifera a lineage of marine amoebae provide a unique opportunity to study genome dynamics as they have a complex life cycle that alternates between diploid and polyploid phases. As a proxy for genome content, we assess the heterogeneity of nuclear size within two taxonomically diverse species, *Allogromia laticollaris* and *Ammonia beccarii*, at different life cycle stages using DAPI staining of nuclei. We find that nuclear size varies nearly 150 fold across life cycle stages, and five fold within a life cycle stage in the population in *A laticollaris*. The nuclei of *A. beccarii* vary 30 fold between life cycle stages, and marked heterogeneity exists between nuclei within a single cell. We hypothesize that variation in nuclear size can be explained by a combination of variable levels of polyploidy and amplification of ribosomal DNA. We are measuring the contribution of ribosomal DNA amplification through fluorescence in situ hybridization and quantitative PCR. We also map genome characters elucidated in this study onto a phylogeny of eukaryotes in order to interpret the evolutionary history dynamic genomes.

94.4 PARKER, E.L.*; KYNARD, B.; PARKER, T.K.; KYNARD, B.E.; USGS, Conte Anadromous Fish Research Center, BK-Riverfish, LLC.; *eparker@usgs.gov*

Effect of Rearing Temperature on the Onset and Duration of Dispersal of Early Life Stages of Shortnose Sturgeon

Shortnose sturgeon (*Acipenser brevirostrum*) undergo a downstream dispersal during the larval life stage. The objective of this study was to determine the effect of three temperature regimes on the timing and pattern of downstream dispersal of Connecticut River (MA, USA) shortnose sturgeon larvae. Tests were conducted in artificial stream tanks with three replicates at each of three temperatures, 10, 15, and 20C. Fish were introduced to experimental tanks immediately upon hatching, and their movements were monitored day and night with video cameras. Rearing fish at 10C caused development to slow and delayed the onset of dispersal. Fish in the 10C group had a single peak of dispersal lasting 8 days. Increasing the temperature (15 and 20C) caused fish to begin dispersing at a younger age (in days after hatch), but also produced a dispersal with multiple peaks. Fish were all at or close to the beginning of the larval life stage (i.e. beginning exogenous feeding) and were all morphologically similar when they began dispersing, regardless of temperature. Fish in the 15 and 20C treatments required a similar number of degree-days to become larvae, but fish in the 15C group took more degree-days to begin dispersal than fish in the 20C group. Fish in the 10C group took many more degree-days both to become larvae and to initiate dispersal than fish in the other two groups. These results show development and dispersal of shortnose sturgeon early life stages can be influenced by river temperature, and anthropogenic impacts that alter river temperature regimes have the potential to affect sturgeon dispersal patterns.

35.5 PARNELL, N.F.*; STREELMAN, J.T.; Georgia Institute of Technology; *gth877n@mail.gatech.edu*

The presence of community structure varies with spatial scale in Lake Malawi cichlid fishes.

A long-standing issue in ecology is the existence and related causes of structure in natural communities. Here, we use null model simulations of species co-occurrence to examine the spatial structure of the cichlid fish assemblage in Lake Malawi, Africa. We employed the C-score model to test the null hypothesis of random structure at increasingly fine spatial scales (lakewide to depth-within-site). Communities were not different from the null model until examined at the finest grain (depth-within-site), at which point we detected a strong and significant signal of structure. To further investigate the intricacies of cichlid community structure at depths within sites, we focused more closely on the identity of species and their trophic habits across replicated local assemblages (rock reefs separated by dispersal boundaries). We identified complex species combinations with putatively positive and negative interactions among them. Our analysis provides insight into how communities may be structured in highly diverse, dispersal-limited vertebrates.

9.8 PARSONS, RL*; VLECK, CM; Iowa State Univ., Ames; *bparsons@iastate.edu*

Effects of brood size on chick-feeding rates, growth and corticosterone in nestling tree swallows

Studies in birds have found that poor nutrition during development can cause reduced growth and elevated corticosterone (CORT) levels in chicks that have long-term negative effects on fitness and cognition in adulthood. This study addressed the question of how natural variation in brood size relates to patterns in early growth and development and CORT levels in tree swallows. Large brood sizes may result in decreased food delivery per chick resulting in reduced growth and elevated CORT levels. Tree swallows provide an ideal system in which to address this question because brood size can vary from one to eight chicks. Unless parents modify their chick-feeding rate to compensate for larger broods, we predicted that such variation should affect food delivery rates to nestlings, their subsequent growth and baseline CORT levels. In the summers of 2007 and 2008 we monitored adult food delivery rates to 61 nests and chick growth rate and CORT levels in a total of 250 chicks, using broods that varied from one to seven chicks. Chick-feeding rates increased as brood size increased, but the feeding rate per chick decreased. Brood size had a negative effect on chick growth; asymptotic mass of chicks from small broods averaged 22.3g and chicks from large broods averaged 21.3g. At the same time, neither baseline CORT nor CORT levels after handling stress varied with brood size, although chicks in poor condition did have elevated basal CORT levels. Within the normal range of brood sizes adult tree swallows appear able to provide adequate nutrition for chicks, as indicated by low baseline CORT, even though brood enlargement results in smaller chicks. Small chick size is linked to reduced survival in other passerine species; the effect of small chick size on survival is not known in this population.

100.7 PARSONS, J.L.*; BALDWIN, B.S.; OUELLETTE, J.R.; KOUBA, A.; RUDE, B.J.; Mississippi State Univ., Memphis Zoo, Memphis Zoo; *jlp418@msstate.edu*

Temporal effects on bamboo nutritional quality for specialist foragers.

Clonal plants such as bamboo show temporal oscillations in aboveground resources, as reserves flux among leaf, stem, and belowground compartments together with significant life-cycle events. Knowledge of changes in forage quality is central to an understanding of the physiology and behavior of animals consuming bamboo-only diets, most of which are highly endangered. Preliminary data from a 3-year study of *Phyllostachys* bamboos were analyzed for effects of disturbance intensity, season, and age class on proximate nutrient composition, with the goal of identifying potential influences on forage palatability for herbivores. Bamboo leaf composition ranged from 8 to 25% protein, 5 to 22% ash, 60 to 80% neutral-detergent fiber (NDF), 25 to 40% acid-detergent fiber (ADF), and 4 to 14.5% lipid. Culm (central woody stem) was 0.5 to 4.5% protein, 1 to 4% ash, 85 to 95% NDF, 55 to 75% ADF, and 2 to 7.5% lipid. Shoots were 7.5 to 35% protein, 3.5 to 10% ash, 40 to 85% NDF, 15 to 70% ADF, and 7 to 16% lipid. We have not detected disturbance effects thus far, but we did find temporal effects on nutritional quality. Bamboo contained more ash and less NDF as it matured within a single year ($P < 0.001$); less ADF and more protein, NDF, and lipid as it aged from year to year ($P < 0.03$); and more ash and less fiber in spring (Feb-May), than in summer (Jun-Sept) or winter (Oct-Jan; $P < 0.01$). These changes may explain diet selection patterns among giant pandas and possibly other bamboo specialists. However, an understanding of micronutrient and allelochemical alterations is also necessary to fully comprehend the influence of this dietary source on specialist consumers, particularly with regard to non-structural carbohydrates, biogenic silica, tannins, or cyanogens.

9.6 PATTERSON, SH*; MACDOUGALL-SHACKLETON, B; HAHN, TP; BREUNER, CW; Univ. of Montana, Univ. of Western Ontario, Univ. of California at Davis; *stephen1.patterson@umontana.edu*

STRESS REACTIVITY AND REPRODUCTIVE SUCCESS

A common assumption in the glucocorticoid literature is that the glucocorticoid acute stress response is an adaptive trait. However, there is little direct evidence to support this claim. We test this hypothesis by exploring how variation in glucocortiocoid stress responsiveness relates to fitness in a breeding population of White-crowned Sparrow (*Zonotrichia leucophrys*). Individual fitness is estimated using the number of offspring fledged within a season and over a lifetime. We assign fledglings to adults using social parentage; for a subset of our data, we also use microsatellite data to assign genetic paternity. Glucocorticoid stress reactivity is measured from serial blood samples taken at 0-3, 15, and 30 minutes post-capture. Analysis is ongoing; results of this analysis will be discussed in a fitness framework. Future work will extend the microsatellite assignment of paternity to all fledglings and explore a possible relationship between glucocorticoid stress responsiveness and the tradeoff between survival and reproduction.

22.6 PAVLICEV, M*; CHEVERUD, JM; WAGNER, GP; Washington University, St. Louis, Yale University, New Haven; *pavlicev@pcg.wustl.edu*

Evolution of modularity: selection for trait disassociation

Genetic variance in intertrait relationship provides potential for evolutionary change in integration of phenotypic units and can supply a model for the evolution of modularity. In modular genetic architecture the pleiotropic effects are restricted to traits with common development and/or function. As the mutational effects of underlying genes upon unrelated traits thus are limited, the probability of deleterious mutation is reduced, increasing evolvability. However, the origin, as well as any rewiring of modular genetic architecture by selection requires variation in the range and strength of pleiotropic effects. Recent studies have demonstrated the existence of such genetic variation by mapping so-called relationship QTL (rQTL), manifesting genetic variation in trait covariance. It was demonstrated that these loci are involved in epistatic interactions that affect the traits differently (differential epistasis; Cheverud et al. 2004; Pavlicev et al. 2008). The variation in intertrait relationship can be present even if the genotypic mean values are not affected, i.e., if the rQTL does not affect the trait means. In such cases the effect can stem from differential canalization of variance in the two traits, or from their genotype-dependent covariance. So far it was shown that stabilizing selection increases integration between traits, regardless of whether the selection itself is correlative (Jones et al. 2007). However, we lack a model for trait disintegration to enable individuation of organismal parts. Here we consider the selection on rQTL and derive the first population genetic model that allows for the selection for trait disassociation, a mechanism that may lead to disintegration of modules.

23.1 PEATTIE, A M*; FEDERLE, W; Univ. of Cambridge; *ap557@cam.ac.uk*

Attachment forces of single adhesive setae from tarantula feet

Spiders and geckos have convergently evolved dry fibrillar adhesives on their feet that allow them to climb smooth vertical surfaces. These two types of adhesives are materially and morphologically distinct. Gecko adhesive fibrils, called setae, are made of keratin, as opposed to arthropod cuticle. Gecko setae split many times, branching into small flattened tips (called spatulae). Spider setae are paddle-shaped, with a planar array of spatulae at a constant (~5 m) height from the seta surface. In this study we present the first attachment force measurements for single setae from the pretarsal claw tufts of a spider, the theraphosid *Grammostola rosea*. We mounted single setae onto pins and measured the frictional and adhesive forces generated when they attached to a glass substrate. *G. rosea* setae were consistently longer than all other gecko setae studied, and bore more spatulae. The mean peak shear force across all claw tuft setae was 131 N 15.7 SE (n=23 setae, 4 animals), while mean peak adhesive force was 50.8 N 5.3 SE. The apparent mean shear force per spatula was not significantly different from that of geckos, nor were their dimensions (200-350 nm wide). Contrary to previous findings in geckos, however, attachment force was not strongly predicted by the number of spatulae on a given seta in spiders. It may be that the spider seta structure is not as effective as geckos at creating maximal contact between the spatulae and the substrate. Claw tuft setae, like claws, are oriented to engage with the substrate during a pulling motion of the foot. Many spiders have additional setae on the ventral surface of the tarsus, which are oriented to engage during pushing motions. Future studies will investigate the differences among these different types of setae, as well as setae from more species and different types of surfaces.

43.6 PEEK, M.Y.*; DICKSON, W.B.; DICKINSON, M.H.; California Institute of Technology; *martin@caltech.edu*

The aerodynamic body drag of Drosophila melanogaster

Research in *Drosophila melanogaster* aerodynamics has provided key insights in understanding how small insects fly. In many previous studies, dynamically-scaled models of flapping wings have helped elucidate aerodynamic mechanisms for hovering and forward flight. We extend this type of experiment to investigate the aerodynamics of a fly body. We use a dynamically-scaled model of a female fly mounted on a robotic platform in a mineral oil tank to measure forces and torques as a function of Reynolds number and body angle. We find that lift and drag vary as simple trigonometric functions. During flight, flies typically maintain a body pitch angle between 20 and 80 degrees. Within this range, addition of model legs fixed in flight orientation significantly reduces pitching torque about the center of mass with little effect on drag. We will assess the magnitude of the forces and torques required to maintain an equilibrium flight posture.

10.1 PENG, Jifeng*; DABIRI, John; California Institute of Technology, Pasadena, CA; *jfpeng@caltech.edu*

A fluid mechanical model for current-generating-feeding of jellyfish and the effect of prey size and escape forces

Many jellyfish species, e.g. moon jellyfish *Aurelia aurita*, use body motion to generate fluid currents which carry their prey to the vicinity of their capture appendages. In this study, a model was developed to understand the fluid mechanics for this current-generating-feeding mode of jellyfish. The flow generated by free-swimming *Aurelia aurita* was measured using digital particle image velocimetry. The dynamics of prey (e.g., brine shrimp *Artemia*) in the flow field were described by a modified Maxey-Riley equation which takes into consideration the inertia of prey and the escape forces, which prey exert in the presence of predator. A Lagrangian analysis was used to identify the region of the flow in which prey can be captured by the jellyfish and the clearance rate was quantified. The study provides a new methodology to study biological current-generating-feeding and the transport and mixing of particles in fluid flow in general.

6.4 PEREZ III, Kaipo*; JOKIEL, Paul L.; RODGERS, Kuulei S.; Hawaii Institute of Marine Biology; *kaipop@hawaii.edu*

Factors influencing coral recruitment: sediment and depth

Laboratory experiments were conducted to determine survival rates from the effects of sediment on planulae of the coral *Pocillopora damicornis*. Manipulative field experiments were also conducted on the Windward side of Moku o Lo'e, Kane'ohe, Hawai'i to determine coral recruitment at three different depths. Coral growth and abiotic factors of temperature, visibility, water motion, and sediment were simultaneously measured. A statistically significant relationship was found between the quantity of sediment added and the rate of successful planula settlement. Very little recruitment was observed at sediment concentrations above 0.9 mg x cm^{-2} in laboratory trials. Coral recruitment in the field was determined to be positively correlated with the abundance of adult colonies and negatively correlated with water motion, sediment, and temperature. Comprehending the complexity of coral recruitment and settlement can be instrumental to management decisions and in furthering scientific understanding of these processes.

S10.8 PERFITO, Nicole*; ZANN, Richard A.; HAU, Michaela; BENTLEY, George E.; Univ. of California, Berkeley, LaTrobe University, Melbourne, Australia, Max Planck Institute for Ornithology, Radolfzell, Germany; *nperfito@berkeley.edu*

Physiological control of non-seasonal reproduction: opportunistic breeding

Zebra finches *Taeniopygia guttata* range over most of the Australian continent inhabiting a diverse range of habitat and climate. The species has long been the prototypical example for opportunistic breeding, able to take advantage of good conditions whenever they occur, but there have been few physiological data collected on wild birds. We have shown that the extent to which zebra finch physiology conforms to expectations for opportunistic breeders depends on habitat predictability. Birds in less predictable habitats of the arid interior maintain their reproductive systems in a near-ready state even during bouts of non-breeding, while birds in more predictable habitats of the temperate south show seasonal cycles in reproductive parameters. Here we consider the potential neuroendocrine mechanisms underlying transitions between breeding and non-breeding states, specifically by measuring three peptides in the brain (gonadotropin-releasing hormone-I, -II and gonadotropin-inhibitory hormone) involved in regulating reproduction. We will also discuss preliminary data testing whether GnRH-II plays an important role in responding to social signals to maintain physiological synchrony between mates.

40.2 PERLMAN, B.M.*; FERRY-GRAHAM, L.A.; Moss Landing Marine Laboratories; *bperlman@mlml.calstate.edu*

Interspecific variation of pectoral fin morphology of surfperches (Embiotocidae) along Central California

Embiotocids are a groups of near-shore fishes that overlap considerably in their distributions. As a result, they are thought to partition themselves into relatively well-defined habitats. Here we ask if aspects of swimming ability, inferred by fin morphology, are related to the primary habitat of 19 embiotocid species, determined from a synopsis of multiple habitat use studies. All embiotocids are labriform swimmers. We measured the following variables from flat fins of preserved specimens: angle of the fin base with the long axis of the body, fin length, fin surface area, and aspect ratio of the pectoral and caudal fins(L^2/SA). We conducted a PCA to investigate relationships among these variables. PC1 appeared to describe size. PC2 described an inverse relationship between pectoral fin aspect ratio and caudal fin aspect ratios. PC3 was dominated by the variable fin angle. ANOVA performed on these PCs with species as a fixed factor suggested that there were no significant size effects, but there were significant differences in fin aspect ratios and angles among species. Species tended to cluster by habitat type in a general sense. Closely related species sometimes grouped together, such as *Amphistichus argenteus* and *A. koelzi*, suggesting a possible phylogenetic basis for fin shape. However, other species, such as *Embiotoca jacksoni* and *E. lateralis*, occupied the extreme opposite ends of the PC2 continuum. Kinematic studies are presently being conducted to determine how such relationships might change given that fins are flexible and shape can change during use. Swimming performance experiments are also being used to quantify aspects of swimming ability among species.

55.10 PEROTTI, Elizabeth A.*; LINDBERG, David R.; ESTES, James A.; University of California, Berkeley, University of California, Santa Cruz; *marinelizard@berkeley.edu*

A bumpy road: the effects of surface complexity on a dominant intertidal limpet

Rock substrates and their properties structure the physical environment of many marine benthic communities. Previous research suggests that surface complexity is important for abundance, recruitment, and behavior of a variety of taxa. This study investigated the relative importance of surface complexity to the ecology of a dominant territorial limpet, *Lottia gigantea*. Our results demonstrate that the limpet communities on San Nicolas Island, California are heterogeneous, substrate-driven, and have the potential to greatly affect algal communities, space competitors, and other limpets. *L. gigantea* size decreased nonlinearly with substrate topography (TI=topographic index), even though there were significant differences in TI between northern and southern regions of the island. Rock units also exhibited differential erosional responses to wave exposure, indicating that the composition and geologic histories of rock units can present to organisms, unique intertidal habitats with respect to surface complexity.

19.3 PETERS, J E; Univ. of Illinois; *peters25@illinois.edu*

Brain size evolution in new and old world marsupials

Consensus is that marsupial brain size is constrained compared to eutherians, and that this has reduced marsupials adaptive ability. A test case for this exists in the dichotomy between New and Old World marsupials. New World (NW) marsupials evolved alongside eutherian competitors, whereas Old World (OW) marsupials evolved in relative isolation. Given their competition with eutherians, and the apparent competitive advantage that larger brains provide, I hypothesize that NW marsupials have been under stronger selective pressure than OW marsupials to increase their brain size, and therefore exhibit larger brains. To test this hypothesis, cranial volume and mandibular length of 454 specimens belonging to 50 NW marsupial species were quantified. These variables were used to calculate encephalization quotient, combined with OW data from Ashwell (2008) and subjected to Wilcoxon or Kruskal-Wallis nonparametric statistical analyses. As predicted, NW marsupials have significantly larger brains than OW marsupials ($p < 0.0001$). I also compartmentalized the data and tested for size trends in functional groups (e.g., within arboreal quadrupeds, terrestrial quadrupeds, etc) or within specific phylogenetic lineages (e.g., diprotodonts, didelphids etc.). Regardless of manipulation, all six orders examined independently differed ($p < 0.001$) with NW forms (Didelphimorphia, Paucituberculata and Microbiotheria) possessing larger brain sizes than OW (Dasyuromorphia, Diprotodontia and Peramelemorphia). These results suggest that the selective pressures associated with brain size were sufficient to allow variation due to adaptive measures, suggesting that constraints play little role in relative brain size within marsupials. Comparisons between marsupials and eutherian mammals are underway to question whether developmental constraints play any role in marsupial brain evolution.

67.2 PFALLER, Joseph B*; ERICKSON, Gregory M; Florida State Univ., Tallahassee; *jpfaller@bio.fsu.edu*

Intraspecific scaling of bite-force generation in a durophagous turtle, Sternotherus minor minor

Among vertebrates, ontogenetic shifts towards more durable prey (durophagy) are common. Such transitions require the development of a feeding apparatus with sufficient morphology to generate and sustain high bite forces. Bite-force generation has been shown to increase with significant positive allometry relative to head dimensions. Nevertheless, to our knowledge, no detailed, quantitative study has examined the intrinsic biomechanical anatomy of an ontogenetic series to explain such allometric increases in bite force. The loggerhead musk turtle (*Sternotherus minor minor*) is a simple, yet relevant, model to explore this phenomenon. Adult *S. m. minor* develop hypertrophied heads and expanded beak surfaces; changes that reflect an ontogenetic diet shift toward durophagy and an ecologically relevant increase in bite force. Bite-force generation was measured from a growth series of 72 *S. m. minor* (range = 5 N - 162 N), and was found to increase with significant positive allometry relative to body (e.g., carapace length; scaling coefficient = 2.9) and head dimensions (e.g., head length; scaling coefficient = 2.6). Of these, a growth series of 30 individuals was dissected and detailed osteological and myological measurements were made to develop a biomechanical model of bite-force generation throughout ontogeny. To evaluate the accuracy of our model, we tested it against actual bite forces measured for individual turtles. Allometric increases in adductor mass and pennation angles, and an allometric decrease in fiber lengths, contributed to an allometric increase in the total cross-sectional area of the adductor musculature. These changes were matched by a relative increase in the mechanical advantage of the jaw system, and collectively explain the significant positive allometry in bite-force generation in this taxon.

97.2 PHILLIPS, MB*; DIAMANDUROS, AW; HYNDMAN, KA; EDWARDS, SL; CLAIBORNE, JB; Georgia Southern University, Medical College of Georgia, Appalachian State University; *matthewbenjaminphillips@gmail.com*

Rh Glycoprotein as an Ammonia Transport Molecule in the Longhorn Sculpin (Myoxocephalus octodecemspinosus) Gill

Fish use their gills to excrete ammonia in order to eliminate nitrogenous waste. We hypothesize that this mechanism is accomplished by one or more transport proteins in the Rh glycoprotein (RhxG) family. Longhorn sculpin (*Myoxocephalus octodecemspinosus*) cDNA was amplified using polymerase chain reaction (PCR) and then the PCR products were visualized on an agarose gel. The cDNA from the gel bands was then sequenced and the gene sequence fragments were assembled and completed by rapid amplification of the cDNA ends (RACE). By this process we have obtained large portions of the gene sequences of the four known paralogues located in the sculpin gill (RhA, RhB, RhC1, and RhC2). Also, *in vivo* ammonia-loading experiments were done to determine the effect of increased internal ammonia on protein and mRNA expression. Treatment groups were exposed to a single ammonium bicarbonate, distilled water, or ammonium chloride (5 mM kg^{-1}) infusion; then gill tissue was collected 4 hr post-infusion and analyzed using quantitative PCR to test changes in mRNA levels and dot blots for changes in RhxG protein levels. Preliminary QPCR data showed a trend of increase in response to ammonia loading. A second infusion test, with a chronic (8 hr) double load of ammonium bicarbonate, was completed with QPCR and dot blot analysis done on the gill tissue. Ambient water samples were also collected to determine *in vivo* ammonia efflux. In conclusion, from this data we have found a general increase in protein and mRNA expression in response to increased internal ammonia.

77.4 PHILLIPS, John B.*; DOMMER, David H.; TRAN, Dan Q.; GNIRKE, Matthew H.; FLINT, Christopher D.; PAINTER, Michael S.; Virginia Tech, Blacksburg, VA; *jphillip@vt.edu*

Light-dependent magnetic compass of larval Drosophila.

A light-dependent magnetic compass has been demonstrated in taxonomically diverse animals. The radical pair mechanism (RPM) implicates a specialized photoreceptor in magnetoreception and proposes that the alignment of an earth-strength magnetic field can modulate photosensitivity in a specialized receptor containing an ordered array of light-absorbing molecules. The magnetic field may be perceived as an axially symmetrical pattern of light intensity/color superimposed on the organisms visual field, or may be sensed by a separate light-dependent pathway independent of vision. To date, however, the biophysical process underlying the light-dependent magnetic compass has not been characterized in any organism. Here we show that the behavior of a simple organism, larval *Drosophila melanogaster*, can be used to visualize the primary biophysical process underlying the light-dependent magnetic compass, revealing; (1) an axially symmetrical, 3-dimensional pattern of response unique to the radical pair mechanism (RPM) and (2) an antagonistic interaction of short- and long-wavelength light consistent with wavelength-dependent effects of light on magnetic compass orientation observed in amphibians and adult Drosophila. Larval *Drosophila* provide a critical link between the properties suggested by theoretical models and artificial radical pair systems, and those observed in the behavioral responses of more complex organisms.

13.3 PIEKARSKI, N.*; OLSSON, L.; Friedrich-Schiller-Universitaet Jena, Germany; *nadine.piekarski@uni-jena.de*

A long-term somite fate map using GFP-transgenic axolotls

Derivatives of single somites are well studied using quail-chick chimeras. In order to investigate comparative aspects of single somite fate, we have extended this work to a urodele amphibian, the Mexican axolotl. Such an approach might enhance our knowledge of how conserved somite fate is, despite drastic differences in anatomy. Skeletal elements, such as the occipital region and the shoulder girdle in the axolotl, are anatomically quite different compared to the chicken, and of special interest for us. Both receive contributions from the somites in quail-chick chimeras. We focused on skeletal and muscular derivatives of somites two to six in the axolotl, which we determined using two different techniques. One technique was injections of dextran-fluorescein into the central part of single somites and detection of the marker in young larvae on paraffin sections using immunofluorescence. The other was transplantations of single somites using GFP-transgenic axolotls. Transplanted GFP-fluorescent somites and their derivatives could be tracked in vivo, and for a better evaluation cryosections were made. Our results demonstrate a very similar origin for the shoulder girdle, or more precisely the scapula, in quail-chick chimeras and axolotl. Thus in both species the shoulder girdle develops in a composite (somites and lateral plate) and segmental (more than one somite) fashion, but with differences in the number of participating somites and in the position of the border between lateral plate and somite derived cells. We postulate that the relative position of the shoulder girdle during development is crucial for these differences in somitic contributions.

44.5 PIENAAR, J*; SCALES, J. A. ; WIENS, J. J. ; BUTLER, M. A. ; University of Hawaii; *jasonpienaar@gmail.com*

LIZARD BODY FORM EVOLUTION AS ADAPTATIONS FOR OPTIMAL LOCOMOTION IN DIFFERENT HABITATS

We hypothesize that locomotion requirements through a given habitat are a major determinant of body form evolution amongst lizards. To test this, we utilize a large comparative data set (n=217) that includes representatives from a variety of habitats as well as measures of snout-vent length, tail length, fore-limb length, and hind-limb length for each species. A supertree phylogeny with branch lengths also exists for these species, allowing us to control for phylogenetic effects and more importantly, phylogenetic inertia. By using both Brownian-Motion (BM) based comparative methods and ones that model trait evolution as a stochastic Ornstein-Uhlenbeck (OU) process with a deterministic tendency to move towards fixed optimal states, we are able to compare a model of trait evolution through random drift to one of adaptation and subsequent maintenance of traits at habitat specific optima. For the adaptive models, we test various habitat categorizations as potential predictors of trait evolution. We find that for all traits, the OU-based models with sub-subterranean, terrestrial, dense-grass and an arboreal category as predictor variables, by-far outperform the BM based models. For snout-vent and tail lengths we show that current observed trait values are strongly influenced by both adaptation to specific niche optima and phylogenetic inertia. Fore and hind limb lengths also exhibit strong adaptation but are much less influenced by inertia. Finally, we obtain estimates of the optimal trait values in each of the selective niches that we would expect in the absence of phylogenetic inertia, which may aid future studies of optimal lizard body forms for given locomotor requirements

16.5 PISCITELLI, M.A.*; MCLELLAN, W.A.; ROMMEL, S.A.; PABST, D.A.; Univ. of North Carolina Wilmington; *map9270@uncw.edu*

Comparing lung size in shallow (Tursiops truncatus) and deep (Kogia spp.) diving cetaceans

Deep diving cetaceans are hypothesized to possess enhanced thoracic flexibility to accommodate pressure-induced reductions in lung volume at depth. Thoracic morphology has only, though, been described in detail in the shallow diving (1-10m) coastal bottlenose dolphin (*Tursiops truncatus*). Based on Boyles and Pascals gas laws, coastal dolphins will experience a 50% decrease in air volume at 10m. In contrast, deep diving (400-800m) pygmy and dwarf sperm whales (*Kogia* spp.) experience a 97% decrease in air volume at depth. Thus, the kogiid thorax may potentially undergo larger changes in volume than that of the bottlenose dolphin. However, kogiids lack some of the specialized morphologies observed in bottlenose dolphins that enhance thoracic flexibility. This study investigated whether deep diving cetaceans may limit thoracic collapse by decreasing lung size relative to body size. Lung mass was measured in the bottlenose dolphin (n = 107) and both kogiid species (n = 17). One bottlenose dolphin and one dwarf sperm whale were cross-sectioned to calculate thoracic cavity and lung volumes. For any given body mass the dolphin lung weighs 2.5 times more and has a volume 2.5 times larger than that of kogiids. Interestingly, the kogiid lung mass to body mass ratio is similar to that of terrestrial mammals. The lung occupies 37% of the total thoracic volume in the dolphin and only 15% in the dwarf sperm whale. These results indicate that the deeper diving kogiids possess smaller lungs than the shallow diving bottlenose dolphin, and will experience reduced pressure-induced changes in both lung and thoracic volumes at depth.

S9.2 PITTMAN, Quentin J; University of Calgary; *pittman@ucalgary.ca*

Postnatal inflammation programs adult physiology

The perinatal environment can be critical in programming many aspects of adult physiology, well being and susceptibility to disease. Increasing evidence now suggests that neuroimmune stress at crucial development periods can permanently alter the animals physiology. We have obtained compelling evidence that an inflammation induced by lipopolysaccharide (LPS) in 2 week old postnatal rat pups causes a long lasting programming of the neuroimmune response; this includes reduced fever, COX-2 activation and hyperalgesia to a subsequent induction of inflammation as an adult. Interestingly, associated behavioral (reduced activity, anorexia, anhedonia and reduced social interactions) are unchanged. The reduced fever in the adult is associated with reduced plasma cytokines, but with an elevation in circulating corticosterone (CORT) after LPS. The elevated CORT is responsible for the reduced responses and occurs because of increased secretion of of liver-derived prostaglandin. Postnatal LPS also causes a host of other long term alterations in the brain even in the absence of a subsequent immune challenge. Postnatal LPS treatment causes long term alterations in specific neurotransmitter receptor mRNA and greater neuronal loss after global cerebral ischemia or seizures as adults. These animals also display increased neuronal excitability, as adults, through mechanisms strongly dependent upon brain TNFalpha. These changes are associated with increased pain sensitivity, differences in memory performance, and in anxiety-like behavior, but no changes in weight. There are long term increases in basal brain and spinal cord COX-2 levels, but the relationship between the neurochemical changes and any of the alterations in the physiology and behavior are currently unknown.

29.5 PLACE, Ned J; Cornell University; *njp27@cornell.edu*

Graded inhibition of reproductive physiology by short photoperiod and aging outcomes in female Siberian hamsters, Phodopus sungorus

Reproductive aging has been shown to be decelerated in female Siberian hamsters raised in short days (SD), and delayed puberty induced by SD rearing was thought to be a plausible explanation for the later effects on aging. However, in the present study, signs of decelerated reproductive aging were evident in female hamsters that were first exposed to SD as adults. As compared to females held in long days (LD), hamsters that had been transferred to SD from 3 to 9 months of age showed better mating success when first bred at 12 months. Moreover, the number of ovarian primordial follicles, which represents the resting pool of germ cells, was greater in females held in SD than in LD, but only in those SD females that demonstrated the most immediate and sustained photo-inhibition. Females exhibiting a more modest response to SD had primordial follicle numbers at 9 and 12 months of age that were low and comparable to those found in age-matched LD females and in SD-nonresponders. Similarly, for females that were gestated and held in SD through 6 months of age, delayed photo-refractoriness and onset of vaginal patency were associated with greater numbers of primordial follicles at later ages. These results highlight the importance of assessing individual responses to environmental cues, as the categorization of animals as responders or nonresponders fails to capture the gradations of the photo-inhibitory effect. This concept may help explain the variation within groups in the levels of a circulating hormone that appears to reflect the size of the ovarian follicular reserve, anti-Mullerian hormone (AMH). Hamsters demonstrating the most robust response to SD, either before or after puberty, have the greatest numbers of primordial follicles at advanced ages and the highest levels of serum AMH.

26.2 PLACHETZKI, D/C*; OAKLEY, T/H; Univ. of California, Santa Barbara; *plachetzki@lifesci.ucsb.edu*

The Origins and Evolution of Metazoan Phototransduction Pathways:A History of Paraphyly and Derivation

How does evolution proceed from common starting points and go on to generate the biodiversity we see today? The evolutionary origin of novel and complex forms has puzzled biologists since before Darwin's time and persists as one of the central questions in biology today. Here, we address this "novelty" question using the biochemical evolution of animal photosensitivity as a model. By integrating studies of comparative genomics, phylogenetics, gene expression and gene function, we have traced the history of the opsin-mediated phototransduction cascade from its origins early in metazoan evolution. This study has yielded three major findings: 1. A new major clade of animal opsins is described from the Cnidaria. 2. Reconstructing the character history and ancestral composition of the animal phototransduction pathway strongly suggests that the *ciliary* mode of phototransduction, common to vertebrate visual photoreceptor cells, represents the ancestral state of animal opsin-based photosensitivity. A corollary of this finding is that the *rhabdomeric* pathway, common to protostome visual photoreceptor cells, represents a derived condition that evolved prior to bilaterian animals, but was absent in Eumetazoa. 3. Specific amino acid substitutions that were likely to play a role in this diversification were identified allowing hypotheses on the molecular basis for the evolution of disparate animal phototransduction pathways. The implications of these findings for animal photoreceptor evolution and for eye evolution are discussed.

101.2 PODOLSKY, R.D.; College of Charleston; *podolskyr@cofc.edu*
Reproductive correlates of exposure to ultraviolet light in an intertidal gastropod
Organisms that reproduce in intertidal areas are exposed to physical stresses that could alter their reproductive behavior and output, in response to potential risks both to themselves and to their offspring. Because exposure to ultraviolet (UV) light can have effects that are especially damaging to rapidly-dividing cells, encapsulated embryos on tidal flats may be especially vulnerable. As part of a study of maternal effects on embryonic risks of exposure to UV light, I measured above-sediment activity, reproductive output, and diel timing of oviposition by adults that were exposed to different levels of UV and visible light. Adults of the intertidal snail *Melanochlamys diomedea* were housed individually in flow-through oviposition containers in outdoor seawater tanks. The containers were covered with one of three types of acrylic shield that were UV-transparent, UV-filtering, or UV-filtering with 50% visible light shade. I will address the hypothesis that egg mass size and timing of oviposition were altered by light exposure in ways that were more favorable for embryo survival. Including the visible-light shade treatment will allow determination of whether adults perceive or respond to diminished UV light per se or to an overall reduction in light intensity. Time lapse images of adult movement in containers will also be used to address the hypothesis that time above ground, where adults search for mates, is constrained by exposure to high levels of UV (or visible) light.

89.6 PONTZER, Herman*; KAMILAR, Jason; Washington Univ.; *hpontzer@artsci.wustl.edu*
Greater Ranging Associated with Greater Reproductive Investment in Mammals: A New Perspective on Foraging Economics
Animals must travel to find food, incurring an energy and time cost. Both modeling studies and experimental work indicate that within species, increasing the distance traveled each day to find food has negative fitness consequences, decreasing the amount of energy invested in maintenance, repair, and reproduction. In this paper, we show that the relationship between daily distance traveled and reproductive success is fundamentally different between species and over evolutionary time in many lineages. Phylogenetically controlled analyses of 161 eutherian mammals indicate that, after controlling for body mass, evolutionary increases in the daily distance traveled are associated with corresponding increases in both total fertility (number of offspring per lifetime) and total offspring mass (grams of offspring per lifetime). This suggests that over evolutionary time, increasing travel distance is often part of a strategy for expanding the daily energy budget by procuring more food energy, and not necessarily a response to decreased food availability. These results have important implications for ecological comparisons among species, including assessments of habitat quality based on locomotor behavior.

59.4 POORE, A G B*; SOTKA, E E; University of New South Wales, College of Charleston; *a.poore@unsw.edu.au*
Historical constraints on host use in herbivorous marine amphipods
It is commonly assumed that marine herbivores are relatively unspecialised consumers, lacking the strong historical associations between herbivore and plant taxa that are evident among terrestrial insect herbivores. Detailed information on the associations between herbivore taxa and their hosts is largely lacking for marine herbivores and is required for predicting herbivore distributions, the impacts of herbivores on plant assemblages and the evolution of specialisation. We analysed host use data for an abundant family of herbivorous amphipods (Ampithoidae) to test the hypotheses that host breadth and composition varied among herbivore lineages, and the role of non-polar secondary metabolites in determining these patterns. The number and composition of hosts used per amphipod species varied among amphipod genera, indicating strong historical patterns to host use in this family. These patterns were not confounded by the uneven distribution of host taxa among geographic regions. The presence of biologically active secondary metabolites in hosts did not predict the composition of herbivorous amphipods, however the more specialised amphipods were those that were never found on chemically-rich hosts a result in contrast to the usual predictions of increasing specialisation being associated with tolerance to plant metabolites.

39.5 PORTER, ME*; LONG, JH; Vassar College; *meporter@vassar.edu*
Cartilaginous vertebral columns: mechanical responses to external loads and internal joint pressurization
While we have shown that vertebral number and centra shape are important predictors of body curvature in cartilaginous fishes during powered turns, morphological correlates predict only about 50% of body curvature among five species. We are interested in determining what other, non-morphological and non-muscular features may be correlated with body curvature during swimming. Based on previous biomechanical work on axial skeletons, we predicted that variation in mechanical properties of the intervertebral joints correlates with variation in body curvature. To test this prediction, we tested motion segments (vertebra-joint-vertebra) from shark vertebral columns. Using a MTS Tytron 250 one-axis testing machine, we designed a rig that allowed us to measure storage and loss moduli of the segment loaded in shear, compression, and bending. Following initial characterization of the intact motion segment, we then punctured the external and internal intervertebral ligaments to eliminate the internal pressure within the capsule of the joint. Motion segments were cycled 50 times to remove the fluid components of the joint. We again tested the viscoelastic mechanics of the motion segment without internal fluid compartments. This procedure measured the effects of joint pressurization on mechanical properties, and we thus used this proxy for pressure as one of the mechanical properties compared across species. These data contribute to the growing understanding of how cartilaginous skeletons respond to loads, and how those responses are correlated with morphology and swimming performance. This work was supported by NSF DBI-0442269.

93.1 POSTAVA-DAVIGNON, Marielle A.*; FULLER, Claire A.; STILLER, John W.; WADDLE, Erica; ROSENGAUS, Rebeca B.; Northeastern University, Murray State University, East Carolina University, East Carolina University; *postava-davig.m@neu.edu*

Fungal pressures within and surrounding nests of the arboreal termite species Nasutitermes acajutlae

Samples were collected from nests of *Nasutitermes acajutlae* in St. John, USVI. *Nasutitermes acajutlae* nest in various habitats (woodland, sparse, mangrove, dry forest, moist forest) on the island that differ in their abiotic attributes. Variables such as ambient temperature and humidity, nest temperature and humidity, light, soil moisture and pH were measured and analyzed for their influence on fungal amounts and diversity in each habitat, as well as within a nest. Washes of core and trail nest material, soil from underneath the nest, and cuticular washes of worker and soldier termites were plated on Potato Dextrose Agar with 25 ug/mL of the antibiotic Thiostrepton. Two plates of each sample were incubated at 25C and 35C for five days and fungal colony forming units (CFUs) counted. Cultured fungi were identified using environmental PCR. Results show that fungal growth is highest in the nest material and soil samples at 25C, and very little grows from the cuticular washes. The CFUs of core material, trail material, and soil samples all differed significantly between habitats, and core samples had the fewest fungi. The lack of growth at 35C may indicate the effectiveness of the high internal temperature of *N. acajutlae* nests for reducing fungal growth. Termites live in microbe-rich environments, many of which could be pathogenic. These results have strong implications from the role of fungal communities in nest site selection, and the influence of fungal pressures on the evolution of termite nest architecture.

97.3 POWERS, DR*; GETSINGER, PW; WETHINGTON, SM; TOBALSKE, BW; George Fox University, Newberg, OR, Hummingbird Monitoring Network, Patagonia, AZ, University of Montana, Missoula, MT; *dpowers@georgefox.edu*

Respiratory Evaporative Water Loss During Hovering Flight in Hummingbirds

Evaporation of water across body surfaces is an important method for heat dissipation in vertebrates. Hummingbirds (family Trochilidae) are among the smallest vertebrate endotherms resulting in extremely high rates of metabolism evaporative water loss (EWL). High rates of EWL contribute to water turnover rates that are as much as 5X their body mass. In this study, we made the first respiratory evaporative water loss (REWL) measurements for free-living hummingbirds during unencumbered hover flight. Measurements were made on 6 species ranging in mass from 3-8 g to determine the impact of REWL on their daily heat and water budgets. All measurements were obtained using a negative-pressure, open-flow respirometry system attached to a drip-free feeder at which the birds hover fed. REWL ranged from 80-150 mg $g^{-1}h^{-1}$ (8-15% of body mass) which is 50 times higher than REWL measured in resting birds, and 2-15 times higher than that measured in other birds during forward flight. Heat dissipated by REWL is about 0.36 kJ $g^{-1}h^{-1}$ which is about 35% of their hovering metabolic rate. Thus, REWL is a notable contributor to water turnover and heat dissipation during hovering in hummingbirds. Since hovering is the most energetically expensive activity for hummingbirds, these data further our understanding of water and heat budget management by a tiny endotherm during intense activity. Supported in part by NSF IOB-0615648.

75.2 PRATT, K L*; WILSON, R S; BLOMBERG, S P; FRANKLIN, C E; University of Queensland, Australia; *k.pratt@uq.edu.au*

Diving and digestion - the effect of an elevated metabolic rate on submergence in an aquatic ectotherm

Diving vertebrates submerge for varying durations, the extent to which is determined primarily by oxygen stores and metabolic rate (calculated aerobic dive limit). Environmental and physiological factors determine oxygen stores and metabolic rate; including temperature and aquatic PO_2, the effects of which are well understood. Almost completely overlooked is digestion, a physiological process which dramatically increases metabolism particularly in infrequently feeding ectotherms (eg. snakes) and the consequences for dive duration are untested. This study aimed to determine changes in metabolic rate and dive duration in response to the combined effects of temperature and aquatic PO_2 and to digestion in the fully-aquatic Arafura filesnake (*Acrochordus arafurae*). In the first experiment, three temperatures (20C, 26C, 32C) were used under aquatic normoxia and hypoxia. Metabolic rate increased with temperature (Q10 = 2.2) but was not affected by PO_2. Snakes used aquatic respiration during normoxia but lost oxygen to the water during hypoxia, increasing aerial respiration to maintain a constant metabolic rate. As temperature increased, maximum dive time under normoxia decreased from 77 min at 20C to 28 min at 32C with hypoxia further reducing dive time to 21 min at 32C. Digestion was more energetically demanding and enduring than changes with temperature and PO_2. Metabolic rate increased with meal size and digestion of the largest meal (15% body mass) resulted in an 11-fold increase in metabolic rate. Aquatic respiration increased three fold during digestion. Dive duration reduced to below 20% of fasting times (< 5 min) with the largest meal and the smallest meal (1.6%) halved maximum dive time.

S9.9 PRENDERGAST, Brian J; University of Chicago; *prendergast@uchicago.edu*

Photoperiodic Regulation of Reproduction and Immunity

Research in our lab focuses on understanding the neuroendocrine and neuroimmunological mechanisms by which seasonally-breeding animals engage annual changes in the activity of the immune system. Of particular interest are the interactions between seasonal changes in the reproductive system and their causal role in seasonal changes in the immune system. Insights into these mechanisms stand to inform questions about trade-offs between reproduction and immunity that occur as animals engage seasonal phenotypic change. Recent and current research projects will be presented, including studies that examine the role of gonadal hormones on behavioral responses to infection and studies assessing the role of naturalistic changes in photoperiod on immune function in a laboratory setting.

31.2 PROESTOU, DA*; SALGER, S; VAUGHN, C; GOMEZ-CHIARRI, M; University of Rhode Island; *dpro1791@postoffice.uri.edu*

Form and function of a novel metalloproteinase from the Eastern Oyster, Crassostrea virginica

Among vertebrates, matrix metalloproteinases (MMPs) are a well-studied family of enzymes. They are zinc-dependent, degrade the extracellular matrix, and play a critical role in many physiological processes. MMPs have been isolated in only a handful of invertebrates and little is known about how they function. We have characterized a novel gene, Cv1MMP, in *Crassostrea virginica*. The goal of our research was to determine the key roles of this newly-identified oyster protein. We took a comparative approach by performing genomic analysis of MMPs across taxa, visualizing temporal and tissue-specific patterns of MMP production using immunofluorescence techniques, and evaluating protein activity in response to a variety of stimuli. The production of Cv1MMP is limited to few cell types, specifically blood and epithelial cells. Cv1MMP labeling was observed in hemocytes, the mantle, and digestive tract. An analysis of digestive tissue at multiple time points during feeding suggests that Cv1MMP production peaks between 10 and 90 minutes post ingestion of algae. Labeled hemocytes were seen migrating through the intestinal lumen. Cv1MMP was also localized in epithelial cells along the periostracal groove and middle lobe of the oyster mantle, which function in pathogen detection and shell formation. MMP activity was detected in oyster hemolymph and levels correlated to degree of infection by the protozoan parasite *Perkinsus marinus*. The presence of Cv1MMP in hemocytes and epithelial barrier tissues, as well as differential MMP activity in infected animals suggest a role for Cv1MMP in digestion, hemocyte migration, shell formation, and immune defense. By comparing the genomic structure, tissue patterns, activity and roles of Cv1MMP with those of MMPs from other taxa, we hope to gain insight to the evolution of function in this versatile family of genes.

S6.7 PROVENZA, F.D.*; VILLALBA, J.J.; Utah State University; *fred.provenza@usu.edu*

Self-Medication in Domestic Herbivores

Imagine an animal foraging in an environment with 25 to 50 plant species that all differ in their concentrations of energy, protein, minerals, and vitamins. Moreover, they all contain secondary compounds that at too high doses can be toxic, but that at the appropriate doses can have nutritional and medicinal benefits. Envision further that how much of any one food an animal can eat depends on the other foods it selects because nutrients and secondary compounds interact one with another. Clearly, given many plant species and their biochemical interactions, there are a great many possibilities for mixing and matching to create a diet. Which plants should an animal choose, and when sick, should it trade-off some nutrients for medicinal secondary compounds? Animals maintain their health and well-being through behavioral interactions influenced by history, necessity, and chance such that at any time an animals foraging behavior depends on 1) its evolutionary history, genetically expressed, in concert with its uniquely individualistic history of the social and biophysical environments where it was conceived and reared, 2) necessity due to its current nutritional, toxicological and pathogenic challenges relative to the biochemical characteristics of foods it can potentially consume at any moment, and 3) chance occurrences that involve gene expression and environmental variability.

102.3 PUGENER, L. Analia; MAGLIA, Anne M.*; Missouri Univ. of Science and Technology, Rolla; *magliaa@mst.edu*

Developmental Evolution of the Anuran Sacrourostylic Region and its Locomotory Implications

In this talk, we discuss the developmental evolution of the sacrourostylic complex of frogs as it relates to locomotion. The sacrourostylic region is one of the most unusual specializations of the anuran skeleton, and seems to have appeared concomitant with the origin of the group and the move toward saltation. The ontogenetic pathway that forms the adult sacrum and urostyle subsequently evolved several times, apparently in association with varied locomotory modes. In some taxa, the hypochord does not extend anteriorly beyond Postsacral Vertebra 1, whereas in others it extends anteriorly to the level of the sacrum. Thus, as the hypochord migrates dorsally during metamorphosis, it fuses to either Postsacral Vertebra 1 or to the sacrum. In the first case, the adult morphology consists of an articulating sacrum and urostyle, as is the case for jumping frogs such as *Acris crepitans* and *Discoglossus sardus*. In the second case, the adult morphology results in a fused sacrum and urostyle, which is characteristic of the burrowing *Spea multiplicata* and the aquatic *Xenopus laevis*. A moveable articulation (especially a bicondylar one) between the sacrum and urostyle constitutes the best joint for saltatorial locomotion, whereas a fusion of these elements increases stability for swimming and digging. Further rigidity in the sacrourostylic complex, which helps maintain a streamlined position during swimming, is achieved by fusion of additional vertebra(e) to the sacrum and urostyle (forming a synsacrum), as in *Hymenochirus curtipes*.

77.3 PURI, Sakshi*; FAULKES, Zen; The University of Texas-Pan American; *zfaulkes@utpa.edu*

Do crayfish like spicy foods? and other tests of crustacean nociception

Nociception is the detection of noxious stimuli. Nociception is closely related to, but is not synonymous with, pain. Because of its clear functional significance, nociception should be common to most animals, but it has been little studied in invertebrates. Nociceptors, the sensory neurons specialized for nociception, are triggered by extreme pH and capsaicin (the ingredient that makes chili peppers hot) in many species, including some invertebrates. We tested the hypothesis that decapod crustaceans have nociceptors that are triggered by these two types of stimuli. Three decapod crustacean species were tested: Louisiana red swamp crayfish (*Procambarus clarkii*), white shrimp (*Litopenaeus setiferus*), and grass shrimp (*Palaemonetes* sp.). Applying 6M sodium hydroxide to the antennae caused no change in behaviour in *P. clarkii* and *L. setiferus*. Applying 6M hydrochloric acid to the antennae of *P. clarkii* also caused no change in behavior. Applying 1M sodium hydroxide to the antennae significantly reduced the activity of *Palaemonetes* sp. in the 10 minutes following application of the stimuli, but applying 1M hydrochloric acid caused no significant change in activity. To test for responses to capsaicin, foods containing variable amounts of capsaicin were given to *P. clarkii*. The crayfish were given Anaheim peppers (low capsaicin content) and habaneros (high capsaicin content) first separately, then together. Crayfish ate both habaneros and Anaheim peppers. When given both types of peppers at the same time, the crayfish preferred habaneros. These results only weakly support the idea that crustaceans have nociception.

78.6 RAGLAND, GJ*; SIM, S; FEDER, JL; HAHN, DA; University of Florida, University of Notre Dame; *gragland@ufl.edu*

Divergence of diapause physiology in a speciating insect: do changes in diapause energetics accompany the evolution of seasonal timing in the apple maggot fly?

The recent evolution of apple-infesting populations of *Rhagoletis pomonella* from an ancestral hawthorn-infesting population provides a textbook example of seasonal adaptation driving ecological speciation. Our study identifies physiological differences in diapause energetics associated with this recent evolutionary formation of two distinct host races. In general, changes in life cycle timing can change patterns of selection on particular life history stages. *R. pomonella* complete one generation per year, entering an overwintering pupal dormancy (diapause) shortly after larvae exit the host fruit. Apples fruit earlier in the year than hawthorns, and the apple host race emerges as adults and enters pupal diapause earlier than the hawthorn host race. Early entrance into diapause subjects the diapausing pupae of apple flies to a longer, warmer, more metabolically demanding pre-winter period, selecting for either decreased metabolism or increased nutrient storage. We show that apple pupae contain more lipid than hawthorn pupae, and we discuss preliminary results distinguishing host fruit and genetic effects on the lipid phenotype. We also present preliminary analyses of host race differences in resting metabolic rate. Finally, we discuss how our results connect to the hypothesized relationship between geographic climatic variation and sympatric speciation via host switching.

49.3 RAKOTOMANGA, M; AZZOUZI, N; SENGER, F; GUYON, R; HITTE, C; BAROILLER, JF; D COTTA, H; OZOUF-COSTAZ, C; GALIBERT, F*; CNRS UMR6061, Universite de Rennes 1, Rennes, France , CNRS UMR6026,Universite de Rennes 1, Rennes, France , CIRAD-EMVT, UPR20 Montpellier France, CNRS UMR7138, MNHN, Paris, France; *francis.galibert@univ-rennes1.fr*

A Radiation Hybrid map of the genome of Nile tilapia (Oreochromis niloticus)

Radiation hybrid (RH) maps are powerful tools to guide sequence assembly of deep whole genome shotgun. In the context of the whole genome sequencing program of Nile tilapia (*Oreochromis niloticus*) we have undertaken the construction of a dense RH map. Splenocytes were recovered from fishes of the clonal line established by Dave Penman (Stirling University). and used for the sequencing program. They were irradiated at 3500 rads, fused to carrier hamster cells (CHO HPRT-) and cultivated in HAT selective medium. DNA was extracted from each individually cultured hybrid cell clone and the presence of tilapia DNA checked by PCR amplification of a specific repetitive DNA marker. To select the best hybrid cell lines, the DNA of the 414 independent hybrid clones was further tested for the presence of 48 microsatellite markers distributed all over the tilapia linkage map. A total of 1500 markers corresponding to genes with orthologs in the stickleback, sea bream and sea bass genomes have been designed and their distribution within the tilapia RH panel is presently underway. Construction of the RH map based on the Travelling Salesman Problem (TSP) approach will follow shortly. We will report on the main aspect of this RH map as well as on the synteny relationship unveiled by the mapping of markers for which the positions of ortholog genes on other fish genomes are known. We also like to emphasize on the need of similar dense RH maps for the other three cichlids for which a 2X sequencing effort is planed.

68.6 RAMSAY, J.B.*; WILGA, C.D.; University of Rhode Island; *jasonramsay@mail.uri.edu*

Jaw depressor function during feeding in little skates, Leucoraja erinacea

The coracomandibularis (CM) and coracoarcualis (CA) muscles of little skates, *Leucoraja erinacea* are arranged in-series and interconnect the lower jaw to the pectoral girdle. Shortening of the CM and CA should result in lower jaw depression. However, manual depression of the hyomandibulae results in simultaneous jaw protrusion and lower jaw depression, as in other batoid species. Thus, instead of strictly shortening to directly actuating jaw depression, the CM and CA may also contract isometrically or eccentrically; functioning to transfer force and motion from the paired coracohyomandibularis (CHM) muscles to the lower jaw or to absorb force and motion, respectively. Hyomandibulae, upper and lower jaw kinematics, as well as motor activity in the CM, CA and CHM, and fascicle shortening in the CM and CA were recorded simultaneously with buccal pressure during feeding. During prey capture the CM and CA actively shorten with synchronous activation of the left and right CHM, resulting in ventrally directed protrusion of the opening jaws. Prior to peak hyomandibula and jaw depression, the CA actively lengthens while the CM continues to actively shorten resulting in an anterodorsal rotation of the protruding jaws at the articulation with the distal hyomandibulae. In contrast, during prey processing the CM and CA actively lengthen as the hyomandibulae are elevated and gape is decreased; compressing the buccal cavity. A second active period follows, in which the CM shortens as the jaws open and hyomandibulae depress. Modulation of CM and CA activity and strain in *L. erinacea* suggests that functional plasticity of certain feeding muscles along with muscular duplication and decoupling of the jaws and hyoid, may play a key role in the increased functional versatility in the feeding apparatus of batoids compared to sharks.

S6.12 RAUBENHEIMER, David; Massey University, Auckland; *d.raubenheimer@massey.ac.nz*

Nutritional PharmEcology

Recent advances in nutritional ecology have demonstrated the importance of understanding the interactive effects that food components have on animal feeding and physiological and life history responses. In this talk I argue that these developments have profound implications for the emerging field of PharmEcology. They demonstrate the importance of: 1) taking a multivariate approach to understanding the responses of animals to toxins and pathogens, and 2) of including macronutrients among the focal variables. I will introduce a framework - the Geometric Framework - that has been developed for modelling the complexity of animal-food interactions, and illustrate its application to questions concerning food-based toxins and disease in insects.

46.3 RAUT, Samiksha*; ANGUS, Robert; Univ. of Ala. at Birmingham, Birmingham; *samiksha@uab.edu*

Assessment of short-term and long-term exposures of non-steroidal estrogen, triclosan in western male mosquitofish, Gambusia affinis

Triclosan (TCS) is an antibacterial agent used in a variety of personal care and industrial products such as soap, shampoo, and textile goods. TCS and its environmentally transformed derivative, methyl-TCS has been detected in waters receiving effluent from wastewater treatment plants. The molecular structure of TCS resembles that of other non-steroidal estrogens. Furthermore, it has been shown to displace [(3)H] estradiol from estrogen receptors in human breast cancer cell lines, suggesting a role in the interference of normal endocrine functions. However, the endocrine disrupting potential of TCS has not been well studied. We hypothesize that TCS acts as an estrogen and an endocrine disrupting agent in fish. To test this hypothesis, we exposed mature male western mosquitofish,*Gambusia affinis* to TCS and measured vitellogenin induction as a biomarker of endocrine disruption. In the present study, mature male mosquitofish were exposed for two weeks to various concentrations of TCS (10nM, 50 nM, 350 nM, and 700nM) using the static renewal method. Ethynylestradiol (10nM) was used as a positive control. At the end of the exposure period, livers were isolated and vitellogenin mRNA expression was determined by real time-PCR analysis. Induction of vitellogenin mRNA expression was seen in the 700 nM TCS treatment group. We also measured standard length, weight, hepatosomatic and gonadosomatic indices in these treatment groups and found no significant differences between treatment groups. These results suggest that TCS acts as a weak estrogen as compared to ethynylestradiol and an endocrine disruptor in aquatic organisms. We are currently investigating long-term effect of TCS exposure on vitellogenin induction and sperm production in mature male western mosquitofish, *Gambusia affinis*.

38.1 REIDENBACH, M. A.*; KOEHL, M. A. R.; Univ. of Virginia, Univ. of California, Berkeley; *reidenbach@virginia.edu*

The spatial and temporal patterns of odors sampled by lobsters and crabs in a turbulent plume

Odor molecules are dispersed across marine habitats by turbulent water flow, and the spatial pattern of odor concentrations in the water varies with distance from the source. Many crustaceans, such as lobsters and crabs, take discrete samples of these odors by flicking their olfactory antennules. The objective of this study was to assess the odor concentrations sampled by the spiny lobster, *Panulirus argus*, and the blue crab, *Callinectes sapidus*, when they flick their antennules to determine if the concentration information they capture at different positions in a turbulent chemical plume can indicate their position relative to an odor source. An odor plume labeled with a fluorescent dye was released from a point source in a 25 m long water flume. Visualization of the odor field at multiple downstream and cross-stream distances from the source, and under various flow conditions were made using planar laser-induced fluorescence, while the velocity vector field was measured using particle image velocimetry. We sampled these odor concentration fields using the kinematics of antennule flicking by the long antennules of *P. argus* and the short antennules of *C. sapidus*. On the scale at which antennules sample an odor plume, filaments of high concentration are surrounded by odor-free water. We found that that as crabs and lobsters get closer to the source, the odor intermittency (i.e. on-off temporal signal) and peak concentration increase, but as the organism gets closer in the cross-stream to the plume centerline, intermittency decreases without a statistical change in the concentration sampled. Both crab and lobster antennules sample these concentration and intermittency differences that indicate position in a plume, but only the long lobster antennules sample odor filament width.

20.2 REILLY, S.M.*; MCELROY, E.J.; WHITE, T.D.; Ohio University, College of Charleston, Buffalo State College; *reilly@ohio.edu*

Abdominal motor patterns in mammalian locomotion: hypaxial muscle function with and without epipubic bones

Recently, we have shown in marsupials that 1) all of the hypaxial layers are involved in during ventilation and that each epipubic bone is retracted like a lever by the pectineus as part of a cross-couplet pattern of primary activity in abdominal muscles that provides long-axis support of the body between diagonal limb couplets. These results are significant because they reveal that hypaxial abdominal muscles are mildly active in pressurizing the gut during resting ventilation and that, at least in marsupials, all of the abdominal hypaxials play a part in ventilation during locomotion. Historicallly the cross-couplet motor pattern appears to be related to the presence of epipubic bone levers which appear in the fossil record in concert with a large suite of unique characters that define the earliest mammals. Equally significant is the question of what happens to abdominal hypaxial function when the epipubic bones are lost in the eutherians? To expand our understanding of mammalian abdominal function we examined the generality of the cross-couplet system in a third South American marsupial and we conducted the first formal studies of abdominal motor patterns in basal placental mammals focussing on a representative rodent and insectivore These data reveal a general pattern that basal mammals apply continuous abdominal muscle tone at rest and actively exhale with abdominal muscles during locomotion and that the loss of epipubic bones is associated with a shift from the cross-couplet dominated motor pattern of marsupials to unilateral activation of abdominal muscles during locomotion.

92.8 REINDL, K.M.; KITTILSON, J.D.; SHERIDAN, M.A.*; North Dakota St. Univ., Fargo; *mark.sheridan@ndsu.edu*

Ligand Binding, Agonist-Induced Regulation, and Signaling Characteristics of Trout Growth Hormone Receptors in Transfected Cells

Previously, we isolated and characterized two distinct growth hormone receptor (GHR)-encoding mRNAs, GHR1 and GHR2, from rainbow trout. In this study, CHO-K1 cells, which do not endogenously express GHRs, were individually transfected with plasmids that contained GHR1- or GHR2-encoding cDNAs. High affinity binding of ^{125}I-salmonid GH by expressed receptors was saturable, displaceable, and ligand selective. Whole-cell binding analysis revealed a single class of binding site; for GHR1 Kd=13 nM, for GHR2 Kd=21 nM. While salmonid prolactin (PRL) displaced ^{125}I-GH from both GHR1 and GHR2, the affinity of either receptor subtype for PRL was substantially less than that for GH; salmonid somatolactin, another member of the GH-PRL family, did not displace labeled GH except at pharmacological concentrations. ^{125}I-GH was internalized by GHR1- and GHR2-expressing cells in a time-dependent manner; maximum internalization reached 57% for GHR1 and 42% for GHR2. GH activated the JAK/STAT and extracellular signal-regulated kinase (ERK) subfamily of MAP kinases in both GHR1 and GHR2-transfected cells; however, greater phosphorylation of JAK and STAT was observed in GHR1 cells than in GHR2 cells and greater phosphorylation of ERK was observed in GHR2 cells than in GHR1 cells. These results indicate that trout GHRs display both overlapping and distinct characteristics that may be important for ligand selection and differential action in target organs. (Supported by NSF IOB 0444860 to M.A.S.)

26.8 REITZEL, Adam R.; TARRANT, Ann M.*; Woods Hole Oceanographic Institution; *atarrant@whoi.edu*

The Nuclear Receptor Complement of the Cnidarian Nematostella vectensis

Nuclear receptors (NRs) are a superfamily of metazoan transcription factors that regulate diverse developmental and physiological processes. We have identified the complete set of seventeen nuclear receptors from a cnidarian, the starlet sea anemone *Nematostella vectensis*. Phylogenetic analyses support *N. vectensis* orthologs of four nuclear receptors subfamilies in the NR 2 family (COUP-TF, TLL, HNF4, TR2/4) and one ortholog of the NR 6 family (GCNF). Other *N. vectensis* genes grouped well with the NR 2 family but did not have clear orthologs with bilaterians and may represent duplications within the cnidarian lineage. Unlike the jellyfish *Tripedalia cystophora*, *N. vectensis* lacks a clear ortholog of the RXRs, and experiments are in progress to determine whether retinoids specifically bind other N. vectensis NRs. Three NRs were not well-supported within any particular NR family and thus may represent ancient NRs that later diversified into bilaterian NR families. These results reveal that NRs are well diversified in the cnidarian *N. vectensis* including both orthologs of bilaterian NRs and novel genes likely stemming from lineage specific duplications. NR expression varies greatly during development, suggesting diverse regulatory roles for these genes. Understanding the evolutionary relationships and developmental expression of *N. vectensis* nuclear receptor complement allows better characterization the evolution of this gene superfamily and provides a foundation for elucidating the functions of cnidarian nuclear receptors.

14.2 REITZEL, Adam M*; TARRANT, Ann M; Woods Hole Oceanographic Institution; *areitzel@whoi.edu*

Transcriptional responses by the estuarine sea anemone Nematostella vectensis to cadmium exposure

Estuaries are heavily impacted by a broad range of anthropogenic contaminants from industrial and agricultural byproducts including toxic metals, aromatic hydrocarbons, pesticides, and pharmaceuticals. The fate of estuarine communities may depend upon the ability of resident organisms to deploy molecular and physiological responses to a combination of these and other stressors. Previous research has provided a wealth of data of these mechanisms in fish and crustaceans, but we currently lack sufficient data on what mechanisms a majority of resident organisms, particularly infaunal species, deploy to combat particular environmental stresses. We used suppressive subtractive hybridization (SSH) and qPCR of candidate gene approaches to quantify transcriptional responses of the estuarine sea anemone *Nematostella vectensis* when exposed to cadmium. Quantitative PCR indicated that the transcript expression of a suite of candidate genes (phytochelatin synthases, heat shock proteins) responded differently to sublethal cadmium exposure. Through SSH we identified additional candidate genes (transporters, nuclear receptor) that may be involved in molecular responses to metal stress. Together, our data provide the first molecular characterization of a cnidarian response to metal pollutants and potential quantitative indicators of organismal metal stress in this ecologically important phylum.

S8.11 RENN, Suzy C P; Reed College, Portland OR; *renns@reed.edu*

Microarrays for Evolutionary Models of Social Behavior: Astatotilapia burtoni and Beyond.

In the postgenomic era, there is extensive interest in the application of genomic technology to the study of less traditional model organisms. Even without full genome sequence, this is possible through the use of cDNA microarrays. While thirty years of research has 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*, the females phenotypes have been largely ignored by all but a few studies. We have taken advantage of an artificial manipulation (single sex housing) in order to induce aggression in females. Through comparison of the gene expression profile of female and male aggressive phenotypes we identify modularity in gene expression. While both aggressive phenotypes share a common gene expression module related to aggression, we find that the females are masculinized to some extent, but also show a uniquely female pattern of gene expression associated with aggression. Due to genome sequence similarity between species, we can use this one cDNA array to explore social regulation of gene expression in other cichlid species for which ther is a wealth of behavioral and ecological research. I will use the example of differential regulation between the sexes in order to demonstrate meta-analysis of gene expression data. These studies lay the groundwork for a systems level analysis to address the modularity of gene expression and the evolution of behavior.

56.5 REVELL, Liam J.*; COLLAR, David C.; HARMON, Luke J.; Harvard University, University of Idaho; *lrevell@fas.harvard.edu*

The Measurement and Interpretation of Phylogenetic Signal

Recently, biologists have been inclined to make process-oriented inferences from measures of phylogenetic signal, defined as the pattern of statistical dependence among the observations for species related by a phylogenetic tree. However, the relationship between the evolutionary process, the rate of evolution, and the phylogenetic signal for continuously distributed characters has never been rigorously examined. We used individual-based phylogenetic simulations of a variety of evolutionary scenarios to examine the relationship between phylogenetic signal and evolutionary process. Under genetic drift we found no relationship between the rate of evolution and phylogenetic signal. For other evolutionary processes such as functional constraint, fluctuating selection, niche conservatism, and various types of evolutionary heterogeneity, the relationship between evolutionary process, rate, and phylogenetic signal is more complex. Thus, we recommend against the over-interpretation of phylogenetic signal in empirical studies.

20.3 REVZEN, S*; GUCKENHEIMER, J.M.; FULL, R.J.; Univ. of California, Berkeley CA, Cornell Univ., Ithaca NY; *shrevz@berkeley.edu*

Study of Neuromechanical Control of Rhythmic Behaviors by Floquet Analysis

The control of rhythmic behaviors like locomotion is challenging to study when compared with control of fixed-point behaviors such as standing. In rhythmic behaviors perturbations away from the typical cycle may have counter-intuitive consequences later in the same cycle or even several cycles in the future. These causal relationships between seemingly different perturbations at different phases of motion can make predictions drawn from PCA and other matrix factorization methods ineffective. Dynamical systems theory describes the interrelation of perturbations in different parts of a cycle using Floquet Theory. The theory guarantees the existence of a change of coordinates that rectifies the dynamics to the simple linear form found in fixed-point systems. We developed our method for estimating a Floquet structure from kinematics to test the Templates and Anchors Hypothesis. This hypothesis states that rapid locomotion is controlled by restricting the many degrees of freedom of the animal's morphology, as represented by an "anchored" model, to follow low dimensional "template" dynamics. The presence of a template would express itself in the Floquet structure as having a few weakly damped modes that decay over multiple strides and span the template, and many strongly damped modes that decay within a stride or a step, and span the remainder of the degrees of freedom of the anchor. Our preliminary results suggest that running death's-head cockroaches, (*Blaberus discoidalis*), posses a template that can be distinguished in the Floquet structure of the animals' kinematics. Our methodology can be applied to the study of neuromechanical control in a broad range of rhythmic behaviors. Supported by NSF FIBR.

52.4 REYSSAT, E*; MAHADEVAN, L; Harvard University; *ereyssat@seas.harvard.edu*

Hygromorphs

Pine cones open and close in response to environmental humidity fluctuations, as can be checked with pine cones picked up from the backyard. This is just one example of how plant organs and tissues from leaves to flowers respond passively to humidity. This behavior arises from the bilayer structure of the scales that are made of water-responsive cells that can swell or shrink anisotropically. A century of work in the botanical community on these structures has catalogued examples and described the structural and ultrastructural aspects. However there is to date, no dynamical description of the opening and closing events. We complement this by studying the dynamics of these processes at the microscopic cellular scale and at the macroscopic level of individual scales and whole pine cones ranging in size from a few mm to 30 cm. The dynamics of opening and closing shows a marked hysteresis that arises from the difference in the physical processes underlying the wetting and drying of soft porous structures. We quantify this in terms of a theoretical model coupling fluid transport to mechanics and geometry that explains our observations. Inspired by these natural hygromorphs, we also built a few simple biomimetic devices with bilayered structures made of polymer and paper and analyze their response to humidity fluctuations. We show that the large geometrical amplification provided by slender bodies enables several interesting applications ranging from sensors to oscillators and even artificial flowers that have a controllable blooming and wilting response.

27.5 RHYNE, Andrew L.*; TORRES-PRATTS, Hernan; LADO-INSUA, Tania; RODRIGUEZ, Luis; SCHIZAS, Nikolaos; Roger Williams University, University of Puerto Rico, Mayaguez, University of Vigo, Spain, University of Puerto Rico, Ponce; *arhyne@rwu.edu*

Patterns of genetic variation of the corallimorpharian Ricordea florida

The long-distance dispersal potential of marine larvae is crucial to the maintenance of populations. As part of a research initiative to estimate the connectivity patterns of Caribbean benthic communities, we examined the genetic variation of the corallimorpharian *Ricordea florida*. *Ricordea florida* is distributed throughout the Caribbean region and is heavily harvested in the marine aquarium trade. Samples were collected from four geographically distant Caribbean locations (Curao, Florida, Guadeloupe and Puerto Rico). Analysis of the nuclear region consisted of ITS1, 5.8S, ITS2 uncovered two geographically partially overlapping genetic lineages in *R. florida*, within the sampled locations. Lineage 1 was found in Florida and Puerto Rico and Lineage 2 was found in Florida, Puerto Rico, Guadeloupe and Curao. Pairwise distance comparisons showed less variability within lineages than between. Preliminary data from cloning of ITS-1 showed that the intra-individual divergence is lower that the divergence between lineages (but higher between individuals of the same lineage). The highly traded *R. florida* is consisted of two distinct genetic lineages that probably represent two cryptic species.

15.5 RICHARDS, Christopher T.*; BIEWENER, Andrew A.; Harvard University; *richards@fas.harvard.edu*

Kinematics and hydrodynamics among ranid and pipid frogs

Recent work has addressed hindlimb kinematics of swimming frogs in the context of muscle function and hydrodynamics. However, there are no detailed studies linking time-varying joint kinematics with the propulsive function of anuran feet. This study explores how individual frogs vary the thrust produced by their feet by modulating joint kinematics to achieve a range of swimming speeds. *Rana pipiens* and *Xenopus laevis* frogs were filmed at high speed. A blade element model was used to estimate hydrodynamic forces on the feet. Swimming velocities ranged from 4.4 to 25.1 body lengths/s (BL/s) in *R. pipiens*, similar to 2.5 to 24.0 BL/s in *X. laevis*. However, the relative contributions of translational and rotational velocity to total foot velocity differed between species; peak translational velocity was 65.9 7.0% of peak total foot velocity in *R. pipiens*, versus 32 8.0% in *X. laevis* (mean S.D for N=26 and 23 strokes). Likewise, translational foot motion contributed 69.3 9.0% of total thrust impulse in *R. pipiens* versus 1.1 21.0% in *X. laevis*, revealing a fundamental difference in locomotor strategy between the two species, despite their similar range of swimming velocities. The joint kinematics that govern the patterns of translational and rotational foot velocity will be explored to understand how hindlimb coordination varies within and among anuran species to control swimming performance.

103.6 RICO-G., A.; Univ. of Connecticut; *alejandro.rico@uconn.edu*
Evolutionary Insights About Hummingbirds' Serrate Tomia
For many years it has been believed that the minute serrations on the tomia (cutting edges of the beak) of hummingbirds serve in the capture of small arthropods. This belief most likely exists because the serrate tomia resemble similar structures that function in prey capture as described in previous studies (e.g. scopate, denticulate and lacerate tomia) of other species. To date, however, there has been no test of this hypothesis about the function of serrate tomia in hummingbirds. I examined the bills of over 1000 specimens representing 189 species and 98 genera of hummingbirds, in 7 museum research collections. My results contradicted the idea that serrate tomia are used for arthropod capture. Additionally, recent data suggest that the tomia might not play a critical role in capturing flying arthropods, because they are mainly caught in the bill base rather than in the tip. Interestingly, hummingbirds share similar bill serrations with their old world counterparts, sunbirds, which are also nectarivores. This evolutionary convergence in tomial serrations suggests a new hypothesis about their function. Here, I propose a new biophysical model to describe the nectar intake mechanism in hummingbirds. In this model, the serrate tomia are used to fully extract any previously gathered nectar that remains on the tongue, allowing all of the liquid to be retained inside the bill. This mechanism works in conjunction with other structures in the interior of the beak in order to enhance nectar intake. This research highlights the necessity to develop further research on the evolutionary convergences of nectarivorous birds.

20.5 RINEHART, MD*; BELANGER, JH; West Virginia University; *mrinehar@mix.wvu.edu*
Similar motor pattern generators produce flexible walking behavior in juvenile and adult crayfish
We have shown previously that juvenile and adult crayfish (*Procambarus clarkii*) use different stepping patterns when freely walking. These differences are primarily due to an increase in relative stance durations in the posterior two pairs of legs and a decrease in relative stance durations in the anterior two pairs of legs in the juveniles. In order to determine whether these differences are caused by inherent differences in coupling relationships between limbs, we re-created treadmill experiments conducted on adult crayfish in which limb coordination was observed after amputation of one, two, or all ipsilateral limbs. Stepping patterns were altered based on which leg was amputated with the adjacent legs showing the most change. In all cases intact legs adjacent to amputated limbs increased stance times with the anterior adjacent leg functionally replacing the missing limb. Protraction of the amputated fourth right leg (R4) showed synchrony with the anterior leg three (R3) when only leg R4 was missing and again when R4 and R3 were both amputated. Upon amputation of all right legs we observed an ascending metachronal wave of activity in the stumps; however, under this condition relative timings showed large amounts of variation. These results largely agree with the autotomy experiments conducted in adult crayfish and imply that central circuitry in the juveniles is similar to adults. This also suggests that observed differences in freely walking juveniles and adults are more likely due to altered sensory feedback, changes in relative load distributions, and/or differences in relative hydrodynamic forces.

60.3 RIQUELME, C.A.*; MAGIDA, J.; SECOR, S.M.; LEINWAND, L.A.; University of Colorado, Boulder, University of Alabama, Tuscaloosa; *cecilia.riquelme@colorado.edu*
Pro-hypertrophic factors present in post-prandial python serum: effects on neonatal rat cardiomyocytes.
Burmese pythons are infrequent eaters and after a meal a rapid and significant increase in the size of several organs has been demonstrated. The dry mass of hearts of constricting snakes can increase up to 60% within 48 hours after feeding and return to fasted size shortly thereafter. This striking response has led us to investigate the mechanisms that regulate this physiologic cardiac hypertrophy and regression in pythons. We have hypothesized that post-prandial python serum might contain molecule(s) that can trigger the enlargement of the heart. To test this hypothesis, we have cultured neonatal rat ventricular myocytes (NRVMs) in the presence of fasted and post-fed serum and changes in cell size were determined. NRVMs cultured in media supplemented with 2% post-fed python serum are significantly larger in volume compared to fasted serum. The increase in size is comparable to a known pro-hypertrophic agonist factor such as phenylephrine. Currently, we are performing a systematic study to determine a complete set of metabolites present in the post-fed serum. Concomitant with these studies, we have been seeking for genes activated by the python serum in ventricular myocytes. To do so, we performed a microarray analysis of mRNA extracted from non-treated NRVMS and cultured in the presence of fasted, post-fed serum and phenylephrine. Interestingly, genes activated upon post-fed serum treatment do not cluster together with genes regulated by phenylephrine. From those genes, stand out lipid metabolism-related proteins and channels. These studies will provide us valuable knowledge on molecular events that regulate physiologic cardiac growth. This research was supported by AHA 0725732Z and the Hiberna Corp

70.6 RISKIN, D K*; BAHLMAN, J Wm; HUBEL, T Y; RATCLIFFE, J M; KUNZ, T H; SWARTZ, S M; Brown University, University of Southern Denmark, Boston University; *dkr8@brown.edu*
Oh what a feeling: the kinematics and kinetics of landing on a ceiling.
Flying animals exhibit obvious adaptations for flight, but they must also be able to land and maneuver in association with solid surfaces. Bats are especially interesting in this regard, since to land on a ceiling they must throw themselves toward an overhead substrate and perform a flip. Bat hindlimbs are gracile compared to those of other mammals, so bats must land in a way that keeps impact forces low, so that hindlimb stresses stay small. We examined the kinematics and kinetics of landing behaviour in three species of bat: an Old World fruit bat (Pteropodidae: *Cynopterus brachyotis*), and two New World fruit bats (Phyllostomidae: *Carollia perspicillata* and *Glossophaga soricina*). *Cynopterus* increased body pitch throughout the landing sequence, until the ventral surface of the body faced the ceiling. Roll and yaw did not change significantly during the landing. We refer to these as four-point landings, because bats struck the ceiling with the thumbs and hindlimbs simultaneously. *Carollia* and *Glossophaga* performed landing maneuvers in which their legs were brought up along the side of the body, causing simultaneous changes in pitch, roll, and yaw during the landing sequence. Bats of those species only touched the ceiling with their hindlimbs, and we thus refer to those as two-point landings. Four-point landings resulted in significantly larger total impact forces (mean = 3.6 body weights) than two point landings did (mean = 0.74 body weights; $P<0.0001$). We postulate that hindlimb stresses are kept relatively small in these three species by minimizing the impact force using the specialized two-point landing, or by applying most of the force with the robust forelimbs during a four-point landing.

84.4 RISTROPH, L. G.*; BERMAN, G. J.; BERGOU, A. J.; WANG, Z. J.; COHEN, I.; Cornell University; *lgr24@cornell.edu*

Sideways flying by phased wing flipping

Insects are enviable flyers and are capable of unusual maneuvers, such as sideways flight. We introduce a new motion tracking technique that reveals how maneuvering fruit flies generate lateral forces in flight. During sideways flight, flies induce asymmetries between the right and left wing angles of attack just as the wings rapidly flip over. We propose a mechanism in which unbalanced drag forces on the wings produce lateral force. Remarkably, the intricate asymmetries in wing motion involved in this mechanism can be simply induced by flipping each wing at slightly different times. In fact, we measure that fruit flies employ more extreme wing rotation timing differences when undergoing more extreme lateral acceleration. This mechanism takes advantage of several unique features of flapping flight, including dynamic angle of attack, independent control of each wing, and the large amplitude arc-like trajectories of the wings.

57.1 RIVERA, J.A.*; BUTLER, M.; University of Hawaii, Manoa; *julio.rivera85@gmail.com*

Determining Phylogenetic Relationships of microhylid frogs using Mitochondrial and Nuclear Gene Sequences

Microhylidae represents an ancient group of Anuras that was thought to have diverged from its Indo-Asian relatives some 64-84 mya (Van der Meijden et al., 2007). The family contains a total of 20 genera and 215 species which are present in Papua New Guinea and its satellite islands. Microhylids show incredible adaptation to a variety of environments including fossorial, scansorial, and arboreal settings that can be seen across the genera. The niche filling seen leads to homoplasy not only in microhylids, but other anurans as well indicating that a morphological phylogeny may not be the best method to indicate relatedness (Bossuy and Milimkovitch 2000). Kohler and Gunther (2007) were able to construct a microhylid phylogeny using 12S and 16S genes from the mtDNA, but were only able to provide resolution for shallow and not deep branching. In order to have a more resolved phylogeny a broader set of genes should be sequenced including mtDNA and nuclear genes. This may help resolve deep branching and provide a strongly supported phylogeny for the large family of microhylids.

97.4 RO, J.*; WILLIAMS, J.B.; Ohio State University; *ro.25@osu.edu*

Cutaneous water loss and lipids of the skin of tropical and temperater birds

Skin serves a number of important functions in the vertebrate body: it provides protection from abrasion, defends against chemical insult and pathogens, aids in regulation of body temperate, and forms a barrier to water loss. In mammals and birds, this latter function is accomplished by the outer most layer of the epidermis, stratum corneum (SC), formed by multiple layers of cornified cells embedded in a matrix of lipids. In birds cholesterol, free fatty acids, triacylglycerol, and sphingolipids such as ceramides, and crebrosides are primary constituents of the intercellular lipid matrix. Previous studies have suggested that lipid composition of the intercellular spaces of the SC influences rates of water loss through the skin. However our understanding of how lipids in the SC influence water permeation through the skin, and how environment affects these lipid domains, remains rudimentary. In this study we measured cutaneous water loss and lipid composition of the SC in 13 species of temperate birds and 14 species of tropical birds (n =140 individuals). We used thin layer chromatography to identify and quantify lipid classes and APPI mass spectrometry to identify individual lipid molecules. Results thus far indicate that birds from temperate regions have lower rates of cutaneous water loss than birds from humid lowland tropical environments. Low rates of cutaneous water loss in temperate birds were associated with a dramatic increase in the quantity of sphingolipids in their SC: temperate birds had a mean ceramide concentration of 87.5 mg/g dry SC, whereas tropical birds had 12.2 mg/g dry SC. In sharp contrast, the amount of cholesterol per unit SC was not significantly different between temperate and tropical birds. Our use of mass spectrometry has thus far revealed over 600 molecular species of sphingolipids in the SC of birds.

98.9 ROBERTS, T.J.*; AZIZI, E.; Brown University; *thomas_roberts@brown.edu*

The series elastic shock absorber: tendon elasticity reduces peak muscle forces during active lengthening

Tendons store and release mechanical energy when force is applied to them. This spring-like behavior can conserve muscle mechanical power for cyclical activities like running, or amplify it for high-power activities like jumping or acceleration. The function of tendon springs during dissipative activities such as deceleration or jumping landing has received relatively little attention. We used an *in situ* muscle preparation (turkey gastrocnemius) to test the hypothesis that tendon stretch limits the peak forces developed in a lengthening contraction. Implanted sonomicrometer crystals measured muscle contractile element length and a muscle servomotor measured muscle force and muscle-tendon length. A series of constant velocity ramp stretches were applied to the muscle-tendon coincident with a 50ms stimulation pulse. Under most conditions, the contractile element shortened during force rise, even as the muscle-tendon unit lengthened. Muscle fascicle lengthening could be elicited only at the most rapid rates of muscle-tendon lengthening. Forces developed when muscle fascicles were stretched at a rate equivalent to 10% maximal shortening velocity were almost twice the magnitude of forces developed when the same stretch was applied to the muscle-tendon unit. During force decline, muscle contractile elements actively lengthened, but at a rate that was usually slower than the stretch applied by the muscle motor. These results describe a tendon-mediated buffering mechanism that may limit the risk of excessive forces and muscle damage during rapid energy-absorbing tasks. Supported by NIH grants AR 055295 to TJR and AR054246 to EA.

49.1 ROBERTS, Reade B.*; KOCHER, Thomas D.; University of Maryland, College Park; *reade@umd.edu*

Single origin of a lake-wide pigmentation locus in the rock-dwelling cichlids of Lake Malawi.

The phenotypic diversity present in the cichlid fishes of Lake Malawi is amazingly rich given the relatively short history in which it has evolved. Perhaps the most varied set of phenotypes is found within pigmentation, with nuptial coloration at times defining, and possibly driving, species boundaries. Extremely similar pigmentation characters repeatedly appear across the Malawi cichlid flock, often in species separated by both geographic and phylogenetic distance. While such a pattern suggests repeated convergent evolution of pigmentation phenotypes, the same pattern could also arise as a result of the sorting of ancestral pigmentation genes, or the migration of pigmentation genes during rare interspecific hybridization events. Here we report the fine mapping of a genetic locus underlying the orange blotch pigmentation phenotype found in four distinct genera throughout Lake Malawi. Our results reveal a single haplotype, and thus a single origin, of the orange blotch locus, as well as some compelling candidates for the gene responsible for the phenotype. Additionally, the orange blotch locus accounts for a range of distinct blotched phenotypes. The single genetic origin of a phenotypic trait found throughout the lake has profound implications to understanding this particularly speciose vertebrate radiation, as well as to future utilization of the Lake Malawi cichlid flock as a model to understand gene function and the evolution of adaptive traits.

84.1 ROBERTS, S.P.*; VANCE, J.T.; WILLIAMS, J.B.; ELEKONICH, M.M.; Univ. of Nevada Las Vegas; *stephen.roberts@unlv.edu*

The effects of age and behavioral development on the flight performance of honey bees

A critical issue in life history theory is how behavior and age affect the lifetime kinetics of whole-organism performance. Studies of this issue should ideally separate the effects of age and behavior without ambiguity, focus on performance traits that are ecologically relevant, and utilize free-living models. In this study we compared the flight performance of honey bees (whose behavioral development and age can be assessed independently via simple manipulations of colony demographics) between distinct behavioral castes (in-hive nurse bees vs. out-of-hive foragers) and across lifespan. Variable-density gases and high-speed video were used to determine the maximum hovering flight capacity and wing kinematics of age-matched nurse bees and foragers sampled from a single-cohort colony over a period of 34 days. The transition from hive-work to foraging was accompanied by a 42% decrease in body mass and a proportional increase in flight capacity (defined as the minimum gas density allowing hovering flight). The lower flight capacity of hive-bees was primarily due to the fact that in air they were functioning at a near maximal wing angular velocity due to their high body masses. Foragers were lighter and when hovering in air they required a much lower wing angular velocity, which they were able to increase by 32% during maximal flight performance. Flight performance of hive-bees was independent of age, but in foragers the maximal wingbeat frequency and maximal wing angular velocity were lowest in precocious (7 to 14-day-old) foragers, highest in normal-aged (15 to 28-day-old) foragers and intermediate in foragers older than 29 days. This pattern coincides with age-dependent biochemical and metabolic properties of honey bee flight muscle.

101.9 ROMERO, M. R.*; KELSTRUP, H. C. P.; STRATHMANN, R. R.; California State Univ., Los Angeles, University of Washington; *MelissaRRR20@hotmail.com*

High-speed video reveals capture of particles by direct interception by cilia during feeding of a gastropod veliger.

Ciliary feeding varies in arrangement of ciliary bands, mechanisms of capture, and concentration of food. Some larvae use opposed parallel bands of preoral (prototroch) and postoral (metatroch) cilia. Hypotheses for the mechanism of particle capture include filtration by adhesion to a cilium (direct interception), but unequivocal evidence for this mechanism has been lacking. High-speed video recordings of gastropod veliger larvae of *Lacuna vincta* indicated direct interception by prototrochal cilia. Adhesion between cilium and particle was seen when a prototrochal cilium tugged a diatom chain into the food groove while in contact with one part of the chain. In several recorded events, a prototochal cilium overtook a particle during its effective stroke; then moved the particle inward with its recovery stroke and the particle subsequently moved to the food groove. Captures varied, however. In some cases the particle was intercepted multiple times in one capture event. In others several cilia passed a particle without interception. Particles occasionally remained in the area of recovery strokes, indicating retention without adhesion to a cilium. In three events, a particle lost from a prototrochal cilium was intercepted and moved into the food groove by metatrochal cilia. Particles as wide as or wider than the food groove were captured and transported but not ingested.

83.3 ROOS, G.*; VAN WASSENBERGH, S.; LEYSEN, H.; HERREL, A.; ADRIAENS, D.; AERTS, P.; Univ. of Antwerp, Belgium, Univ. of Ghent, Belgium, Univ. of Harvard, Cambridge, Univ. of Ghent, Belgium; *Gert.Roos@ua.ac.be*

Ontogeny of feeding kinematics in the seahorse Hippocampus reidi from newly born to adult

One of the most important aspect of an animals life, adult or juvenile, is the ability to feed. Undoubtedly, the size and shape of an animals feeding apparatus will affect its working method and its constraints. In fish, larval morphology transforms into an adult-like body form during a period of metamorphosis. This causes changes in shape and size that inevitably have drastic functional consequences. To date, only a single study covered the entire range from the first-eating larval stage to reproductive adults when investigating scaling effects on feeding kinematics in zebrafish. The present study investigated the ontogeny of feeding kinematics in seahorses, which show a different feeding strategy (pivot feeding), a period of parental care inside the males brood pouch prior to first-feeding, and a strong allometric growth toward the adult stages. Five age categories were studied (1-3 days, 1 week, 2 weeks, 3 weeks and adults). The results show that, even in 1-day old individuals, the feeding apparatus already functions similarly compared to adults. However, the maximal movements during a feeding strike, their timings and velocities are subjected to profound ontogenetic effects.

26.7 RORICK, M.M.*; WAGNER, G.P.; Yale University; *molly.rorick@yale.edu*

The Origin of Conserved Protein Domains and Amino Acid Repeats Via Adaptive Competition

Some proteins, such as homeodomain transcription factors, contain highly conserved regions of sequence. It has been recently suggested that multiple conserved functional domains overlap and together explain the high conservation of these regions. However, we are still left with the question of why so many conserved functions cluster together in one relatively small region of the protein. Is there an evolutionary mechanism that can produce this kind of clustering? Here we have modeled one such mechanism: *conserved functional domains get displaced from the more variable parts of the molecule that are undergoing adaptive evolution because poorly optimized novel functions in variable regions generally out-compete conserved functions for control over amino acid identity*. We also studied the evolution of single amino acid tandem repeats (a.k.a. homopeptides), which are common in eukaryotic proteins and especially prevalent in transcription factors. Some homopeptides are encoded by nonhomogenous mixtures of synonymous codons, so their presence cannot be explained by a neutral process slippage. Further, Mularoni et al. (2007) find that the most constrained proteins in fact have the greatest number of repeats. Although it is clear that selection is playing a role in the evolution of such repeats, the exact mechanism by which they arise remains unclear. Our model provides two ways to explain their origin, maintenance and over-representation in highly conserved proteins. We demonstrate that either *competition between multiple functional domains for space within a sequence, or reuse of a sequence for many functions over time, can cause the evolution of such repeats*. Both of these causal processes are especially characteristic of multi-functional proteins such as homeodomain transcription factors.

74.6 ROS, Ivo G*; BIEWENER, Andrew A; LEE, David V; ANTONEN, Jennifer; HIGGINS, Trevor; Harvard U., UNLV; *ivo.ros@gmail.com*

Mechanical Differences between Trotting and Galloping in Quadrupeds

It is generally believed that quadrupeds transition from a trot to a gallop to reduce peak forces and galloping is energetically advantageous to trotting at higher speeds. To enhance our understanding of the underlying mechanics, we contrasted the interactions of the whole body ground reaction force (GRF) and the center of mass (CoM) between trotting and galloping. Goats and dogs steadily galloped and trotted over four adjacent force platforms while 3D body and limb kinematics were recorded simultaneously. In trots the GRF tightly tracks the CoM throughout the stride. As predicted by the theoretical spring-loaded inverted pendulum (SLIP) model, this leads to greater fluctuations of the horizontal *translational* kinetic energy (KE) and CoM trajectory compared with galloping. In contrast, during galloping GRFs of the fore and hind legs act in front of and behind the CoM respectively, producing torques about the CoM that add rotational KE to the body. This results in oscillating pitch rotations, or *rotational* KE fluctuations. As a consequence, galloping goats and dogs travel with a more uniform horizontal KE, flatter CoM trajectories and lower, more vertically oriented GRFs than would be expected for trots at similar speeds. Our results therefore indicate that switching from a trot to a gallop lowers peak forces by reducing the vertical GRF component, applying less work to the CoM. (Supported by DARPA Biodynotics)

93.4 ROSENGAUS, Rebeca*; AVULOVA, Svetlana; REICHHELD, Lindsey; Northeastern University; *r.rosengaus@neu.edu*

Losing the battle against fungal infection: suppression of termite immune defenses during mycosis

The progression of *Metarhizium anisopliae* fungal infection on the cellular immune defenses of the dampwood termite *Zootermopsis angusticollis* was studied by quantifying the number and types of circulating hemocytes of naive nymphs and nymphs exposed to either a control suspension lacking conidia, $2x10^3$, $2x10^6$ or $2x10^8$ conida/ml doses. Hemocyte density was monitored on days 1, 2, 3, 4, 7 post-exposure. Our results show that the density of prohemocytes and particularly plasmatocytes, but not granular hemocytes, changed as a function of both conidia dosage and time elapsed since exposure. The development of mycosis beyond the third day resulted in an almost complete collapse of plasmatocytes which coincided with the appearance of hyphal bodies in the hemolymph and the onset of sluggish behavior, culminating in termite death. Prophenoloxidase activity (PO), used as a proxy for estimating investment in immunity function, surged two to three days after exposure to a 10^8 conidia/ml and then waned to baseline values by day seven post exposure. Thus, the initial immune response in these termites is overtaken by *M. anisopliae*, mainly by destroying the hosts plasmatocytes and reducing PO activity that is necessary for the successful encapsulation of the invading fungus.

88.3 ROSS, C.F.*; STRAIT, D.; DECHOW, P.C.; RICHMOND, B.; SPENCER, M.; SCHREIN, C.; WEBER, G.; SLICE, D.; University of Chicago, University at Albany , Baylor College of Dentistry, George Washington University, Arizona State University, University of Vienna; *rossc@uchicago.edu*

In vivo bone strain and finite-element modeling of the craniofacial haft in catarrhine primates

Hypotheses regarding global or overall deformation regimes in the primate skull remain untested in most taxa, in part because the in vivo bone strain data that provide the direct test of these hypotheses can only be gathered from restricted areas under strain gages. Well validated finite-element models provide a means of evaluating hypotheses regarding global deformation regimes because they not only allow extrapolation beyond the in vivo gage sites, but they also provide a picture of overall deformation. Here we compare in vivo bone strain data gathered from six sites on four *Macaca* individuals during mastication with strain data from the surface of a finite-element model of the skull of *Macaca* loaded using external forces estimated using measured muscle cross-sectional areas and masticatory EMG data. The global deformation regime of this validated macaque model is compared with the patterns of deformation of a finite-element model of *Pan* and with deformation patterns reported by Endo from his in vitro experiments on skulls of *Gorilla* and *Homo*. These comparisons reveal a common global craniofacial deformation regime among catarrhine primates, despite diversity in their craniofacial morphology. This suggests that diversity in catarrhine craniofacial skeletal morphology is not associated with variation in the manner in which the skeleton deforms during chewing. This variation must instead be due to selection on other aspects of cranial function, such as food ingestion, gape, vision, olfaction, or protection of soft tissue structures.

45.3 ROTH, E.*; REISER, M.B.; COWAN, N.J.; Johns Hopkins University, Howard Hughes Medical Institute; *eatai@jhu.edu*

Reconciling Open- and Closed-Loop Experiments in Sensorimotor Control of Drosophila

In optomotor yaw regulation experiments, a rigidly tethered fly (*Drosophila*) modulates yaw torque to frontally fixate a moving vertical stripe. In closed-loop experiments, the measured yaw torque stabilizes the error signal (the angular displacement of the stripe) via real-time feedback. In open loop, torque is measured without this feedback. Heisenberg and Wolf (1988) observed that, when presented with stimuli oscillating at low frequency, flies exhibited qualitatively different responses to the same error signals in closed- and open-loop trials. They concluded that flies distinguish open- from closed-loop conditions and employ different sensorimotor transformations (controllers) accordingly. We present evidence that, for stimuli with faster dynamics (higher frequency content), closed- and open-loop responses are comparable. Further, we address the question of whether a fly *knows* that it is flying under closed-loop conditions through the analysis of a candidate model of the sensorimotor transform: a standard PID (proportional, integral, derivative) controller with a biologically feasible nonlinear saturation to the integral term. We demonstrate that even this simple controller can capture the categorical differences in behavior previously observed as well as the similarities seen in high-frequency trials. In the model, the internal states of the open-loop system exhibit sensitivities to biases in noise or initial conditions. Feedback mitigates these factors which, in open loop, drive the state of the system to regimes not typically encountered in closed loop. Implementing a single controller, the behavior transitions between categorically different responses as governed by the internal state of the system, not mediated from a higher center.

94.2 ROTJAN, Randi*; CHABOT, Jeffrey R; LEWIS, Sara; Harvard University / New England Aquarium, Pfizer, Inc., Tufts University; *rrotjan@neaq.org*

Vacancy chains in different social contexts determine resource acquisition by Coenobita clypeatus terrestrial hermit crabs

Hermit crabs require gastropod shell resources for protection. Because shells are often scarce, crabs have evolved complex behavioral and social protocols for shell acquisition via competition. Previous studies on hermit crab resource assessment and competition behaviors have mainly been restricted to simplified laboratory conditions. In contrast, field observations show that shell acquisition in natural populations often involves complex behavioral interactions among conspecifics. Combining lab and field manipulations, we describe vacancy chains, where a single vacant shell initiates a sequential chain of shell switches involving many crabs. Vacancy chain theory has been developed by economists to describe distributions of discrete, reusable resources such as jobs or houses. We tested the central prediction that vacancy chains will provide aggregate benefits distributed across many users when a single new resource becomes available. Lab experiments demonstrated that vacancy chain participants gained significant shell quality improvements. We also experimentally examined how shell damage and crowding, two key dimensions of resource quality, affected the likelihood of winning contests. We introduce a novel resource-use paradigm to accommodate social context, and field observations confirmed 3 social contexts for vacancy chains (asocial, synchronous, and asynchronous), distinguished by differences in shell assessment behaviors and the reversibility of shell switches. Finally, we present an agent-based simulation model to examine how population size and density impact the frequency of vacancy chain types, and the associated behavioral and ecological costs and benefits. Vacancy chain theory represents an innovative approach to understanding resource acquisition behaviors that is applicable across a wide taxonomic range.

89.5 RUTKOWSKA, Joanna*; MARTYKA , Rafal; CICHON, Mariusz; Institute of Environmental Sciences, Jagiellonian University; *joanna.rutkowska@uj.edu.pl*

Trade-off between maternal immunocompetence and offspring viability in zebra finches

The immune system is an important player in individual physiological trade-offs; however, intergenerational effects of immunocomeptence have rarely been explored. Immunocompetent mothers should produce high quality offspring, especially if maternal immunological agents present in the eggs protect embryos and later nestlings against pathogens. However, maternal immune response could come at the cost of draining resources from breeding investments. We examined the relationship between the strength of maternal antibody production in response to novel antigen and offspring performance and survival in three separate experiments. In each of them, the female immune system was challenged with sheep red blood cells (SRBCs), and the response was scored using hemagglutination test. Experiments differed in two aspects: timing of immune challenge in relation to breeding and degree of offspring competition within broods that was manipulated by experimental synchronization of hatching. In all cases, offspring survival until adulthood was negatively related to maternal antibody titers. Because that effect was observed among offspring of females mounting an immune response both during as well as a few months before breeding, we conclude that maternal antibody production per se is not directly responsible for lower offspring viability. Comparison of the two experiments differing in the level of offspring competition revealed that higher competition within synchronized broods strengthened the negative relationship between maternal antibody titers and offspring survival. We conclude that high maternal immunocompetence is associated with lower offspring viability irrespective of current maternal immune status.

10.3 RYERSON, W.G.*; DEBAN, S.M.; University of South Florida, Tampa; *wryerson@mail.usf.edu*

Scaling of suspension feeding in tadpoles

We investigated the scaling of the buccal pumping mechanism in an ontogenetic series of suspension feeding *Xenopus laevis* tadpoles by examining the morphology, kinematics, fluid flow, and pressure generated in the buccal cavity. Tadpoles were imaged during feeding to obtain kinematics and fluid velocity. Reynolds number was calculated using fluid velocity and morphology data, and pressure was calculated using flow data and a pipe model of the branchial filter basket. Buccal volume and head width exhibited negative allometry, with scaling coefficients of 1.22 +/- 0.20 and 0.36 +/- 0.15, respectively. Scaling of the kinematics did not match scaling patterns of bass or aquatic salamanders. Only scaling of maximum hyoid distance (0.60 +/- 0.74), duration of mouth closing (0.74 +/- 0.51), and duration of hyoid elevation (0.69 +/- 0.55) could not be distinguished from isometry. The only negatively allometric variable was maximum gape distance (0.52 +/- 0.37). No effect of size was found for duration of mouth opening (-0.05 +/- 0.60), duration of hyoid depression (0.40 +/- 0.51), and velocity of hyoid elevation (-0.31 +/- 0.39). Velocity of mouth opening (-0.72 +/- 0.20), velocity of mouth closing (-0.50 +/- 0.35), and velocity of hyoid depression (-0.65 +/- 0.16) decreased with increasing size. Fluid velocity increased with size, and is best predicted by a piston model that includes head width and hyoid depression velocity. Reynolds number increased with size and spanned two flow regimes (laminar, intermediate) ranging from 2 to over 100. Pressure was found to be greatest in the smallest tadpoles and decreased as size increased, ranging from 2 kPA to 80 kPa, suggesting that abiotic factors such as the physical properties of water may set a lower size limit on suspension feeding.

103.1 SADLEIR, R.W.*; LEE, S.; Field Museum & Univ. of Chicago, Univ. of Illinois, Chicago; *rsadleir@uchicago.edu*

PHENOTYPIC PLASTICITY IN ALLIGATORINAE EVOLUTION & VISUALIZING 3-D SHAPE CHANGE

During ontogeny, organisms can display different phenotypes as a result of living under different environmental conditions. Recent research suggests such environmentally induced phenotypic plasticity can promote evolutionary diversification among populations. The growing *Alligator mississippiensis* agroindustry provides a unique opportunity to investigate whether different environmental conditions through ontogeny can induce cranial shape variability and whether the magnitude of variability corresponds to or exceeds species boundaries. In various species of crocodilians, captive-raised populations have been casually recognized to have cranial morphologies very different from wild populations. In a 2D geometric morphometric analysis of extant crocodilian variation, farm-raised *A. mississippiensis* specimens cluster closer to *A. sinensis* suggesting that differences in shape due to ontogenetic environment transcend species morphospace boundaries. Inferential power improves when fossil taxa are included. Results reveal the morphospace range of wild and captive *A. mississippiensis* is nearly inclusive of its taxonomically closest extinct taxa *A. olseni*. Captive *A. mississippiensis* occupy a novel region of morphospace orthogonal to the wild populations ontogenetic shape change. This suggests the phenotypic plasticity in *A. mississipiensis* is large enough to account for the scale of evolutionary differentiation among *Alligator* species back to the Miocene. This hypothesis is explored at higher analytical resolution using a greater fossil sample, and presents a new method of visualizing and animating geometric morphometric shape change in 3-D using the freeware Blender. A sample of 16 farm-raised *A. mississippiensis* of known age and ontogenetic environmental condition was compared to a post-hatchling size range of 22 wild specimens from the same geographic range.

35.2 SALZBURGER, Walter; University of Basel, Switzerland; *walter.salzburger@unibas.ch*

The interaction of sexually and naturally selected traits in the adaptive radiations of cichlid fishes

The question of how genetic variation translates into organismal diversity has puzzled biologists for decades. Despite recent advances in evolutionary and developmental genetics the mechanisms that underlie adaptation, diversification and evolutionary innovation remain largely unknown. The exceptionally diverse species flocks of cichlid fishes are textbook examples of adaptive radiation and explosive speciation and emerge as powerful model systems to study the genetic basis of animal diversification. East Africas hundreds of endemic cichlid species are akin to a natural mutagenesis screen and differ greatly in ecologically relevant, hence naturally selected, characters such as mouth morphology and body shape, but also in sexually selected traits such as coloration. Here, I will focus on two fitness-relevant traits, the pharyngeal jaw apparatus and anal fin egg dummies. I will discuss what is currently known about the genes underlying the morphogenesis of adaptively relevant traits and highlight the importance of the forthcoming cichlid genomes in the quest of the genetic basis of diversification in this group.

S1.6 SANE, Sanjay P.; National Center for Biological Sciences; *sane@ncbs.res.in*

The tale of two mechanosensors: antennal role in insect flight

Mechanosensors located at the base of insect antennae are crucial in the control of flight trajectories of insects such as moths and butterflies. In these insects, the antennal base consists of two sets of mechanosensors involved in control and sensing of antennal motion. One set, called the Johnstons organs is composed of several scolopidial units which respond to the relative motion between the flagellar-pedicel joint. Another set, the Bohms bristles, consists of bristle fields arranged orthogonally on the surface of scape and pedicel. Although the exact mechanisms of their involvement in flight are still under investigation, it is increasingly evident that these two sets of mechanosensors fulfill functionally distinct roles during flight in the hawk moths. The Bohms bristles are ideally positioned to respond to large angular movements of the antenna and likely mediate the precise positioning of the antennae during flight. In contrast, the individual units of Johnstons organ respond to the higher frequency vibrations of the antennae during flight. Neuroanatomical investigations of the Bohms bristles pathway suggest that the sensory information from the bristle fields arborizes in close proximity to the dendritic fields belonging to the antennal motor neurons. This suggests that there may be a close communication between the input from the Bohms bristles and the antennal muscles to enable a rapid but precise control of the antennal position *via* a simple negative feedback loop. A constant inter-antennal angle may then enable the Johnstons organs to unambiguously measure the input from the antennal vibrations to provide specific sensory feedback necessary for flight control. Thus, inputs from both mechanosensors are necessary to ensure that antenna can serve as a mechanosensory organ that reports information about self-motion during flight.

68.5 SANFORD , C. P. J.*; DAY, S. ; KONOW, N.; Hofstra University, Hempstead NY, Rochester Institute of Technology, Rochester NY, Johns Hopkins Medical Institute, Baltimore MD; *christopher.p.sanford@hofstra.edu*

The Role of Mouth Shape on the Hydrodynamics of Suction Feeding in Fishes

One of the key events in the evolution of fishes was the decoupling of the maxillary bone from the skull resulting in a highly mobile maxilla. It has been suggested that this maxillary mobility resulted in increased suction feeding performance by allowing the flow of water entering the mouth to be more anteriorly directed. Using DPIV the hydrodynamics of suction feeding in the bowfin (*Amia*) was examined prior to, and following maxillary immobilization in an effort to empirically test this assertion. We show that when the maxilla is immobilized (i.e. the mouth opening is wedge shaped rather than circular) the strike is initiated when the prey is closer to the predator. Also, maximum suction pressure is less, and occurred earlier following maxillary immobilization. Finally, Maximum gape is larger and there is an increase in duration of significant fluid flow when the maxilla is immobilized. However, there is no difference in the area of significant fluid flow or fluid speed in front of the mouth. This work suggests that there are important hydrodynamic consequences of mouth shape that can be compensated for by changes in behavior. Supported by the NSF (IOS#0444891, DBI#0420440).

12.3 SANGER, TJ*; MAHLER, DL; LOSOS, JB; ABZHANOV, A; Harvard Univeristy; *tsanger@oeb.harvard.edu*

The evolution of developmental patterns in the Anolis skeleton

One of the major challenges in modern biology is elucidating both the ultimate and proximate mechanisms of adaptive phenotypic evolution. Caribbean *Anolis* lizards exhibit numerous morphological specializations that are well understood in their ecological and phylogenetic contexts, making them an ideal group to examine the developmental and molecular mechanisms that underlie morphological divergence. We have begun a series of studies to more thoroughly assess skeletal variation among *Anolis* habitat specialists and examine its developmental bases. We are primarily interested in studying variation in cranial and limb proportions among the trunk-crown and trunk-ground habitat specialists. Trunk-ground anoles, which live primarily on broad substrates, have relatively long limbs and a short snout compared the trunk-crown anoles living higher in the canopy on narrower perches. A preliminary phylogentic reconstruction of *Anolis* skull evolution indicates that the face and cranium have evolved independently suggestive of developmental modularity, but also potentially indicating a complex selective history. An allometric analysis of the developing skeleton for eight species indicates that the facial region of the skull and long bones diverge at the earliest stages of morphogenesis further indicating that a change in skeletal patterning may have occurred during the divergence of these habitat specialists. Variation in skull depth and width appears to have a more complex pattern of allometric growth. Using *A. carolinensis* and *A. sagrei* as model species we have also begun examining the expression patterns of several candidate genes known to be involved in skeletal development. To conclude we summarize these expression patterns and discuss their potential roles in the divergence of anole morphology.

4.1 SANTANA, S.E.*; DUMONT, E.R.; University of Massachusetts Amherst; *ssantana@bio.umass.edu*

Connecting performance and behavior: the evolution of bite performance and biting behavior in bats

Morphological variation is usually regarded as determinant of differences in performance, behavior and ecology within and among species. The interaction between behavior and performance is a neglected part of this ecomorphological paradigm that could also affect ecological diversification. Here we used bats (Chiroptera, Phyllostomidae) as a model system to investigate the relationship between performance, behavior, and ecology. We studied the patterns of evolution and tested for correlations between bite performance and biting behavior among 20 species of bats with differing diets, and we reconstructed ancestral states for biting behavior and its plasticity. Our results indicated that although behavior possessed a strong phylogenetic signal, performance did not. Most variables exhibited accelerating evolution over time, and the rapid evolution of performance and behavior coincided with major dietary shifts from insect-feeding to plant-feeding. The evolution of bite performance and biting behavior were not correlated. However, bats modulated their performance by significantly changing their biting behavior to maximize bite force while feeding on hard foods. These results indicate a complex relationship between performance and behavior in this system. The ancestor of phyllostomids was likely a generalist characterized by high plasticity in biting behavior, a condition that later evolved secondarily in specialized frugivores and potentially contributed to their diversification.

84.6 SANTHANAKRISHNAN, Arvind*; MILLER, Laura ; DICKSON, William; DICKINSON, Michael; UNC Chapel Hill, California Institute of Technology, California Institute of Technology; *asant0@email.unc.edu*

Aerodynamics of Small Insect Flight and the Role of Bristled Wings

The lift production in the flapping flight of fruit flies at Reynolds numbers of approximately 120 has been attributed to the generation of a stable leading edge vortex that remains attached during the entire stroke of its motion cycle (see Birch et al., J. Exp. Biol., 2004). Little is known, however, about the aerodynamics of flight in the smallest flying insects such as haplothrips (Re~10). Furthermore, these insects have been observed to use bristled wings as opposed to rigid wings. In this presentation, we consider Reynolds numbers from 1 to 80. We used quantitative experimental flow field and force measurements on a dynamically scaled model with angles of attack varying from 0 to 90 degrees. The effect of having bristles on the flow field is examined and compared to that of an equivalent rigid wing. The three-dimensional kinematics of the actual insect flight is simplified herein, and the motion of the wing in pure translation (middle of a stroke) and rotation are considered. In the context of vortex dynamics, two interesting regimes are observed in the flow field: a stable leading edge vortex and a detached trailing edge vortex at the higher end of Re, and attached leading and trailing edge vortices in the lower end of Re. The implications of these flow field regimes in relation to the lift production and the biological limit of flying insects will be presented.

35.1 SANTINI, F*; CARNEVALE, G; HARMON, LJ; ALFARO, ME; Univ. of California, Los Angeles, Univ. of Pisa, Univ. of Idaho; *santini@eeb.ucla.edu*

Explaining patterns of diversity within ray-finned fish

Using a large molecular timescale we present the first systematic study of the patters of diversity of ray-finned fish, and explore the potential paleobiological, biogeographical and ecological causes of such patterns. Our study indicates that the crown teleosts, which originated ~200 MY ago, experienced a significant shift in diversification rates compared to non-teleost actinopterygians. This shift coincides with, and might have been linked to, the occurrence of the fish specific genome duplication. Further shifts in diversification rates occurred subsequently in the ancestors of the two largest teleost clades: the ostariophysans, a group almost exclusively confined to freshwater that originated ~ 150 MY ago; and the percomorphs, a predominantly marine group that originated ~120 MY ago and subsequently diversified mostly in tropical ecosystems during the past 50 MY. Within these two clades we can further identify a number of species-rich and species-poor lineages. The existence of some of these species-poor lineages may be explained by the ecological niches they occupy (e.g., benthic deep sea environments), while in other cases (e.g., boarfish or john dories) it might be due to high extinction rates, as shown by the fossil record. Similarly, the high diversity of some other lineages might be linked to the appearance of new types of environments (e.g., coral reefs, where diverse clades such as gobies, blennies and wrasses radiated) or geographical areas where these lineages could diversify (e.g., the Amazonian basin, where a significant percentage of the diversity of ostariophysan fishes is located). We will also investigate the role that major extinction events, such as the KT, may have played in shaping the present diversity of teleost fishes.

60.9 SAPIR, N.*; NATHAN, R.; WIKELSKI, M.; The Hebrew University of Jerusalem, Max Planck Institute for Ornithology; *nir.sapir@mail.huji.ac.il*

Heart-rates of European bee-eaters migrating over southern Israel

One of the major challenges in the study of long-distance bird migration is the quantification of bird behavior and energetics during both stopover and cross-country flight periods. Progress in addressing this challenge is still hampered by scarcity of tools for simultaneously acquiring bird location and energetics en route. During the springs of 2005 and 2006 we trapped eleven 50 g European bee-eaters (*Merops apiaster*) migrating over southern Israel and attached them with a 1-g continuously-emitting transmitter that was frequency modulated by heart and flight muscle potentials. The birds stayed in the area for 0.5 to 9 days before departing during daytime for cross-country flights of up to 220 km, during which their heart-beat and wing-flap rates were recorded by two vehicle-mounted telemetry systems. Bird behavior during tracking was documented by direct observations and was corroborated by the wing-flap signal, the null-reception pattern and telemetry bird movement measurements. We found that wing-flap rate was significantly lower during stopover flights comprised of continuous flaps compared with cross-country flap-pause flights. Heart-beat rate during stopover powered flights was 10 % higher but statistically indistinguishable from powered cross-country flights, and was 2.6 times higher than resting heart-beat rate. Heart-beat rate during resting was statistically indistinguishable from both stopover and cross-country soaring flights. Our results suggest that, as expected, powered flight is much more energetically demanding than soaring flight. Surprisingly, soaring flight in this species seem to be associated with particularly low heart-beat rate compared with other, much larger, soaring bird species.

33.2 SATTERLIE, Richard; University of North Carolina Wilmington; *satterlier@uncw.edu*

Two Types of Mechanoreceptors in the Wings of a Pteropod Mollusc

Two types of surface mechanoreceptors have been identified in the wings of the pteropod mollusc *Clione limacina*, based on immunohistochemical, electron microscopical and electrophysiological evidence. The first type includes primary sensory cells with central cell bodies in the pedal ganglia. They are immunoreactive to an antibody against *Aplysia* sensorin. The second type include peripheral cells with cell bodies immediately under the wing epithelium. These cells presumably connect with identified second-order sensory neurons of the pedal ganglia. Serial section electron microscopy of sensory processes (with 3-D reconstructions) confirms the dual origin of the epithelial processes, both of which consist of ciliary cone projections from the epithelial surface. Both primary and second-order mechanoreceptor neurons are involved in the wing retraction reflex as well as a lower-threshold swim acceleration based on peripheral modulation of the wing swim musculature.

44.6 SCALES, J A*; KING, A A; BUTLER, M A; University of Hawaii, Manoa, University of Michigan; *jscales@hawaii.edu*

Evolution of fiber type composition in a lizard locomotor muscle

Locomotion has often served as a model system for adaptive evolution. Many studies have examined how morphology, especially limb proportions, is shaped by different locomotor demands. However, few studies have examined muscle properties such as fiber-type composition, although its importance has always been assumed. Here we explicitly test whether fiber-type composition of a locomotor muscle (the iliofibularis) is adaptive for the behavior of lizards by testing various evolutionary models based on the predator escape and foraging strategies of lizards. An adaptive model based on predator escape strategies provided the best explanation for the evolution of fast-twitch fiber types. Lizards that depend on sprints to avoid predators should have high relative proportions of fast glycolytic fibers, while cryptic lizards should have high relative proportions of fast oxidative glycolytic fibers. This pattern suggests a trend in evolution toward muscles composed largely of one fast-twitch fiber-type associated with behavioral specialization. The best-fitting models for slow-twitch fiber type composition were a single global optimum suggesting a general selective pressure across these lizard species, or a Brownian motion model, suggesting some support for neutral evolution. These data provide evidence that different fiber-types within the same muscle may evolve under different evolutionary pressures.

20.1 SCHILLING, N.*; CARRIER, D.R.; Friedrich-Schiller-University, Jena, University of Utah, Salt Lake City; *nadja.schilling@uni-jena.de*

Function of the epaxial muscles during trotting

In mammals, the epaxial muscles are believed to stabilize the trunk during walking and trotting because the timing of their activity is not appropriate to produce bending of the trunk. To test whether this is indeed the case, we recorded the activity of the m. multifidus lumborum and the m. longissimus thoracis et lumborum at three different sites along the trunk (T13, L3, L6) as we manipulated the moments acting on the trunk and the pelvis in dogs trotting on a treadmill. Confirming results of previous studies, both muscles exhibited a biphasic and bilateral activity. The higher burst was associated with the second half of ipsilateral hindlimb stance phase, the smaller burst occurred during the second half of ipsilateral hindlimb swing phase. The asymmetry was noticeably larger in the larger in the m. longissimus thoracis et lumborum than in the m. multifidus lumborum. Although our manipulations of the inertia of the trunk produced results that are consistent with previous studies indicating that the epaxial muscles stabilize the trunk against accelerations in the sagittal plane, the response of the epaxial muscles to manipulations of trunk inertia were small compared to their response when moments produced by the extrinsic muscles of the hindlimb were manipulated. Our results indicate that the multifidus and longissimus muscles primarily stabilize the pelvis against 1) vertical components of hindlimb retractor muscles and 2) horizontal components of the hindlimb protractor and retractor muscles. Consistent with this, stronger effects of the manipulations were observed in the posterior sampling sites.

11.11 SCHMIDT, Victor*; MCCARTNEY, Michael; UNC, Wilmington ; *vts7867@uncw.edu*

Sexual Conflict and the Development of Gamete Incompatibility in the Blue Mussel

The blue mussel genus *Mytilus* contains four species with a rich biogeographic history typified by secondary contact and hybridization. In the Canadian Maritimes hybrid zone a strong yet incomplete block to fertilization exists between *M. edulis* and *M. trossulus*, which still permits high levels of hybridization and gene introgression. We are evaluating two main hypotheses for the development of incompatibility between these two species; the first states that cross species fertilizations lead to unfit hybrids, and thus selection to prevent hybridization (reinforcement) favors the evolution of gamete incompatibility. Results from cross population fertilizations (allopatric versus sympatric) so far indicate that this pattern does not hold. An alternative hypothesis is provided by sexual conflict as follows. Sperm competition should select for fast-fertilizing sperm, while eggs will evolve barriers to multiple sperm fertilizing an egg (polyspermy). This form of sexual conflict within species may coincidentally promote the evolution of blocks to fertilization between species. This process can operate without secondary contact and may explain cross species fertilization blocks found in allopatric females. For this hypothesis to hold true, females showing strong resistance to polyspermy (within species) must also show strong incompatibility with heterospecific sperm (between species) and vise versa. This relationship is currently under investigation using *M. edulis* females from Cobscook Bay, Maine, which show broad variation in the concentration of *M. trossulus* sperm required to fertilize 20% of their eggs(F20). These females were crossed with both homo and heterospecific males. Each female was scored for resistance to heterospecific fertilization by estimating F20, and for polyspermy resistance by calculating the concentration of sperm required to induce multiple sperm entry in 50% of eggs.

S10.2 SCHOECH, Stephan J; Univ of Memphis, TN; *sschoech@memphis.edu*

Food supplementation experiments: A tool to reveal mechanisms that mediate timing of reproduction

Food supplementation studies of free-living animals have been used to address the role of resource availability in timing reproduction. A meta-analysis by Schoech and Hahn (2008) suggests that responsiveness to the supplementary cue of food is lessened at higher latitudes, with the assumption that the brief time during which conditions are appropriate to rear offspring has led to an evolved reliance on photoperiod. Unfortunately, little experimental work has examined potential underlying mechanisms to mediate this differential responsiveness to supplemental food across latitudes. However, considerable research links nutritional state and plasma glucocorticoid levels: both of which can impinge upon the reproductive axis. My labs long-term research on Florida Scrub-Jays shows that suburban birds with access to ad lib supplemental food express early breeding and lessened plasma corticosterone (CORT) levels in comparison to jays in nearby natural habitat. Further, supplementation in natural habitat advances laying, with the effects generally being the greatest in bad years (i. e., years defined by late breeding and poor reproductive output by nonsupplemented controls). Similarly, reproductive output of supplemented jays is greater and exhibits considerably less variance than controls, suggesting fitness benefits of supplementation that are tied to advanced breeding. Generally, CORT levels in early breeding supplemented jays are lower than those of controls. Also, regression analysis suggests that clutch initiation dates of nonsupplemented female breeders are predicted by baseline CORT levels. Although these data are not conclusive and trends can be obscured by year-effects, they suggest a role for corticosterone in timing of breeding. Whether this link might help to explain the above referenced latitudinal trends remains to be seen.

91.6 SCHORR, R.A.*; FLORANT, G.L.; Colorado State University; *robert.schorr@colostate.edu*

Do polyunsaturated fatty acids play a role in mammalian hibernator overwinter survival?

Prior to hibernation, mammalian hibernators typically increase dietary polyunsaturated fatty acid (PUFA), which alters PUFA composition in a variety of tissues. This change can have a profound effect on a hibernator's ability to prepare for and reduce energy costs during hibernation. In particular, increased PUFA content can increase torpor bout length, decrease body temperature, and reduce the rate of body mass loss. These obvious benefits to a hibernator have led us to hypothesize that increased PUFA content prior to hibernation will increase overwinter survival for the hibernator. Currently, there is little empirical evidence that supports the theory that increased acquisition and accumulation of PUFAs leads to a greater probability of survival. We used four years of mark-recapture data from a meadow jumping mice (*Zapus hudsonius*) population in central Colorado and modeled overwinter survival probability using individual serum fatty acid composition. Survival models were analyzed in Program MARK using the robust design model. Compared to post-hibernating mice, pre-hibernating mice had increased serum arachidonic acid serum levels. Most other serum fatty acids showed little seasonal changes in relative composition; however -linolenic acid (ALA) was an important predictor of overwinter survival. Using ALA content to predict overwinter survival suggested that increasing ALA by 1% increased overwinter survival by 63%. From our findings we concluded that seasonal changes in relative PUFA levels may not be as important as the availability of particular fatty acids for season-specific needs. The role ALA plays in increasing overwinter survival has not been established, but this fatty acid has been implicated as one of the essential fatty acids invaluable for maintaining low body temperature and decreasing body mass loss.

93.2 SCHULTHEIS, K.F.*; ROSENGAUS, R.B.; BULMER, M.S.; Northeastern University, Towson University; *schultheis.k@neu.edu*

Symbiont-mediated immunocompetence in the dampwood termite (Zootermopsis angusticollis)

Termites have a long co-evolutionary history with prokaryotic and/or eukaryotic gut microbes. The interaction with the eukaryotic protozoa has been historically considered critical in the nutritional welfare of lower termites. We hypothesized that, in addition to their nutritional role, hindgut symbionts may provide some benefit to their hosts immunologically. Specifically, we propose that the presence of flagellated protozoa in the hindgut of termites have antifungal properties. A series of experiments conducted on the dampwood termite *Zootermopsis angusticollis* tested whether gut extracts of faunated and defaunated individuals influence viability of *Metarhizium anisopliae* conidia to the same extent. Nymphs were defaunated by exposure to pressurized oxygen, which eliminates the protozoa community while still retaining most of the bacterial symbionts. Extracts of guts from defaunated insects were incubated with fungal conidia and colony forming units (CFUs) were quantified and compared to those conidia incubated with extracts of faunated control (pressurized only) counterparts. Our results indicate that conidia viability is significantly less when incubated with extracts of faunated guts then when incubated with extracts of defaunated guts. *In vivo* studies testing the effect of gut protozoa on the susceptibility to fungal infection are underway. We predict that defaunated termites should be more susceptible to mycosis than faunated control nestmates. These data would support the hypothesis that gut symbionts of termites play a role in the hosts immunocompetence.

87.1 SCHULTZ, Eric T.*; BLOB, Richard W.; PTACEK, Margaret B.; University of Connecticut, Clemson University; *eric.schultz@uconn.edu*

Copulation kinematics in Poecilia, a genus of livebearing fish

Copulatory organs evolve rapidly in response to diverse selective pressures affecting survival and mating success. In livebearer fishes (subfamily Poeciliinae), intromission of sperm is accomplished with the gonopodium, a modified anal fin. Gonopodium length evolves in concert with mating behavior, but this association varies at different taxonomic levels. In the mollies (genus *Poecilia*), unlike at the family level, the gonopodium is 10% longer in species that copulate following courtship than in species that copulate without courtship. Furthermore, gonopodium length varies hypoallometrically in every species; the gonopodium is one-third of the body length in small males but only one-fifth of the body length in large males. In an effort to clarify the functional consequences of these morphological patterns, we are quantifying both intra- and interspecific variability in copulatory kinematics. Using high speed digital videography at 500 frames per second, we have recorded the copulation attempts of five species of mollies, including a range of male sizes within each species. We focused on the speed with which the gonopodium is moved in a circumduction, from resting to the angle of intromission. Circumduction speed is predicted to vary with the size of the gonopodium, its musculoskeletal base, and with mating behavior. Circumductions are expected to occur at slower speeds in species with courtship, and in smaller individuals with relatively longer gonopodia. Our tests of these hypotheses contribute to reconstructing the evolutionary history of copulatory organ form in a functional context.

4.3 SCHWANZ, Lisa E*; BRISSON, Dustin; GOMES-SOLECKI, Maria; OSTFELD, Richard S; Cary Institute of Ecosystem Studies, University of Pennsylvania, New York Medical College; *schwanzl@ecostudies.org*

The impact of the spirochete Borrelia burgdorferi on white-footed mice: implications for the ecology of Lyme disease

Parasitic infection can have diverse direct and indirect effects on host phenotype. The implications of such effects are magnified for zoonotic diseases, where changes in an animal hosts immunocompetence and intra- or interspecific interactions lead to altered disease ecology and may cascade into altered risk of human disease. Lyme disease infects thousands of people in northeastern US every year and is caused by the spirochete *Borrelia burgdorferi*. The bacterium is transmitted by blacklegged ticks that have fed on infected small mammals. In particular, white-footed mice are known to be important components of the disease ecology of *B. burgdorferi*. Using an oral vaccine against *B. burgdorferi* mixed with bait and placed in live-traps, we immunized three field populations of white-footed mice against the pathogen within a Lyme-disease-endemic zone. We examined the influence of *B. burgdorferi* on white-footed mouse immune function, pathogen diversity, activity levels, and foraging behavior. We discuss the results with respect to the evolutionary ecology of host response and the community ecology of disease.

56.1 SCHWARTZ, M.L.*; NORENBURG, J.L.; Seattle University, WA, Smithsonian Insitution, Washington, DC; *norenburgj@si.edu*

Molecular phylogenetics and taxonomy of pilidiophoran nemerteans: tackling a can of worms.

Pilidiophoran taxonomy is based on *ad hoc* morphological character combinations and perceptions of taxa by experts, and it has taken, until recently, only very limited advantage of objective phylogenetic methods. More than half of the approximate 420 species in the group are allocated to three mega-genera; the remainder to about 80 mostly monotypic genera. Here we present the most comprehensive phylogenetic hypotheses of pilidiophoran relationships to date, based on 76 taxa, sequence data for three genes, and more than 100 morphological characters. Pilidiophora is monophyletic, with several well-supported clades, including clades of the genera *Baseodiscus* and *Notospermus*, a clade of orange-capped worms, and a small clade of traditional *Cerebratulus* species. However, relationships between stable clades remain problematic, because branching pattern and intermediate nodes are not well resolved. It is not surprising that morphology is one source of conflict, but molecular data also have been surprisingly inconsistent. Phylogenies derived from 16S rDNA and COI data partitions are poorly resolved and do not recover clades that are well supported in other analyses. However, the partition-addition-bootstrap-alteration (PABA) approach reinforced the usefulness of multiple data sets; two or more data partitions always substantially increased overall phylogenetic signal and resolution. These results provide ample evidence that pilidiophoran taxonomy poorly reflects ancestry and that the three mega-genera urgently need revision.

8.1 SEARS, Michael W.; Southern Illinois University; *msears@zoology.siu.edu*

Implications of habitat selection and dispersal for the responses of small ectotherms to climate change

During the next several decades, animals will need to adapt to rising global temperatures. Though many correlational models predict that animals will track climates over geographical space, such results hinge on the assumption that there are no barriers to dispersal that prevent animals from reaching these new habitats. This assumption is most likely violated for small terrestrial animals because of their susceptibility to small scale fluctuations in environmental temperatures. Recent modeling efforts in my lab have shown how the thermal preferences and physiological performance of individuals interact with physical characteristics of the landscape to give rise to patterns of activity for small lizards. Here, I use similar models to show how a population of eastern fence lizards (*Sceloporus undulatus*) in NM might respond to predicted increases in air temperature under climate change scenarios, assuming no evolution of thermal preferences or physiological capacities. With respect to physical space, as operative temperatures rise above the preferred range of temperatures for activity, suitable patches of habitat become less abundant and more isolated from one another. With respect to time, in mid-summer, warmer temperatures during midday along with earlier and later periods of daily activity, promote higher energetic expenditures without similar gains in opportunity for foraging. Further, temperatures suitable for activity begin earlier and end later during the year, creating higher annual energetic requirements. The compound stresses of habitat fragmentation and isolation along with higher energetic demands present obstacles for population persistence that aren't directly addressed by correlational models. Further, results presented here question the robustness of predictions from models that do not examine landscape processes at scales relevant to the biology of individual organisms.

22.2 SEARS, K.E.; University of Illinois; *ksears@life.uiuc.edu*
Covariation, disparity and constraints in marsupial and eutherian limb evolution
Marsupial newborns complete a life-or-death crawl to the teat, powered solely by their forelimbs. As a result, marsupial fore- and hind limbs have disparate functional requirements early in development. In contrast, eutherians develop largely in utero, and neither limb has early functional requirements. I hypothesize that the highly disparate functional requirements on marsupial fore- and hind limbs reduced their evolutionary covariation relative to eutherians. Reduced covariation is generally thought to increase evolvability, but I hypothesize that the increased modularity of marsupial limbs facilitated the specialization of the forelimb for the crawl, thereby constraining its further evolution. To test these hypotheses, I quantified the limb skeletons of a diverse selection of marsupial (n=72) and eutherian (n=126) species, and analyzed among-species covariance, correlation and disparity. All mammals exhibit higher evolutionary covariance among elements of individual limbs than between fore- and hind limbs. However, as hypothesized, marsupials display markedly less covariation between fore- and hind limbs than eutherians. A principal components analysis generated a forelimb morphospace (MS), which is consistent with the existence of a marsupial forelimb constraint. Although analogous marsupial and eutherian functional groups (FGs) (e.g., arboreal quadrupeds) fall in similar MS areas, the marsupial FGs are always significantly less divergent from the overall centroid than their eutherian counterparts. Therefore, the forelimbs of all marsupials are more similar, and relatively less specialized. Accordingly, the average correlation between marsupial FGs is higher than that between analogous marsupial and eutherian FGs, while the among eutherian FG average is lower.

100.9 SECOR, Stephen M.*; LIGNOT, Jean-Herve; University of Alabama, CNRS, DEPE, Strasbourg; *ssecor@biology.as.ua.edu*
Impact of meal fat content on the postprandial responses of the Burmese python
Prey vary significantly in body fat as a function of season and the availability and composition of their diet. Largely unknown is the impact that meal fat content has on postprandial metabolism and gastrointestinal performance. We assessed the effects of meal fat on the metabolic, morphological, and physiological responses of Burmese pythons (*Python molurus*). Pythons responded to rodent meals (25% of body mass) of 5, 10, and 20% body fat by increasing oxygen consumption rates that peaked at 12.8, 15.0, and 11.8-fold of standard metabolic rates, respectively. Specific dynamic action was significantly greater for the 20% fat meals compared to the 5 and 10% fat meals. Passage from the stomach was slower for the 20% fat meals, such that by day 4 of digestion 48% of the 20% fat meals remained in the stomach compared to 12% of the 10% fat meals. Meals 5% body fat induced no postfeeding change in small intestinal mass, whereas the small intestine more than doubled in mass for the 20% fat meals. Fat droplets were absent from small intestinal enterocytes for the 5% fat meals, present in the anterior half of the intestine for the 10% fat meals, and found throughout the small intestine for the 20% fat meals. Microvilli were noticeably longer for the 5% fat meals compare to the other meals. Ventricular mass increased by 25-30% for the 5 and 10% fat meals and by 50% for the 20% fat meals. Kidney mass increased by 60, 75, and 100% for the 5, 10, and 20% fat meals, respectively. Small intestine nutrient uptake rates, although averaging higher for the 5% fat meals, did not significantly differ among diets. Due to differences in small intestinal mass, intestinal uptake capacities of amino acids was significant less for the 5% fat meals compared to the 20% fat meals. For the python, high fat content of their diet slows digestion and impacts intestinal morphology and function.

86.6 SEIPEL, Justin E*; FULL, Robert J; Univ. of California, Berkeley; *jseipel@berkeley.edu*
How Center-of-Mass Dynamics of Hexapedal Locomotion Collapses to a Single Leg Template Model
Many running animals and some robots produce similar center-of-mass motions and force patterns, like a pogo-stick. We found that the simplest pogo-stick template models explain steady-state motion, but identified a need to explain the robust response to perturbations common in animal locomotion and compliant-legged robots. Spring-Loaded Inverted Pendulum models driven by a Clock with the capability of Torque generation at the hip (CT-SLIP) appear sufficient to explain perturbed center-of-mass behavior in cockroaches and the hexapedal robot, RHex. Using formal mathematical reduction and supporting experimental data, we show how the dynamics of a cockroach's tripod support are effectively reduced to a single virtual leg CT-SLIP model. A sagittal plane model of the tripod support of the cockroach is formalized as a set of Euler-Lagrange equations of motion. Similarly, equations are found for the single leg CT-SLIP. We analyzed the tripod and single-leg systems local responses to perturbations along identical steady-gaits by calculating respective Jacobians. We found that despite apparent structural differences in the equations of motion, the two systems have similar dynamic responses to perturbations. This result shows how tripod-stance dynamics can be represented by a single virtual leg and offers theoretical proof of effective simplification or collapse of dimensions in complex systems. This approach demonstrates how such templates could lead to effective strategies that simplify control. This effort contributes to the methodology of "templates and anchors," for modeling complex systems including animals, robots, and other devices, as well as enabling design of both controllers and whole systems.

48.3 SENSENIG, Andrew T.*; AGNARSSON, Ingi; BLACKLEDGE, Todd A.; University of Akron; *a_sensenig@yahoo.com*
Co-evolution of silk material properties with spider webs
Silk fibers spun by spiders perform varied and numerous roles, but have been studied most intensively in the context of prey capture in webs. Orb-weaving spiders produce several types of specialized silk that differ in material properties, and are adapted to specific roles within orb webs. While fiber breaking force, total energy absorption (toughness), elastic energy absorption (loss modulus), and stiffness are known to depend on the particular role of the fiber within a web, they may also depend on details of web architecture that vary across species, such as web size, the spacing of supporting radial threads, or the width between rows of sticky silk. Thus, silk material properties may have both ecological and phylogenetic constraints on their evolution. We examine this question in the context of a large survey of orb-weaving spiders within the family Araneidae, in which web architecture has undergone several independent transformations between high and low fiber density webs.

50.3 SFORMO, T*; KOHL, F; MCINTYRE, J; KERR, P; DUMAN, J; BARNES, B; Univ. Alaska Fairbanks, California Department of Food and Agriculture, Univ. of Notre Dame; *rfts@uaf.edu*

Simultaneous freeze tolerance and avoidance in individual fungus gnats, Exechia nugatoria

Freeze tolerance and freeze avoidance are described as mutually exclusive strategies in overwintering animals. We describe an insect species that combines both strategies under winter field conditions. The fungus gnat *Exechia nugatoria* (Diptera: Mycetophilidae), collected in Fairbanks, Alaska, displays two freezing events when cooled to -50C; they survive the first but not the second freezing event. To determine which body compartments froze, we dissected the abdomen from the thorax and cooled the parts separately. Results indicate a significant difference between abdominal and head/thoracic freezing. The abdomen froze at -30C, and gnats showed 70% survival. The head/thorax froze at -50C, and gnats showed 100% mortality. We suggest that differential freezing and subsequent survival is accomplished by regional dehydration that prevents inoculative freezing between the frozen abdomen and the supercooled thorax. NSF 0618436

BERN.1 SHARP, PJ; EDINBURGH UNIVERSITY; *peter.sharp@roslin.ed.ac.uk*

VERTEBRATE PHOTOPERIODIC SIGNALLING

Photoperiodic time measurement is achieved through a hypothalamic pacemaker that generates a circadian rhythm of photoinducibilty. Coincidence of light and the photoinducible phase of this rhythm stimulates expression of TSH beta in pars tuberalis cells that results in a local increase in TSH in the adjacent medial basal hypothalamus (MBH). This in turn stimulates local metabolism of T4 to T3 in MBH tanycytes. Photoinduced increase in T3 in the MBH may both regulate neuropeptide release into the hypophysial portal vasculature by modulating the plasticity of tanycyte endfeet, and regulate efferent pathways to areas of the hypothalamus synthesizing photoperiodically- regulated neuropeptides. The pars tuberalis TSH beta- T4/T3 tanycyte photoperiodic signalling pathway occurs both in birds, and in long and short day-breeding mammals. It is activated by long days irrespective of whether the animal is reproductively photosensitive or photorefractory. Mammals differ from lower vertebrates in dependence on circulating pineal melatonin signalling for transducing photoperiodic information to pars tuberalis melatonin receptors. Whilst mammals use photoreceptors in their eyes to monitor the presence of light for photoperiodic signalling, birds use extra retinal photoreceptors. The identity of the pathway through which photoperiodic signalling is detected by the avian pars tuberalis is uncertain since circulating melatonin does not control photoperiodically-regulated avian gonadal cycles. However, melatonin appears to be generated locally within the avian MBH in photoresponsive dopaminergic neurones, raising the possibility in birds that photoperiodic signalling within the MBH is transduced by circadian- gated changes in local concentrations of melatonin.

41.1 SHIELDS, Jeffrey D.*; MILLER, Terrence L.; BOYKO, Christopher B.; VIMS, Molloy College, NY; *jeff@vims.edu*

A First Look at the Phylogeny of the Entoniscidae

The Entoniscidae are a bizarre group of parasitic Isopoda that live internally within their decapod hosts. They live internally in the hemocoels of their hosts and apparently grow there without molting. Because of their endoparasitism, the entoniscids are cryptic species with only 37 species described in 16 genera. The family exhibits high host specificity, typically at the host species level but also at the host genus and family level. Females of the species have few defining characters but males and larval stages often possess distintictive characters on which to base an initial examination of their phylogeny. We analyzed the phylogeny of the Entoniscidae using female and male characters, and juvenile characters where known. Outgroups consisted of members of the Bopyridae and the Dajidae. The phylogenetic analysis also included the bopyrid genus *Entophilus* as it is the only endoparasitic bopyrid and may align more closely with the Entoniscidae.

56.2 SHIELDS, C. C.*; MARKO, P. B.; WOODS, H. A.; MORAN, A. L.; Clemson Univ., Univ. of Montana; *shields@clemson.edu*

Nudibranch diversity in the Ross Sea, Antarctica: Theyre cold, but are they old?

The Southern Ocean (SO) surrounding Antarctica is extremely cold and geographically isolated. The phylogenetic affinities of only a few SO taxa, e.g. the notothenioid fish, have been examined in detail; in these, a high degree of endemism and radiation within the SO has been established using molecular phylogenetic methods. We used Bayesian inference to construct a phylogenetic tree of nudibranch molluscs based on cytochrome-c oxidase (COI) mtDNA. Sequence data includes 56 specimens collected on SCUBA over two seasons in McMurdo Sound, Antarctica, 49 species collected in the NE Pacific and New Zealand, and 153 sequences from GenBank. We found surprisingly broad taxonomic diversity within the Nudibranchia of the Ross Sea. The tree topology shows 15 lineages (>22% divergent from the nearest sequence in the tree) of Antarctic nudibranchs. Nine of these lineages contain single taxa that split from their closest non-Antarctic relative in the phylogeny between 38 and 63 million years ago (using COI divergence rate of 1% per million years). Although our tree contains few non-Antarctic species from the southern hemisphere, these data are consistent with an old and phylogenetically diverse Antarctic nudibranch fauna that predates isolation of the SO by the Antarctic Circumpolar Current. The remaining Antarctic lineages form two monophyletic clades (split from temperate relatives 38 and 42 mya) that apparently diversified within the SO. In order to construct a more robust two-gene phylogenetic tree that gives better resolution at deeper nodes, we are in the process of combining 18S ribosomal DNA sequence data with the COI data.

59.1 SHIPLEY, Lisa A.*; FORBEY, Jennifer; Washington State University, Boise State University; *shipley@wsu.edu*

Revisiting the niche: when is a mammalian herbivore a specialist?

Although dietary specialization is considered rare in mammalian herbivores, examining the causes and consequences of the breadth of their feeding niche is critical for understanding selective pressures in diet and habitat selection, herbivory and coevolution. However, criteria for defining mammals as specialists has remained ambiguous and inconsistent. Unlike many phytophagous insects, no mammal is an absolute monophage. Therefore, placing mammals on a continuum from specialist to generalist, rather than assigning them to strict categories, allows ecologists to gain a comparative understanding about feeding strategies. Dietary specialization has been defined either by the fundamental niche (the range of nutritional tolerances in the absence of extrinsic pressures), or by the realized niche (the diet consumed in the natural habitat). The first approach may suffer from artificiality of lab conditions, and the second from known and stochastic variability in nature. As classically defined, specialists have a narrower realized niche than do generalists, but may have a larger fundamental niche because they may be able to tolerate a wider range of conditions along one niche axis (e.g., a specific plant toxin). Defining feeding specializations has also suffered from inconsistencies in the level of organization of both the diet and the herbivore (e.g., plant part, individual, population or species). In fact, many mammals are specialized to a functional aspect of plant food such as chemistry or architecture, rather than the plants taxonomy. A mammals feeding niche may also be defined and maintained by morphological and physiological adaptations or learned and inherited behavior. Current and longterm distribution of resources and strategies of competitors are key shapers of feeding strategies employed by mammals.

33.5 SHIRGAONKAR, Anup A; CURET, Oscar M; PATANKAR, Neelesh A; MACIVER, Malcolm A*; Northwestern University; *maciver@northwestern.edu*

How ribbon-fin swimmers swim

What is the propulsion mechanism for fish with elongated ribbon-like fins, such as weakly electric gymnotiform fish, the African *Gymnarchus niloticus*, and others? We combine computational fluid dynamics and digital particle image velocimetry to uncover the principle of thrust generation for an idealized ribbon fin with sinusoidal deformation kinematics. We show that the primary mechanism of thrust production is the generation of a streamwise central jet and associated attached vortex rings. We derive scaling relationships for how thrust varies with various kinematic and structural parameters. We also show that in addition to surge force (parallel to the long axis of the fin), the fin can generate heave thrust (perpendicular to the long axis of the fin). The magnitude of the heave force increases with the ratio of the wavelength of the traveling wave along the fin to the length of the fin. For typical knifefish fin geometries, this crossover point is around 1.5. Thus the ribbon-fin confers the ability to generate thrust in multiple directions according to how many traveling waves the fish places on the fin. Our results will be useful for understanding the neural basis of control in the weakly electric knifefish and other aquatic animals that use similar propulsors, as well as for engineering bio-inspired vehicles with undulatory thrusters.

75.3 SIEG, A*; OCONNOR, M; AGOSTA, S; MCNAIR, J; GRANT, B; DUNHAM, A; Drexel Univ, Univ of Pennsylvania, Academy of Natural Sciences, Widener Univ, Univ of Pennsylvania; *aes48@drexel.edu*

Orthogonal Regression and Phylogenetic Correction Applied to Mammalian Metabolic Allometry

A contentious issue in metabolic ecology is the slope of the relationship between body size and metabolic rate. Slopes in metabolic allometry are often estimated via ordinary least squares regression (OLS) without considering trait variation and error variance in the independent variable. Allometric exponent estimation is also often performed without reference to phylogeny. We apply an orthogonal regression technique with variance-oriented residuals (LSVOR) to estimate the mammalian basal metabolic rate (BMR) allometric exponent. This regression technique is less biased than OLS when both physiological variables have random variation. We culled BMRs from the literature. Our database includes all available multiple unique measurements of body mass and BMR for each of 680 mammal species. To phylogenetically correct the data, we used the fullest available mammal phylogeny (Bininda-Emonds 2007). We estimate the slope of mammal metabolic allometry with and without phylogenetic correction and outliers and use re-sampling to generate confidence intervals. Analysis of 440 species yields a distribution of slope estimates that, with phylogenetic correction, does not include 0.75. Without phylogenetic correction or removal of outliers, the OLS slope=0.69 (0.66-0.72) and LSVOR=0.73 (0.70-0.75). With phylogenetic correction and removal of outliers, the OLS slope=0.73 (0.72-0.74) and LSVOR=0.77 (0.76-0.78). Our technique and our rich dataset allow us to control for issues currently confounding physiological allometry: the preponderance of certain clades (e.g. rodents) in mammal data and performing regressions on two variables with differing error variances.

104.2 SIMON, M.A.*; SMITH, D.; TRIMMER, B.A.; Tufts University, Medford, MA; *michael.simon@tufts.edu*

Visualizing internal structural movements during soft-bodied crawling using phase-contrast X-ray microvideography

In soft-bodied animals, the movements of internal tissues cannot be isolated from those of muscles involved in locomotion. Furthermore, internal tissue movements may contribute to the kinematics and dynamics of locomotion. In the caterpillar *Manduca sexta*, the gut is anchored at the mouth and anus and is also loosely tethered throughout the abdomen by an extensive array of trachea. Using phase-contrast X-ray microvideography of crawling 5th-instar larvae, we have found that the gut moves asynchronously and in advance of the anteriograde wave of segmental contractions during crawling. We observed similar internal movements using transmitted visible light to illuminate semitransparent hatchlings, which are less than one-thousandth the mass of fifth-instar larvae. Therefore, we conclude that such internal tissue movements are coupled to locomotion throughout the larval stages. One consequence of this motion is that an animal's body mass will shift forward in its anterior abdominal segments even during those segments' proleg stance phase. Given this information, we are now exploring the potential mechanical role of the gut in storing or dissipating energy during locomotion.

43.4 SIMONS, E. L. R.*; O'CONNOR, P. M.; Ohio Univ, Athens; *er238604@ohio.edu*

Cross-sectional geometry of the forelimb skeleton and flight mode in pelecaniform birds

Pelecaniforms are a group of marine birds that vary greatly in body size, whole wing shape, and flight mode. Members of this clade utilize static (thermal) soaring (*Pelecanus, Fregata*), dynamic soaring (*Morus*), alternating flapping and gliding (*Sula, Phaethon*), and continuous flapping (*Phalacrocorax*). The objectives of this study were to investigate differences in cross-sectional geometry of the three main wing elements in birds that utilize different flight modes. The mid-shaft of the humerus, ulna, and carpometacarpus (CMC) from 16 species (n = 94) were microCT scanned at Ohio University. The following biomechanical parameters were derived for each element: CA/TA, the amount of cortical bone relative to total bone cross-sectional area; Imax/Imin, a shape ratio indicating resistance to bending; and J/L, length-standardized resistance to torsion. Results indicate that static soaring birds (*Pelecanus, Fregata*) exhibit lower CA/TA values in all three elements relative to dynamic soaring birds, flap-gliders, and flapping birds ($p < 0.001$). *Phalacrocorax* and *Anhinga* exhibit the largest CA/TA values, suggesting a possible link to buoyancy reduction. The static and dynamic soaring birds exhibit significantly higher J/L values than either flapping or flap-gliding birds ($p < 0.001$), suggesting a higher resistance to torsional loading. For all flight modes, the CMC exhibits the most elliptically shaped mid-shaft cross-section (high Imax/Imin values), suggesting that this element may be experiencing more bending loads. These results will be discussed in the context of whole wing shape and contrasted with selected procellariiform birds, a distantly related clade of seabirds characterized by a similar range of body sizes and flight modes.

78.2 SINCLAIR, BJ*; RAJAMOHAN, A; Univ. Western Ontario; *bsincla7@uwo.ca*

Plasticity in chilling survival of Drosophila melanogaster larvae

The majority of insects die of chilling injuries unrelated to ice formation, but the processes and plasticity of these injuries are not well-understood. We have been exploring the roles of genetic background, development, dietary manipulation, acclimation, hardening pre-treatments and recovery conditions to build a comprehensive model of the factors maximising chilling survival of *Drosophila melanogaster* larvae. Both genetic background and developmental stage significantly influence chilling tolerance, and interact with long-term acclimation and short-term hardening to influence chilling survival. Certain dietary manipulations can significantly improve cold tolerance, but acclimation is not as effective as short-term hardening at improving cold survival. Combinations of high and low temperature pre-exposure are highly effective at improving cold survival, which hints at mechanisms of chilling injury. Surprisingly, survival of chilling exposure is not enhanced by manipulating recovery conditions.

78.1 SISON-MANGUS, M.P.*; ZACCARDI, G.; KELBER, A.; BRISCOE, A.D.; Univ. of California, Irvine, Lund University, Sweden; *msisonma@uci.edu*

Duplicate UV opsins for co-mimicking Heliconius butterflies

Heliconius erato has tetrachromatic color vision, with the ability to see from the ultraviolet (UV) to the red part of the light spectrum. Red-green color vision in this animal is facilitated by the opponent interaction of two long-wavelength (LW) receptors; one receptor with a LW opsin and another receptor produced by the co-expression of the LW opsin and a non-opsin red filter pigment. Remarkably, we found that besides the LW and blue opsins, the animal also possesses two copies of UV opsins, the first time a duplication of this gene family member has been observed among Lepidoptera. Since the closely-related nymphalid butterflies *Danaus plexippus* (Subfamily Danainae) and *Vanessa cardui* (Subfamily Nymphalinae) only possess a single copy of UV opsin, we investigated the evolutionary origin of this unique opsin duplication. We screened cDNAs for UV opsin duplicates among butterflies from different tribes (Argynini and Heliconini) of the subfamily Heliconiinae and found that the UV opsin duplication is only seen among *Heliconius* species. Phylogenetic reconstruction of the lepidopteran UV opsin family shows the monophyletic grouping of *Heliconius* UV opsins suggesting that the duplication occurred prior to the speciation of *Heliconius* butterflies. In addition, a relative rates test indicates that the two opsin duplicates are not evolving at an equal rate, hinting that the two copies may have diversified functionally.

59.6 SKOPEC, MM*; NEBEKER, C; DEARING, MD; Weber State University, University of Utah; *micheleskopec@weber.edu*

Catechol-O-methyl transferase may play an important role in allowing Neotoma stephensi to specialize on juniper

Dietary specialization is thought to be rare in mammalian herbivores because of limitations of their detoxification system in processing large doses of a single type of plant secondary compound. One species of woodrats, *Neotoma stephensi*, specializes on juniper (*Juniperus monosperma*) and therefore, must efficiently biotransform the terpenes present in juniper. Based on a previous study, we hypothesized that catechol-O-methyl transferase (COMT) is a candidate enzyme critical for biotransformation of terpenes found in juniper. COMT is a conjugation enzyme that conjugates a methyl group to its substrate; the loss of a methyl group as a conjugate may be less energetically costly than glucose or amino acid conjugates used by other conjugation enzymes. We measured the protein expression of COMT using western blots in N. stephensi fed either a 70% juniper diet or a terpene-free diet. We found that N. stephensi fed the 70% juniper diet had 2.5x the amount of COMT as the N. stephensi fed the terpene free diet ($F_{1,6}$=17.928 p=0.005). Increased levels of COMT may be an adaptation that allows N. stephensi to use conjugation over functionalization. Conjugation enzymes have broader substrate acceptability and produce less reactive metabolites. COMT in particular does not result in the loss of a high energy conjugate like glucose or an amino acid.

90.2 SLATER, G.J.; Univ. of California, Los Angeles; *gslater@ucla.edu*
Quantifying the Influence of Allometry on Mechanical Performance: A Study of the Evolution of Felid Cranial Form
Skull form within a lineage often varies allometrically, but the impacts of this shape variation on performance are rarely quantified. The skulls of large and small felids are shaped very differently. Big cats have relatively elongate facial skeletons and reduced neurocrania relative to small cats. Given their elongate rostra, large cat skulls are expected to exhibit increased bending moments and reduce strength in torsion. Here, I use Finite Element Analysis (FEA) of three cat skulls, spanning the full range of body sizes and skull shapes, to test the mechanical implications of skull shape allometry. FE models were analyzed using a newly developed scaling method that allows more accurate determination of the impacts of shape on performance. Large cats produced relatively lower bite forces than small cats, but these differences were small and empirical bite force estimates generally follow expectations of geometric similarity. Nevertheless, despite their longer rostra, large cats had stronger and more mechanically efficient skulls than small cats during both bilateral and unilateral canine biting. Large cats achieve this efficiency, in part, by increasing skull bone volume relative to surface area, i.e. they have thicker skulls. Thus, allometry of external skull form in big cats appears to be driven more by the need to increase gape to kill larger prey, rather than a need to produce and resist greater absolute bite forces and the unpredictable loads from large struggling prey. To compensate for the latter, big cats evolve thicker skulls despite possible trade-offs in increased mass and metabolic costs.

75.4 SMIT, B.; MCKECHNIE, A.E.*; Univ. of Pretoria; *aemckechnie@zoology.up.ac.za*
Avian seasonal metabolic adjustments in a southern subtropical desert: winter down-regulation of basal metabolic rate
One of the major patterns of phenotypic flexibility in avian basal metabolic rate (BMR) consists of seasonal adjustments. At present, the vast majority of data is from species inhabiting temperate and boreal latitudes in the northern Hemisphere, with BMR typically up-regulated during winter. We measured summer and winter BMR in the field for five species resident year-round in the Kalahari Desert of southern Africa, and found that BMR was generally lower in winter compared to summer. Mass-specific BMR was significantly lower in winter in three diurnal species, the Crimson-breasted Shrike (*Laniarius atrococcineus*; 29%), Fork-tailed Drongo (*Dicrurus adsimilis*; 35%) and White-browed Sparrow-weaver (*Plocepasser mahali*; 17%), and in a crepuscular species, the Pearl-spotted Owlet (*Glaucidium gnoma*, 30%). In contrast, the nocturnal African Scops-owl (*Otus senegalensis*) did not show any significant seasonal variation in mass-specific BMR, but significantly reduced body mass, and thus total BMR, in winter. The limited data currently available on avian seasonal metabolic adjustments suggest that whereas northern Hemisphere species generally up-regulate BMR in winter, the opposite is true in the southern Hemisphere. However, north-south comparisons are complicated by differences in body mass and absolute latitude, and more data are required before global patterns can reliably be identified. Nevertheless, our data reveal a dichotomy in the direction of seasonal adjustments in avian BMR, and raise the possibility that in some cases such adjustments are related to reductions in winter energy requirements, rather than enhanced cold tolerance.

S7.5 SMITH, A. M.*; BLOOM, A.; GARCIA, S.; Ithaca College, NY; *asmith@ithaca.edu*
Multiple cross-linking mechanisms in molluscan adhesive gels
Some terrestrial slugs produce remarkably sticky and elastic gels as defensive secretions. Previous work on these gels has shown that metals play a central role in their cross-linking. The transition metals iron and zinc are common in these gels, as are calcium and magnesium. A major question is how these metals cross-link the gel, and whether there is more than one mechanism by which they do so. Chelation of metals with EDTA for an extended time breaks down the mechanical integrity of the gel, thus demonstrating a direct effect of the metals on gel mechanics. Furthermore, metals, particularly calcium, were shown to have a general stiffening effect on commercial gels at the concentrations seen in the glue. Metal removal does not completely break down the gel, however, as size exclusion chromatography experiments show that the major cross-links involve a 40 kDa protein and these are unaffected by metal chelation after the glue sets. If chelation occurs before the glue sets, however, this cross-link does not form either. Measurements of the stiffness of commercial gels with metals and glue proteins added separately and together show that both stiffen gels on their own, but the effect is merely additive; they are not necessarily interdependent. The findings suggest that the mechanical strength of the gel depends in part on metals such as calcium and zinc forming direct cross-links and also on other cross-links involving the 40 kDa protein, which are catalyzed by metals before the glue sets.

7.5 SMITH, Kevin G.*; LIPS, Karen R.; CHASE, Jonathan M.; Washington Univ. in St. Louis, Southern Illinois Univ., Carbondale; *kgs@wustl.edu*
Epidemic disease homogenizes amphibian communities
The modern biodiversity crisis is characterized by an unprecedented loss of species, owing to threats such as habitat loss, global change, and emerging pathogens. If these threats cause local extinctions nonrandomly across communities, then among-community biotic distinctiveness, or beta diversity, will be lost. This underappreciated loss of diversity, known as biotic homogenization, can rob ecosystems of important functions and disproportionately affect regional diversity such that regional extinctions outnumber local extirpations. Here, we show that a pathogenic agent of global amphibian decline, Batrachochytrium dendrobatidis (Bd), homogenizes diverse tropical American amphibian communities by causing nonrandom extinctions resulting in a dramatic loss of beta diversity. Prior to the appearance of Bd, amphibian communities had high beta diversity owing to the presence of many endemic species, and thus were less similar than would be expected by chance. Following invasion by Bd, the nonrandom loss of endemic species resulted in significantly reduced beta diversity, such that amphibian communities became more similar than expected if loss of species were random. Furthermore, post-decline community similarity was no longer structured by geographic distance, indicating that presence of Bd now drives patterns of amphibian biodiversity and overrides historical biogeographic determinants of community composition and diversity. Our results suggest that threats such as Bd can act as powerful ecological filters at the local scale, reducing biodiversity to homogenized relict assemblages of threat-tolerant species and causing concomitant biodiversity loss at regional and global scales.

61.5 SMITH III, Julian P.S.*; EGGER, Bernhard ; TYLER, Seth; LADURNER, Peter; ACHATZ, Johannes; MERLIE, Sara; Winthrop University, University of Innsbruck, University of Maine, University of Maine; *smithj@winthrop.edu*

Neoblasts in Nemertodermatida

Our current understanding of the stem-cell (neoblast) system in Platyhelminthes comes primarily from a wealth of experiments on regeneration in the Tricladida, supplemented by recent studies of, e.g., the macrostomorph *Macrostomum lignano* and the acoel *Isodiametra pulchra*. To date, there are no comprehensive studies of the neoblast system in the potentially more primitive Nemertodermatida. Accordingly, we have carried out preliminary S-phase (BrdU and EdU) and M-phase (anti-phosphoH3) labeling experiments in *Flagellophora cf apelti*, *Sterreria cf psammicola*, and *Nemertinoides elongatus*, supplementing these light-microscopic histochemical studies with electron microscopy. We have found neoblast populations in all three species, and interestingly, both *Sterreria* and *Nemertinoides* appear to have neoblasts in the epidermis, a feature unknown in triclads, macrostomorphs, polyclads, or acoels, but long known to be true of the catenulid flatworms. Comparison of our results with similar studies from other lophotrochozoans shows that annelids and nemertines possess epidermal stem cells and suggests that the presence of epidermal neoblasts may constitute the plesiomorphic state in the Platyhelminthes, whereas Acoela and Rhabditophora both generate new epidermis instead through inwandering of neoblasts from the parenchyma.

36.3 SOCKMAN, K.W.*; SALVANTE, K.G.; Univ. of North Carolina, Chapel Hill; *kws@unc.edu*

How Song Competition Changes the Brain and Behavior of a Male Songbird

If male advertisement signals attract females because the signals reflect some aspect of the male's quality, then incidental receivers, such as eavesdropping males, also should glean information about the quality of these competitors and should adjust their behavior and its neural substrates accordingly. In European starlings (*Sturnus vulgaris*), females base mate choice, in part, on the length of a male's song, which positively correlates with his reproductive success, immunocompetence, and age. We periodically exposed male starlings to either long songs or short songs over 7 days and followed this by 1 day of no song. We previously reported that males exposed to long songs sing more than males exposed to short songs do. This raises questions about how the brain integrates information about the song environment and modulates song effort accordingly. Serotonin has well-known modulatory effects on auditory processing. In songbirds, a discrete network of forebrain vocal-control nuclei regulate song production, learning, and plasticity. We now report that, compared to males exposed to short songs, those exposed to long songs had greater serotonin secretion in the auditory telencephalon, which itself was positively correlated with song effort, and had a 30% larger vocal-control nucleus RA (robust nucleus of the arcopallium), even when we statistically controlled for total song-count. These findings raise the hypothesis that competition-induced serotonergic secretion in the auditory telencephalon modulates input to the vocal-control nuclei, which, in turn, modulate behavioral responses to song competition.

91.11 SOKOLOVA, I.M.; University of North Carolina at Charlotte; *isokolov@uncc.edu*

Surviving global change in polluted environments: Metal-temperature interactions in metabolic physiology of a marine ectotherm

The thermal environment plays a key role in the distribution of marine ectotherms through the direct effects on their physiology and indirectly affecting their susceptibility to other stressors. Our studies show that exposure to a trace metal, cadmium (Cd) sensitizes eastern oysters *Crassostrea virginica* to temperature stress, and vice versa. Cd exposure results in a significant increase in metabolic costs of basal maintenance in oysters, mostly due to the elevated costs of protein synthesis and expression of stress proteins. Combined Cd and temperature stresses lead to the reduced aerobic capacity of oysters due to the limitation of oxygen delivery systems, higher Cd sensitivity of mitochondrial function and a decrease in mitochondrial abundance. At moderate temperatures cell protection capacities are sufficient to minimize the negative effect of Cd exposure on oxygen supply systems, and the oxygen supply is sufficient to provide for elevated maintenance costs. With rising temperature, the synergistic effects of elevated temperature and metal exposure on aerobic metabolic machinery on one hand, and elevated costs of basal maintenance on the other, result in progressive hypoxemia and a mismatch between energy demand and supply. As a result, energy-dependent protective mechanisms (e.g., antioxidants, metallothioneins and heat shock proteins) fail leading to elevated mortality and whole-organism physiological stress. Such interactive effects of temperature and pollution stress can have important implications for survival of ectotherms in the face of the global climate change and anthropogenic pollution and must be taken into account in environmental risk assessment. Supported by NSF CAREER (IBN-0347238).

S6.1 SORENSEN-FORBEY, J.S.; Boise State University; *jenniferforbey@boisestate.edu*

Pharmacological principles and approaches for ecologists

Nearly 500 years ago, Paracelsus fathered the field of toxicology by introducing the concept of the dose-response relationship of toxins. He stated that "All substances are poisons; there is none which is not a poison. The right dose differentiates a poison from a remedy". Since then, pharmacologists have sought to understand mechanisms by which toxins, or drugs, are processed such that the right therapeutic dose of a drug could be achieved in patients. Pharmacologists now know that the right dose is largely dependent on the extent to which drugs are *absorbed* across the gut and into cells, *distributed* in the body, *metabolized* by enzymes, and *excreted* from the body. The mechanisms of absorption, distribution, metabolism and excretion are collectively known as ADME. More recently, ecologists have realized that the same ADME mechanisms that define the dose-response relationship of drugs in humans also define the quantity (i.e. dose) of plant secondary metabolites (PSMs) herbivores will consume as well as the behavioral or physiological (i.e. toxicological) consequence of ingested PSMs. I will review the progress ecologists have made by using pharmacological techniques to investigate ADME mechanisms in herbivores. I will also highlight several ADME mechanisms that have not received adequate attention and introduce novel uses of pharmacology that could significantly advance the field of plant-herbivore interactions.

S6.3 SOTKA, Erik E.; College of Charleston; *sotkae@cofc.edu*
The emerging role for pharmacology in understanding marine plant-herbivore interactions
The past 25 years of research on marine plant-herbivore interactions have witnessed remarkable advances in our understanding of the secondary metabolites that marine plants use to protect themselves from being consumed by their herbivores. In contrast, we have virtually no knowledge on the biochemical mechanisms employed by marine herbivores to detoxify secondary metabolites. Arguably, the state of the field is equivalent to that of terrestrial herbivore ecologists in the early 1970s: the marine literature documents profound variation in feeding tolerance among herbivores without a thorough understanding of why this variation exists (ultimate mechanisms) and how this variation exists (proximate mechanisms). Here, I will outline a series of vexing issues in the ecology and evolution of marine plant-herbivore interactions that will likely benefit from a molecular approach to detoxification mechanisms. These issues include: do detoxification rates limit the feeding rates of herbivores and thus their ecological and evolutionary impact on marine ecosystems? Are marine herbivores and plants entangled in a diffuse coevolutionary arms-race? Is the host range of marine herbivores mediated by feeding tolerance for secondary metabolites? Can we predict herbivore diversity-ecosystem function relationships based on the diversity of detoxification mechanisms? I will make the argument that a focus on enzyme-compound interactions will allow us to move beyond a more-traditional approach that simply correlates feeding choices with plant traits. Translating population- and species-level variation in feeding tolerance into variation at the biochemical level represents the next great challenge for marine chemical ecologists and their interdisciplinary collaborators, but should offer tremendous insight into the evolutionary ecology of marine herbivores.

89.2 SOUTH, Adam*; STANGER-HALL, Kathrin; LEWIS, Sara M. ; Tufts University, University of Georgia; *adam.south@tufts.edu*
Evolutionary origins and functions of nuptial gifts in fireflies
During courtship and mating in diverse insect taxa, males provide females with nuptial gifts in the form of captured prey, spermatophores, or body parts. Such nuptial gifts often provide a net benefit to females by increasing lifetime fecundity, although associated fitness costs have also been documented in some species. Nuptial gifts thus play a key role in reproductive physiology, insect mating systems, and sexual selection, yet the distribution of such gifts across related taxa is poorly understood. During mating in several firefly species, males transfer a proteinaceous spermatophore that provides a net fitness benefit to females, while other species lack spermatophores. Additionally, some firefly species exhibit a sexual wing dimorphism in which females are flightless due to a lack or reduction of wings. Many firefly adults are non-feeding, so reproduction depends on resources acquired during larval stages. We hypothesized that lacking a sexual wing dimorphism (females capable of flight) might select for nuptial gifts, based on a higher potential for male-derived nutrients to increase female fecundity. Ancestral trait analysis based on a molecular phylogeny suggests that both nuptial gift production and the absence of sexual wing dimorphism were the ancestral traits in fireflies. In addition, we used Pagels test of correlated character evolution to determine that sexual wing dimorphism is significantly correlated with the loss of nuptial gifts. This is the first phylogeny-based analysis in any insect taxa that has considered the relationship between life history traits and nuptial gift evolution. Our results provide new insight into the selective forces driving the evolution of nuptial gifts and associated sexual behaviors.

67.3 SPAGNA, J.C.*; PATEK, S.N.; SUAREZ, A.V.; William Paterson University, Univ. of California, Berkeley, Univ. of Illinois, Urbana-Champaign; *SpagnaJ@wpunj.edu*
Polymorphic trap-jaws: intra- and interspecific scaling of jaw forces in trap-jaw ants
Trap-jaw ants exhibit a remarkable range of mandible morphology from short and robust to elongate and spiny. One fundamental issue in this system is whether this variation is primarily caused by developmental or evolutionary factors. In one case, sisters in the trap-jaw ant species *Odontomachus cephalotes* exhibit within-colony variation in body and mandible size that exceeds cross-species differences in many other trap-jaw ants in this genus. Here, we measure size variation, acceleration, and modeled force generation within *O. cephalotes*, then compare this to size and strike force to model predictions derived from seven monomorphic trap-jaw ant species. Across a size range covering 92% of the range of 7 monomorphic species, *O. cephalotes* workers mandible length was negatively allometric relative to body length (mean slope 0.79, 95% CI 0.59-0.99), while mandible mass was positively allometric by mandible length (mean slope 4.38, 95% CI 3.88-4.90). The relatively short, massive jaws of the larger *O. cephalotes* workers contrasted with interspecific scalings, which were isometric. From these results, *O. cephalotes* largest workers should produce mandibular forces similar to those of large monomorphic species (~100mN), but at smaller sizes, *O. cephalotes* workers should strike with about twice as much force as similarly-sized species (60 mN vs. 30 mN). The lower variation found in the polymorphic species suggests that interspecific differences in strike forces are influenced by evolutionary as well as developmental factors.

25.10 SPEISER, D.I.*; JOHNSEN, S.; Duke Univ.; *dis4@duke.edu*
The optics and evolution of scallop eyes
Scallops can possess upwards of one hundred eyes along their valve margins. These eyes contain two distinct retinas and form images by the reflection of light off a concave spherical mirror. It is thought that focused light falls on only one of the two retinas and that the scallop lens corrects for spherical aberration caused by the mirror. Here, we report the results of a comparative study of scallop eye morphology conducted using confocal microscopy and optical modeling software. Via antibody stains for tropomyosin we have identified muscle fibers surrounding the scallop eye. The presence of these fibers suggests that the scallop eye may be a dynamic structure that can alternately focus light on either retina through small changes in its shape controlled by muscular contraction and relaxation. Contrary to expectation, we also found that some scallop species, such as *Argopecten irradians* and *Chlamys hastata*, have a lens with a spherical front curvature that does little to correct for spherical aberration. However, we found that other species, such as *Amusium balloti* and *Placopecten magellenicus*, have a lens with a hyperbolic front curvature that does help correct for spherical aberration and nearly doubles the spatial resolution potentially provided by the eye. Studying scallop eyes in a phylogenetic context reveals that these corrective lenses may have evolved at least twice in Pectinoidea, in the subfamilies Pectininae and Palliolinae, and that their appearances may coincide with the evolution of improved swimming ability within these clades. A positive correlation between scallop swimming ability and visual acuity is further supported by evidence that swimming scallops have eyes with smaller inter-receptor angles than those of non-swimmers, with values ranging from 1, for the eyes of the highly mobile *Amusium balloti*, to 4, for those of the sessile *Spondylus americanus*.

38.2 SPONBERG, S.*; MONGEAU, J.M.; MILLER, J.P.; FULL, R.J.; Univ. of CA, Berkeley, Montana St. Univ.; *sponberg@berkeley.edu*

Decoding Cockroach Antennal Tactile Navigation Using Naturalistic and White Noise Stimuli in a Control Theoretic Framework

Control theoretic models for stabilization and navigation behaviors provide a framework for generating hypotheses of sensory encoding. Cockroaches demonstrate remarkable tactile tracking abilities using antennae to preview surfaces during high-speed wall following in low-light environments. A simple control model suggests a control strategy relying on proportional and derivative information of wall distance. Bulk recordings of all mechanoreceptive units in the flagellum of the cockroachs antenna are consistent with this model showing phasic and tonic components in the envelope neural response. However, it remains unclear if explicit velocity- and position-dependent signals from antennal deflection are encoded in the individual mechanoreceptors and if they are appropriately tuned to match stable wall-following. Here we record small numbers of individual units via (*en passant*), suction electrode recordings of the antennal nerve within the head of the cockroach (*Periplaneta americana*). The antenna flagellum is driven with a speaker to evoke naturalistic and band-limited white noise responses in antennal position. Recordings from both stimuli reveal derivative and position dependent firing. Activity across the population of mechanoreceptors shows a temporally filtered response that matches the time course of response kinematics, but is composed of differential responses in component mechanoreceptors. We integrate these results with a more anchored version of the earlier control theoretic model, incorporating within-stride lateral plane dynamics. This approach reveals sufficient encoding for stable wall-following and suggests that significant processing occurs at the primary mechanoreceptive afferents.

9.3 SPRAGUE, R.S.*; SPRAGUE, J.C.; BREUNER, C.W.; University of Montana, Missoula; *rachel.sprague@umontana.edu*

Glucocorticoid physiology during incubation fasts in Laysan Albatross

Laysan Albatross undergo repeated 2-3 week fasts throughout incubation, during which they can drop 25% of their body mass. It is known that during short, unpredictable fasts, glucocorticoid stress hormones (corticosterone in birds: CORT) rise as body mass declines. However, it is not clear whether the relationship between CORT and body mass holds during long-term, predictable fasting. Given that elevated CORT levels are associated with nest abandonment, species with repeated, long fasts during incubation may delay or depress the secretion of CORT to preserve their reproductive effort. We monitored body mass, CORT, and, for the first time, corticosteroid binding globulin (CBG), during incubation fasts over the entire incubation period in Laysan Albatross *(Phoebastria immutabilis)*. As expected, body mass declined both within fasts and over the season. At the same time, total CORT increased both within individual incubation shifts and over the season. As supported by many other studies, baseline CORT was negatively correlated with body mass. CBG did not significantly change as the incubation season progressed, though it increased during individual incubation fasts and was positively correlated with total CORT: as mass declined during fasts, total CORT levels and CBG capacity both increased. This contradicts previous studies that have shown decreases in CBG capacity with falling body mass. In summary, we found that CORT secretion does increase during long, repeated fasts in this species, though CBG may also rise to protect the reproductive attempt from the inhibitory effects of CORT on parental behavior.

97.5 SPRAGUE, J. C.*; SMITH, J. N.; WOODS, H. A.; Univ. Montana; *jonathan1.sprague@umontana.edu*

Waiting to Exhale: Tracheal Air-filling in Embryos of Manduca sexta

Insects exchange gases via branching tubes called trachea, which are air filled in larvae, pupae, and adults. In embryos, by contrast, tracheae are liquid filled and therefore nonfunctional. The transition from liquid- to air-filled tracheal tubes is a key event in ontogeny, but how it happens is unclear. Wigglesworth argued that air filling is a consequence of fluid absorption by tracheoles, which either draws outside air into the embryo or ruptures fluid inside the tracheal system. Here we describe a complementary mechanism in embryos of *Manduca sexta*. Time-lapse videos show that embryonic tracheal systems undergo rapid air filling about of the way through development. Air bubbles originate in sub-spiracular spaces, probably by nucleating onto increasingly hydrophobic tracheal cuticle. The bubbles expand rapidly (< a few seconds) to fill local tracheal trees and longitudinal branches between spiracles. Using several manipulative experiments, we show that expansion is driven in part by spring-like deformation of the eggshell. In turn, eggshell deformation is driven by earlier water loss. This mechanism couples local microenvironments around eggs to a key event in ontogeny, tracheal air-filling. Functionally, air filling in the embryonic stage may prepare the tracheal system for gas exchange during hatching or in the larval stage. Alternatively, it may have a respiratory function in the embryo itself. We are currently testing these alternatives by measuring metabolic performance of embryos during respiratory challenges.

72.3 STAAB, KL*; HERNANDEZ, LP; George Washington University; *kstaab@gwmail.gwu.edu*

Kinethmoid-Mediated Premaxillary Protrusion: Development of a Complex Trait Provides Clues to Its Evolution

Studies on the evolution of complex biological systems are difficult since their construction cannot be observed over an evolutionary timescale. Complex traits are defined as consisting of multiple elements, often of differing embryological origins, and with multiple linkages that are integrated to form a single functional unit. Developmental studies can show how these units are assembled within individuals, offering clues as to how the trait might have been constructed on an evolutionary timescale. The zebrafish possesses an upper jaw mechanism characterized by significant upper jaw protrusion during feeding. The zebrafish effects premaxillary protrusion via the kinethmoid, a synapomorphy for the order Cypriniformes. The kinethmoid is a sesamoid ossification that is entirely suspended by ligaments to the premaxillae, maxillae, palatines, and neurocranium. Upon mouth opening, the kinethmoid flips on its end as the premaxillae move anteriorly. Along with the bony and ligamentous elements, there are three divisions of the adductor mandibulae complex that render this system functional. We investigated the development of this complex protrusible upper jaw in the zebrafish to generate hypotheses regarding the evolution of this character. Early in development the adductor mandibulae muscle arises as a single unit. The muscle begins to divide after the ossification of the maxillae, on which the A1 division will ultimately insert. The kinethmoid originates as a cartilage within the ligament uniting the two maxillae; it later ossifies at the points of ligamentous attachments. We combine these structural developmental data with functional kinematic data at similar developmental stages which, along with outgroup comparison, has led to hypotheses about how this complex biological system evolved.

36.5 STAATERMAN, Erica R.*; CLAVERIE, Thomas; PATEK, Sheila N.; Univ. of California, Berkeley; *estaaterman@berkeley.edu*

Antipredator startle signal of the California spiny lobster (Panulirus interruptus)

Acoustic antipredator signals are ubiquitous, yet we have little understanding of their effectiveness and behavioral deployment specifically in the marine environment. Some prey produce warning signals to prevent attack from predators, while others use acoustic signals to startle a predator after the attack has begun. We examined the antipredator rasp sound generated by the California spiny lobster (*Panulirus interruptus*). Using a pole apparatus equipped with a low-light camera and hydrophone, we presented either a model fish (predator), model lobster (conspecific), or pole (control) to spiny lobsters at Santa Catalina Island, during the day and night, in the field and in controlled tank conditions. In addition, we hand-held lobsters at varying distances from a hydrophone and measured the attenuation of the rasp sound. The behavioral trials showed that when the intruder did not touch the lobsters, they rasped in only 18% of the trials, whereas they rasped in 56% of the trials when there was contact ($X^2=10.8$, df=1, $p=0.001$). Physical contact and behavioral response were also significantly correlated; lobsters exhibited a tail flip escape response in 95% of the physical contact trials ($X^2=47.7$, df=3, $p<0.001$). The intruder type and direction of approach had no significant effect on lobster behavior or rasping. In the acoustic tests, the average dB level of the rasp relative to the background noise ranged from 1.8 dB at 50 cm to 1.0 dB at 200 cm; thus, the sounds attenuate minimally and remain obscured within the loud background noise. Both the acoustic and behavioral results indicate that the spiny lobster rasp is likely to be used in close range to startle attacking predators.

8.2 STAHLSCHMIDT, ZR*; DENARDO, DF; Arizona State Univ. - Tempe; *zs@asu.edu*

Implications of egg-brooding induced hypoxia on the development and quality of offspring in Children's pythons (Antaresia childreni)

Python egg-brooding typifies parental care in that it consists of multiple behaviors that provide for multiple developmental needs. For example, tightly coiling around the eggs benefits embryonic water balance but females periodically adjust their posture to improve embryonic gas exchange. Regardless of these postural adjustments, egg-brooding creates a hypoxic intra-clutch environment which constrains embryonic metabolism. We further examined the impact(s) of brooding-induced hypoxia to determine 1) any fitness-related costs to offspring, and 2) whether any long-term costs are alleviated by periodic postural adjustments. We artificially incubated clutches of Childrens pythons (*Antaresia childreni*) at optimal temperature (i.e., 31.5C) and humidity (i.e., near saturation), but modulated oxygen partial pressure (PO_2) to create three treatments: normoxic (i.e., 20.3 kPa O_2), brooding (i.e., PO_2 profile typical of clutch PO_2 (PO_2clutch) in maternally brooded clutches), and low (i.e., predicted PO_2 profile of maternally brooded PO_2clutch if females did not make postural adjustments). We made serial morphometric and performance measurements during incubation (X = 47 d), at hatching, and at 14 d post-hatching. From incubation day 35 to 14 d post-hatching, normoxic offspring were larger, faster, and stronger than those incubated in either hypoxic condition demonstrating that brooding-induced hypoxia confers significant fitness-related costs to offspring. Since we detected no differences between the two hypoxic conditions, postural adjustments may not alleviate hypoxia-related costs to embryos. Our results demonstrate that even a parental behavior critical to offspring survival may represent a compromise between competing developmental needs and thus entails obligate costs.

62.3 STANTON, Daniel L*; SMITH III, Julian PS; Winthrop University; *stantond2@winthrop.edu*

The Role of Melatonin in the Cellular Processes in the suppression of Asexual Reproduction in Stenostomum virginianum (Platyhelminthes, Catenulida)

Melatonin is a naturally occurring hormone responsible for diurnal activity in organisms ranging from single-celled algae to humans. We found that a 0.1mM concentration of exogenously applied melatonin suppressed asexual fissioning in Stenostomum virginianum ($p<0.05$). These results are consistent with data from triclad flatworms. At present, it is unclear how melatonin suppresses asexual reproduction. The suppression may be caused by a down-regulation of mitosis, an up-regulation of apoptosis, or by a combination of the two. We have examined the effect of melatonin on the mitotic rate of S. virginianum. Preliminary data show that exogenously applied melatonin does not appear to inhibit mitosis. We will present data on the effects of melatonin on apoptosis. Further research will allow for a better understanding of how melatonin affects the cellular cycle and influences biological activities in an organism. (Supported by funds from the Winthrop University Research Council)

29.3 STEVENSON, T/J*; BERNARD, D/J; BALL, G/F; Johns Hopkins University, McGill University; *tsteve13@jhu.edu*

Photic and non-photic regulation of GnRH-I in male European Starlings (Sturnus vulgaris).

In many temperate zone avian species, the vernal increase in photoperiod is the initial predictive cue that triggers a cascade of events leading to a shift in neuroendocrine state. In several photoperiodic species, changes in gonadotropin releasing-hormone-I (GnRH-I) secretion are primarily responsible for the seasonal variation in gonadotropin release from the pituitary gland and sex steroid synthesis. We recently cloned and characterized the GnRH-I cDNAs in two songbird species. This breakthrough permitted, for the first time, an analysis of GnRH-I mRNA expression in the brains of seasonally breeding European starlings (Sturnus vulgaris). We observed that GnRH-I mRNA exhibits marked variation across reproductive states with greatest expression observed in photostimulated males. GnRH-I mRNA levels gradually decrease to lower levels in photorefractory males, paralleling the observed pattern of testicular involution. These findings contrast data demonstrating that the decrease in GnRH-I protein occurs after testis regression. In addition to photoperiodic cues, social cues fine-tune the timing of reproduction. We recently found that male starlings paired with females have a greater number of GnRH-I immunoreactive (-ir) cells compared to males housed alone. Furthermore, the increase in GnRH-I-ir cells was localized in the rostral-intermediate region of the preoptic area. These data show for the first time that photoperiod-induced changes in reproductive physiology in starlings are associated with alterations in GnRH-I mRNA expression. Moreover, the GnRH-I system is directly regulated by social cues. Future studies will determine whether the latter similarly reflects a change in GnRH-I gene expression.

96.3 STEWART, J.R.*; ECAY, T.W.; HEULIN, B.; East TN State Univ, Station Biologique de Paimpont; *stewarjr@etsu.edu*

Calcium Provision to Embryos of the Reproductively Bimodal Lizard, Lacerta vivipara

Squamate reptiles provide opportunity to study the relationship between reproductive mode and pattern of embryonic nutrition because viviparity has evolved in numerous lineages and some species, such as *L. vivipara*, exhibit geographic variation in reproductive mode. Alternative hypotheses predict that either: 1) the evolution of viviparity precedes the evolution of placentotrophy, or 2) the evolution of placentotrophy is concurrent with the evolution of viviparity. Embryos of oviparous squamates typically obtain calcium from both yolk and eggshell, whereas embryos of viviparous squamates receive calcium from yolk and placenta. We compared the ontogeny of calcium content of yolks, embryos and eggshells of an oviparous and a viviparous population of *L. vivipara* to test the hypothesis that embryonic calcium mobilization of oviparous and viviparous populations does not differ. Oviposited eggs of oviparous females have heavily calcified shells (1.23 mg Ca^{++}) relative to calcium in yolk (0.17 mg Ca^{++}) and embryonic utilization of shell calcium exceeds that of other oviparous squamates. Hatchlings contain 0.9 mg Ca^{++}; 0.73 mg of which is extracted from the shell. Yolk calcium content of eggs of viviparous females does not differ from that of oviparous females, but viviparous eggs lack highly calcified shells. However, viviparous females retain the capacity for uterine calcium secretion and placental transfer is among the highest recorded for squamates, accounting for 75% of neonatal calcium. The substantial reliance on uterine calcium secretion in this lineage suggests that viviparity evolved in tandem with a concomitant shift to placental calcium provision. Supported by a grant from the NSF (IOB-0615695).

34.2 STEWART, T.A.*; ALBERTSON, R.C.; Syracuse University; *tastew01@syr.edu*

The Evolution, Development, and Genetics of Jaw Asymmetry in Lake Tanganyika Scale Eating Cichlids

Perissodus microlepis, Perissodus straeleni, and Perissodus paradoxus are cichlid fishes native to Lake Tanganyika in central Africa, which forage through lepidophagy, or scale-feeding. Each species is laterally asymmetrical, their heads tending towards either the left or right side of the sagittal plane. These are the most derived species within the Perissodini tribe; their highly specialized morphologies are derived from generalist deepwater predators. Geometric morphometric shape analysis of craniofacial structures was performed to describe both their anatomical basis and the origin of these asymmetries within the Perissodini tribe. Biomechanical models of the oral jawsimple-lever and four-bar linkage modelsindicate that scale eating cichlids show discrete, sided differences in jaw shape, and that these differences predict lateralization in the force and speed of jaw rotation. Morphometric analysis of larval P. microlepis indicates that laterality is determined early in development, before feeding occurs, suggesting a genetic basis for handedness. Furthermore, QTL mapping in Malawi cichlids has identified a single locus of major effect for jaw laterality. We intend to examine the association between this locus and jaw handedness in Lake Tanganyikan scale eaters. Nature is replete with examples of craniofacial asymmetries (i.e., narwals, owls, flatfish), and many human birth defects are characterized by asymmetric craniofacial malformations (hemifacial microsomia, Treacher-Collins syndrome, hemihypertrophy). Studying the evolution of laterality in Perissodus and ultimately identifying the genetic factors that contribute to the asymmetric development of skeletal structures will shed light on the evolutionary and clinical consequences of vertebrate laterality.

99.6 STILBORN, S.S.M*; MANZON, L.A.; SCHAUENBERG, J.D.; MANZON, R.G.; Univ. of Regina, Biology; *stilborn@uregina.ca*

Expression of Sea Lamprey, Petromyzon marinus, Deiodinase Type II Throughout Metamorphosis and Following a Thyroid Challenge.

Thyroid hormones (TH) are crucial for major developmental events in all vertebrates studied to date. Most notable is their involvement in vertebrate metamorphosis. However, lampreys appear to be an exception; natural and induced metamorphoses seem to require decreased serum TH levels. We isolated a 1.8kb fragment, including the full-length coding region, of the 10-11kb sea lamprey deiodinase type II (D2) mRNA transcript. The predicted amino acid sequence has 47% identity and 60% similarity to human D2 and includes the selenocysteine characteristic of selenoproteins. However, we have yet to identify the selenocysteine insertion sequence (SECIS) in the 3' UTR. Real-time PCR detected D2 mRNA in all tissues examined, including intestine, liver, kidney, and brain. In the intestine, liver, and kidney (included gonad and nephrogenic tissue) D2 mRNA levels were highest in immediately premetamorphic larvae through metamorphic stage-2. Thereafter, transcript levels decreased significantly in stages 3 and 4, and remained low into the parasitic phase. D2 is responsible for cellular activation of TH, thus decreased D2 mRNA levels during metamorphosis is consistent with other data showing thyroid axis suppression coincides with, and/or induces, lamprey metamorphosis. Finally, to determine if lamprey D2 levels are regulated by changes in thyroid status, as is the case in most other vertebrates, larval sea lamprey were treated with 50M T_3 or 200nM T_4 for 3-12-days, or 0.05% $KClO_4$ for 6-24-days. Data on mRNA transcript levels in several tissues will be presented and discussed in the context of the lamprey thyroid axis and its regulation. Funded by NSERC.

S8.4 STOCK, D.W.; University of Colorado, Boulder; *David.Stock@Colorado.edu*

Zebrafish developmental genetics and the mechanisms of dental evolution

Dentition in fishes exhibits enormous diversity in shape, number, and location of individual teeth. The developmental and genetic mechanisms underlying this diversity are just beginning to be characterized through studies in a variety of taxa. My laboratory is carrying out comparative analyses of tooth development focused on the zebrafish, *Danio rerio*, because of the unparalleled genetic, molecular, and embryological tools available for the analysis of its development. One of the most distinctive features of dentition in the zebrafish is its restriction to a single pair of elements of the pharyngeal skeleton, the fifth ceratobranchials. Such dentition is characteristic of the order Cypriniformes, to which the zebrafish belongs, and is the result of evolutionary reduction of tooth-bearing locations. To understand the mechanisms of this reduction, we compared oropharyngeal development of the zebrafish and the characiform Mexican blind cave tetra, *Astyanax mexicanus*. In addition to being among the most closely-related species to the zebrafish retaining oral teeth, *A. mexicanus* is amenable to many of the same manipulations employed in zebrafish developmental genetics. Comparisons of gene expression between these species and mutant analyses in the zebrafish revealed several candidate genes for involvement in cypriniform dentition reduction. Transgenic and pharmacological manipulation of the expression of some of these genes in the zebrafish and *A. mexicanus* produced altered numbers of teeth and tooth cusps. These results provide insight into mechanisms of dentition reduction in cypriniforms and the origins and ontogenetic distribution of multicuspid teeth in fishes.

1.11 STORZ, Brian/L*; HEINRICHS, Jessica; YAZDANI, Arash; PHILLIPS, Ryan/D; MULVEY, Brett/B; ARENDT, Jeff/D; MOERLAND, Timothy/S; TRAVIS, Joseph; Florida State University, Tallahassee, FL, University of California, Riverside, Riverside, CA , Kent State University, Kent, OH; *bstorz@bio.fsu.edu*

Reassessment of the environmental mechanisms controlling developmental polyphenism in spadefoot toad tadpoles part II

Understanding the environmental regulation of polyphenism, the expression of multiple, discrete phenotypes from one genotype, is important for linking the environment to development, the genotype to phenotype, and understanding the evolutionary process. Spadefoot toads can either develop as typical filter-feeding tadpoles (omnivores) or be transformed, in both morphology and behavior, into carnivores that actively prey on microcrustaceans and cannibalize conspecifics. In the most exhaustive analysis to date of the environmental factors potentially regulating spadefoot-toad developmental polyphenism, we used 2 different species, 27 different treatments, and over 1000 tadpoles to re-examine the current model of carnivore environmental induction. Forty-four carnivores were induced in the current study, but these were spread among different temperature, food-type, density, and substrate treatments. Our results suggest that induction of the carnivore phenotype is much more complex than the existing one-cue-one phenotype model presently in the literature.

S8.5 STREELMAN, JT; Georgia Institute of Technology; *todd.streelman@biology.gatech.edu*

Constraint and diversification in the evolutionary development of cichlid dentitions

Closely related cichlid fishes from Lake Malawi exhibit continuously replacing dentitions on two jaws, and dramatic variation in tooth number, tooth size, tooth spacing and tooth shape. We have studied gene networks that organize cichlid dentitions through development. Here, I highlight notable examples of conservation and divergence in gene expression that pattern teeth across jaws and species.

24.4 STROTHER, J.A.; Univ. of California, Irvine; *strother@uci.edu*

The hydrodynamics of gill ventilation in teleost fishes

The gills of teleost fishes have been described as a model counter-current exchanger. The coordinated movements of the buccal cavity and the opercula drive water through the gills in a direction opposite to that of the perfusing blood flow. While counter-current exchange has the potential for very efficient transport, these exchange rates may be compromised by streams of water that pass around the gills (non-respiratory shunting) or by variation in the flow of water through different parts of the gills (flow heterogeneity). To determine how such issues might affect gas exchange, the flow around the gills of a bony fish was measured using particle image velocimetry (PIV). The freshly-excised gill arches of a tilapia (*Oreochromis mossambicus*) were placed in a closely fitting flow-through chamber, and the flow rate and distance between the arches was varied. PIV was used to measure the velocity of water along the trailing edge of the primary lamellae, from which several measures of respiratory efficiency were calculated. We found that, with the observed morphology, non-respiratory shunting and flow heterogeneity remained low. However, as the flow rates or spacing between the gills arches was increased these effects began to compromise respiratory performance. It is possible that such effects impose functional constraints on the rate of ventilation and the morphology of the gills in teleost fishes.

4.5 STUART, Y.E.*; DAPPEN, N.; LOSIN, N.; Harvard University, University of Miami, Univ. of California, Los Angeles; *yestuart@fas.harvard.edu*

Predator response to novel aposematic coloration in a poison dart frog

Aposematism is the use of warning signals by prey to advertise their unprofitability to potential predators. The efficacy of an aposematic signal generally relies on a predator population quickly learning to associate the warning signal with unprofitability of the prey. Hence, it is possible that novel aposematic signals introduced at low levels into a population through mutation or immigration would be eliminated before predators learn to avoid the prey. Moreover, existing aposematic signals should be under stabilizing selection to remain the same. We conducted a field-based experiment at La Selva Biological Station, Costa Rica, to determine how predators respond to a novel, but real, aposematic phenotype of *Dendrobates pumilio*, a poison dart frog from Costa Rica and Panama. We created color clay models of the local La Selva color morph, of a novel but real color morph found only in Panama, and of two non-aposematic control color morphs. We placed the models in the forest and later examined them for signs of predation. We find that aposematic morphs are attacked at the same rate as control morphs, suggesting equal protection afforded by either crypsis or aposematism. However, after using two different methods to control for the disparity in detectability between morphs, we find that given discovery, predators attack the novel aposematic morph less than control morphs, but more than the local aposematic morph. This suggests imperfect stabilizing selection by predators in the La Selva population. If imperfect stabilizing selection is a general trend across the species range, then this mechanism may help explain the evolution of the diverse, aposematically-colored phenotypes found in *D. pumilio*.

S6.5 SULLIVAN, RJ; California State University, Sacramento; and University of California, Davis; *sullivar@csus.edu*

The evolutionary mechanism of action of neurotoxins: punishment or reward?

Humans have not been exempt from plant-herbivore interactions. In an evolutionary timescale, human ancestors (hominids) were dependent primarily on wild plant foods, and thus were no less subject to herbivore offences than other animals. Ecological theory of hominid consumption and exploitation of wild plants anticipates avoidance of, or selective exposure to, plant secondary metabolites (PSMs) because of their harmful effects. The history of plant domestication is, in large part, a process of selective detoxification of wild plants for safe consumption by humans, but this process occurred very recently in evolutionary history. Many animals adaptively exploit PSMs, and research of self-medication by primates has contributed to theories of selective medicinal use of wild plants by hominids as a precursor to modern human drug behaviors. However, evolutionary ecological perspectives that see human interactions with common plant toxins as governed primarily by punishment from herbivore offences, are overshadowed by current neurobiological theories that emphasize reward and reinforcement as the principal dynamic affecting human substance use, including that of commonly-used PSMs like nicotine. My talk will engage with the evolutionary question of how important reward can have been when cast against the ubiquitous selection pressures from toxic PSMs in the wild plants that constituted the foods of our hominid ancestors, and will discuss contradictions between the punishment inherent in herbivore offence mechanisms and the reward emphasized in contemporary neurobiological theories of human drug seeking behavior.

48.6 SUMMERS, A.P.*; GORB, S.; UC Irvine, University of Kiehl; *asummers@uci.edu*

Underwater gecko feet - how clingfish and snailfish adhere to wet surfaces

Clingfishes (Gobiesocidae) and snailfishes (Liparidae) have independently evolved, ventral suction disks that they use to adhere to substrates with unpredictable surface characteristics. Adhesion is completely underwater and appears largely mediated by suction (see Maie et al. this meeting). In both groups of fishes there are regions of the suction disc covered in papillae: in the clingfishes these regions are around the edges of the disk and in the snailfish they are arranged in chevrons in the middle of the disc. Examination of these papillae with cryo and conventional SEM reveals them to be islands of densely packed simple rod like structures 300nm in diameter and 3000-4000nm in length. There is some evidence that that these are hierarchical structures with the small terminal tips emanating from larger rods 3000nm in diameter and 15um long. To test the adhesive properties of these nanostructured arrays we used a microscale material testing system in a chamber filled with artificial seawater. We pressed a sapphire ball into papillae from 4 clingfish and 2 snailfishes and found that the adhesive forces were up to 70% of the force used to press the ball into the papilla. We conclude that, much like the spatulate hairs on the foot of a gecko or insect, these rods are making very close contact with the substrate allowing van der Waals forces to play a role in adhesion. The viscosity of water also pays a role, contributing substantially to adhesions as well.

99.1 SUZUKI, Yuichiro*; SQUIRES, Diego C.; RIDDIFORD, Lynn M.; Wellesley College, Wellesley, MA, University of Washington, Seattle, WA, Janelia Farms, Janelia Farm, Howard Hughes Medical Institute, Ashbrun, VA; *ysuzuki@wellesley.edu*

Distal-less regulates developmental stability in the flour beetle, Tribolium castaneum

Organisms have an amazing capacity to develop normally in the face of environmental and genetic perturbations. The mechanism underlying developmental stability remains elusive. Here we examined the role of *Distal-less* (*Dll*) in mid-larval stages of the flour beetle, *Tribolium castaneum*. We found that removal of *Dll* expression during this period resulted in dramatic unpatterned proliferation and loss of structural integrity and identity of larval appendages, leading to the formation of blastema-like tissues. A large amount of variability in appendage morphology was observed following *Dll* dsRNA injection, unlike larvae injected with *dachshund* dsRNA. These *Dll* dsRNA-injected larvae underwent numerous supernumerary molts, which could be terminated with injection of either *JH methyltransferase* or *Methoprene-tolerant* dsRNA. We suggest that effects of local tissue instability accumulate in the absence of *Dll*, leading to a wound response in the appendages. Thus, *Dll* appears act to maintain developmental stability in the larval appendages. Supported by NIH 2R01 GM60122.

78.5 SUZUKI, Takao*; KURATANI, Shigeru; RIKEN CDB, Japan; *tsuzuki@cdb.riken.jp*

Morphological Integration of Moth Wing Patterns Cryptically Mimicking a Dead Leaf

How animal body parts acquire adaptive patterns through changes in developmental program is a fundamental question of phenotypic evolution. Here, we report morphological integration seen in the moth wing in the evolution of mimesis.

As a model organism, we picked up a nocutuid moth, *Oraesia excavata*, whose forewing is thought to mimic a dead leaf by assuming a part of leaf vein system composed of one main nerve and two lateral veins. Using individuals collected in Mt. Rokko, Hyogo, Japan, we established a breeding system of this species in the laboratory. We measured phenotypic variation and correlation of each wing pattern element with statistical morphometrics, and found that the elements for the dead leaf showed variance several hundreds times lower than those among the others. These results suggested that the leaf pattern had been subjected to a stabilizing selection, to establish a rather invariant developmental patterning resistant to genetic variations. It was also indicated that these function-related characters (one main nerve and two lateral veins) had gained a dense correlation among themselves, strong enough to form a functional module to maintain the shape of a dead leaf. Futhermore, it was revealed that these modularity of wing pattern is not only produced by conserved homologous relationships, but also by novel relationships of pattern elements acquired by integration/percellation. These results suggested that the wing developmental program possess flexibility to create de novo modular architectures for ecological adaptation.

66.2 SWALLA, B.J.; Univ. of Washington; *bjswalla@u.washington.edu*
Development and Evolution of Ptychoderid Hemichordates
Hemichordata are the sister group to Echinodermata, yet share some morphological features with Chordata, including gill slits. Hemichordates contain both solitary enteropneust worms and colonial pterobranchs, but molecular phylogenies suggest that the colonial pterobranchs are a sister group to the direct developing Harrimaniidae, including the saccoglossid worms. We have been investigating the relationships within and between Ptychoderidae, the enteropneust family that includes Glossobalanus, Balanoglossus and Ptychodera. These complex enteropneusts have ciliated feeding larvae, similar to echinoderm larvae. Their metamorphosis converts a planktonic larva into a benthic, burrowing worm. We are identifying external and internal morphological characters that typify the three genera of ptychoderids, in order to construct taxonomic keys for identification of these enteropneust worms. In addition, we following the developmental origins of morphological characters in the larva and following metamorphosis. For example, ptychoderid worms have a complex collar nervous system that contains giant cells, and may or may not contain hollow cavities within it. Ptychoderid enteropneust worms also show increased ability to regenerate anterior structures when amputated, compared to saccoglossid worms. We believe that understanding the developmental origin of specific tissues and structures will allow insight into their possible homologies with chordate characters.

S7.1 SWANSON, B*; ANDERSON, S; Gonzaga University; *swansonb@gonzaga.edu*
Evolution of complex biomaterial performance: the case of spider silk
Biomaterials provide an opportunity to use the staggering diversity, complexity and exceptional properties of natural materials for applications from the biomedical to the military. To these ends, state of the art engineering techniques have been focused on understanding the relationships between biomaterial structure and properties. Concurrently, comparative biologists have recognized that biomaterials are an important component of biodiversity and that biomaterials are integral to the evolution and ecology of the species that produce them. Therefore, biomaterials are examined from multiple points of view and we posit that true understanding of these materials will depend on the integration of engineering and biological techniques and knowledge. An excellent example of a biomaterial for which understanding requires both biological and engineering techniques is spider silk. Silk is essential for a variety of functions in the ecology of the diverse spider clade. It is also a complex biological polymer that exhibits uniquely exceptional toughness by combining high strength and extensibility. I first review our understanding of the functional structure of silk and how recent advances in nanomechanical characterization have improved our understanding of the fiber. I then describe recent research that examines the evolution of silk properties in basal spiders. From these data we can begin to reconstruct the evolution of exceptional properties in this fiber and understand the correlations and constraints on complex biomaterial evolution.

70.2 SWARTZ, SM*; RISKIN, DK; IRIARTE, J; MIDDLETON, KM; BREUER, KS; Brown University, University of Chicago, California State University, San Bernardino; *sharon_swartz@brown.edu*
Scaling of flight characteristics in bats
The more than 1200 living bat species range in body size from 2 g to >1,500 g but share a single pattern of wing architecture: all possess flexible skin membranes supported by elongated digits. We sought to determine how the inertial costs of flight scale with body size among six species differing 45-fold in body mass, selected from the Pteropodidae, a single lineage of bats. Under isometry, the moment of inertia of a wing should scale with body mass$^{5/3}$. If wing kinematics are conserved across species, this would result in an increased inertial power per kilogram body mass for larger bats than for smaller ones. Bats were videographed at 1000 Hz, and the positions of 17 kinematic markers on the body and one wing were resolved in three dimensions. By modeling the wing as a set of 31 topologically linked point masses, we use the high-resolution kinematics to model the dynamics of wing inertia. Wing moment of inertia of a wing changes by as much as 70% during a wingbeat cycle. Both fine-scale kinematics and wingbeat frequency vary systematically with body size, but these two parameters vary inversely in such a manner that mass-specific inertial power during flight is independent of body size. This pattern differs from that observed in terrestrial mammals, and could indicate a fundamental constraint on the design of the bat flight apparatus.

48.2 SWEENEY, AM*; MATZ, MV; MORSE, DE; JOHNSEN, S; University of California, Santa Barbara, University of Texas, Austin, Duke University; *sweeney@lifesci.ucsb.edu*
Patterns of S-crystallin evolution are correlated with optical acuity in cephalopods
Positive selection on surface charge and thermodynamic stability in *Loligo opalescens* lens S-crystallin proteins contributed to the evolution of low refractive index regions in the exterior of the lens. This evolutionary development allowed squid to develop highly acute and sophisticated graded refractive index lenses necessary for good vision underwater. In this study, we simultaneously explored visual acuity and patterns of S-crystallin evolution across cephalopods. We found that an organisms overall optical acuity is reflected in the physical characteristics of S-crystallins expressed in the lens and their patterns of evolution. Octopuses have a small suite of highly similar crystallins, and accordingly, their visual acuity is relatively low. All studied families of decapod squid exhibit the same large suite of S-crystallins and the same pattern of charge evolution previously described in *Loligo*. Accordingly, the decapod squids' optical capabilities are quite similar to each other, and are more acute than those of octopuses. In addition, each squid family's S-crystallin suite appears to be more closely related to itself than to the other squid families' S-crystallins. As a result, we predict that squid S-crystallins have had a history of concerted evolution. We discuss the possibility that concerted evolution may be a mechanism for maintaining S-crystallin monodispersity in the lens, which is necessary for optical function and cataract prevention.

103.3 SWIDERSKI, D.L.*; ZELDITCH, M.L.; Univ. of Michigan, Ann Arbor; *dlswider@umich.edu*

Evolution of jaw size and shape in New World tree squirrels

Animals that differ by more than an order of magnitude in body mass might be expected to also differ in shape particularly in the shapes of functionally relevant structures like the jaws. The lineage of New World tree squirrels encompasses both 1,000 g. *Sciurus niger* and 100 g. *Microsciurus alfari*. On average, large and small members of *Sciurus* (e.g., *S. niger* vs. 400 g. *S. deppei*) do differ in the size and shape of the mandible, but the shape differences are slight and do not extrapolate to species of *Microsciurus*. Larger differences can be found among species of similar size and different ecologies. Compared to the North American *S. niger*, the Amazonian *S. spadiceus* has a deeper incisor and ramus, but a shorter molar row and smaller angular process. Similar differences distinguish *S. granatensis* and *S. deppei*, but a different combination of traits distinguishes these smaller *Sciurus* from similar sized *Tamiasciurus hudsonicus*. This diversity of morphologies and inferred evolutionary trajectories is not consistent with isometric scaling, or with a single allometric trend, but it is consistent with recently described patterns of variation in jaws of *S. niger*.

35.3 SYLVESTER, JB*; RICH, CA; LOH, YE; FRASER, GJ; STREELMAN, JT; Georgia Institute of Technology; *gth644s@mail.gatech.edu*

Brain diversity develops at the boundaries

The brain is the best-studied vertebrate organ. Modifications of brain structure are largely responsible for novel behaviors that galvanized evolutionary radiation of fishes, birds and primates. Following decades of research in model organisms, we know a great deal about how the process of development makes a brain. However, we know less about the developmental mechanisms employed during the evolution of brain diversity. The literature suggests that brain diversity evolves via neurogenesis, as the cells of previously patterned brain regions proliferate, differentiate and/or undergo apoptosis. Here, we use Lake Malawi cichlid fishes to explore an underappreciated mechanism of brain diversification. We ask if brains vary among recently evolved evolutionary lineages because of developmental patterning; that is, do initial neural compartments differ in size and organization, prior to subsequent neurogenesis? First, we show divergence among major Malawi lineages (rock- vs. sand-dwellers) in the proportion of the embryonic brain allocated to telencephalic vs. thalamic prosomeres, prior to neurogenesis. Next, we demonstrate variation among lineages in a gene regulatory circuit (*otx2, shh, irx1, wnt1*) known to position the embryonic boundary (the zona limitans intrathalamica, ZLI) between the thalamus and the anterior forebrain. Notably, we have previously identified a single nucleotide polymorphism in *irx1*, alternately fixed in rock- versus sand-dwelling Malawi lineages. We propose that changes in the deployment of *irx1* affects the relative orientation of the ZLI and hence the size and structure of initial forebrain compartments in rock- vs. sand-dwelling Malawi cichlids. Thus, differences in early patterning might lay prosomeric foundations on which neurogenesis builds as brains develop diversity.

40.5 SZYMIK, Brett G*; SATTERLIE, Richard A; Eastern Connecticut State University, University of North Carolina Wilmington; *szymikb@easternct.edu*

Changes in Wingstroke Kinematics Associated with an Increase in Swimming Speed in a Pteropod Mollusk, Clione limacina

In order to produce useful movement, all locomotory systems must manage the interface between the body and the environment. This interaction is more pronounced in soft-bodied aquatic organisms whose bodies are easily deformed by their surroundings. *Clione limacina* is a pteropod mollusk (*Gastropoda*) that swims by rhythmically flapping two wing-like parapodia. Its swimming is akin to underwater flight. Much is known about the morphology of *Clione* as well as the neural origins and control of *Clione*s swimming behavior. *Clione* demonstrates two distinct swimming speeds, termed slow and fast swimming. Slow swimming is a constant behavior that *Clione* uses to maintain its position in the water column, while fast swimming is observed during hunting and escape. *Clione* has proven itself to be a trove of information regarding how oscillating locomotory neural networks behave. This study begins to address how those neural signals are translated into behaviors that produce meaningful movement. High speed videography and the direct linear transformation technique (DLT) were used to obtain three-dimensional data from multiple points on the animal's body. Given its low-intermediate *Reynolds* number (generally < 200), alternative mechanisms of thrust generation that allow the animal to overcome drag are likely important to *Clione*. Its wings come closer to its body during fast swimming, virtually wrapping around the body in some animals. The wings also produce a sculling motion during wing reversal that is more prominent during fast swimming. These observations suggest a squeeze mechanism involving the wings and body that generates thrust during the recovery phase of the wingstroke, when the animal would otherwise be in a state of stall.

40.3 TAFT, Natalia K.; University of Massachusetts Amherst; *natashak@bio.umass.edu*

A New Twist on Bending: Properties of the Pectoral Fin Rays of the Benthic Longhorn Sculpin, Myoxocephalus octodecimspinosus.

Many benthic fishes use their pectoral fins for substrate contact, which requires a combination of stiffness for weight bearing and flexibility for gripping the substrate. The fin rays are the bony structures that support and define the shape of the pectoral fin. I hypothesize that there are morphological specializations of the fin rays that enable benthic fishes to perform these behaviors. I used microCT scanning technology to examine the structure of the pectoral fin rays in the benthic longhorn sculpin, *Myoxocephalus octodecimspinosus*. I found that the cross-sectional shape of the rays is not uniform along the proximo-distal length of the ray. Distally, the fin ray halves, or hemitrichia, are crescent-shaped, as has been described previously for ray-finned fishes. However, proximally all hemitrichia are circular in cross-section. I hypothesize that the bending properties of the fin rays are largely determined by cross-sectional shape. I predict that this anisotropy confers resistance to bending proximally and flexibility distally. I tested this hypothesis by using controlled bending trials to compare the location of maximum curvature among fin rays. Fin rays with a higher proportion of their total length that was circular in cross-section had a more distal location of maximum curvature. Therefore, a circular cross section does confer resistance to bending proximally. These results support our hypothesis that benthic fishes have morphological specializations of the fin rays that are associated with their functional role in substrate contact behaviors.

77.6 TALLEY, Jennifer L.*; CHIEL, Hillel J.; WHITE, Edward B.; WILLIS, Mark A.; Case Western Reserve University, Texas A & M University; *jlt17@case.edu*

Using characterized air flow to explain insect pheromone tracking behavior.

Male American cockroaches and tobacco hornworm moths exhibit stereotypical odor tracking to female sex pheromones. We plan to address the differences in these two insects behavior (a product of mode of locomotion, sensory systems, and the environment in which they are embedded) by characterizing the lab wind tunnel where the insects are performing odor tracking behavior. We used hot wire anemometry to measure the flow where roaches walk and moths fly under different turbulent conditions at the wind speeds used for roaches (25 cm/s) and moths (100 cm/s). Our conditions were designed to predictably manipulate the temporal and spatial structure of the flow: 1) control (without added turbulent structures), 2) a grid spanning the cross-section of the wind tunnel, 3) a cylinder placed perpendicular to the flow direction, and 4) the cylinder placed downwind of the grid. The control treatment is less turbulent than the grid condition which is less turbulent than the cylinder and grid & cylinder conditions. We found that at 25 cm/s, within the boundary layer, there is more temporal information but less spatial information available in the turbulent conditions than in the control condition. Roaches challenged to track an odor plume in the grid condition steer more into the mean wind direction, tend to aim their bodies more directly upwind, and walk faster than in the control condition. Roaches in cylinder conditions steer more off the mean wind direction and stop longer and more often. Their responses to the grid and cylinder in series are intermediate to their responses to grid or cylinder alone. Ultimately, moth behavior under these same conditions will be measured and compared.

69.2 TAN, Huiling*; WILSON, Alan M.; The Royal Veterinary College, U.K.; *htan@rvc.ac.uk*

Turning Performance of Horses

Sprinting around a bend increases effective body weight as body mass experience both gravity and centripetal acceleration equal to v^2/r. Human maximum running speed has been shown to be limited by the ground reaction force legs can withstand and the maximum speed of human sprinters is lower on a bend with a speed reduction that is concomitant with a leg force limit. Recent studies show that greyhounds and mice do not have to run slower on a curve partly due to the decoupling between muscles for weight support and propulsion in quadrupeds. Here we explore the limits of turning performance in horses trained to perform maximum rate turns. We collected horizontal speed and heading from polo horses undertaking maximum rate turns under field conditions during training (Number of horses: 5; Number of turns: 5) and during a real competitive polo game at a range of speeds (Number of horses: 16; Number of turns: 200) using mobile data collection techniques based on GPS and inertial sensors. All the horses did decelerate prior to and during turning to achieve higher angular velocity. The maximum angular velocity observed was 5 rad/s achieved at a horizontal speed below 2 ms^{-1}. The data fitted a model of a limiting centripetal acceleration, which was 8 ms^{-2} during the training for sharp turns on sand surface and 5.5 ms^{-2} during the polo game on grass surface. This may represent a safe grip limit in generating horizontal force or mechanical factors involving limb interference.

S2.10 TANAKA, K.; Japan Agency for Marine-Earth Science and Technology; *katsuhikot@jamstec.go.jp*

Life history of gnathiid isopods: a brief overview

Gnathiidae is a family of the order Isopoda including over 180 species worldwide. The larvae are known as common ectoparasites of fishes, particularly in coral reef regions. Adult gnathiids however are morphologically very different from the larvae, show strong sexual dimorphism and are regarded to be non-feeding. The biphasic life cycle of gnathiids including a fish-parasitic larval phase and non-feeding adult phase may be an evolutionary product of inter- and intra-specific interactions which gnathiids and their ancestors have experienced and a good example for considering the diversity and adaptation of parasitic crustaceans. Although our current understanding on the life cycle of gnathiids is still based on information on a limited number of species and/or fragmented descriptions, some general features can be deduced as follows: 1) larval gnathiids are temporary ectoparasites and develop into adults after alternating several times (three times in many cases) between ectoparasitic events and host-independent molting; 2) larvae stay on fish hosts for only a short period (minutes to hours on teleosts) during each ectoparasitic event and then 3) rest and molt in benthic habitats (e.g. mud burrows, sponges) between subsequent ectoparasitic events; 4) adults reproduce in benthic habitats, identical to larval benthic habitat in some species and different in others, and sometimes form harem-like aggregations. Several isopod families such as Cymothoidae are also known as ectoparasites of fishes but the repetition of short ectoparasitic events and the high dependency on benthic habitats are less remarkable in those taxa than in Gnathiidae. I will briefly review the life history of gnathiids, employing the data on two Japanese species, and discuss the possible factors, such as predation, affecting their specialization.

40.4 TANGORRA, J. T.; GOTTLIEB, J.; ESPOSITO, C.; LAUDER, G. V.*; Drexel University, Harvard University; *glauder@oeb.harvard.edu*

Biorobotic analyses of fish fin function

A hallmark of aquatic propulsion in bony fishes is the use of multiple control surfaces to modulate locomotor forces and body position. Studying the in vivo function of fish fins has revealed a great deal about how fish use fins to generate locomotor forces. But in vivo analyses of fish fins are limited by the inability to prescribe movement patterns and difficulties in directly measuring force. Such difficulties can be overcome by using robotic models. Furthermore, biorobotic models of teleost fish fin function can be used to explore a wide parameter space of kinematics not possible using only experiments on live fishes, while simultaneously measuring forces, kinematics, and hydrodynamic patterns. We have constructed self-propelled robotic models of the pectoral, dorsal, and caudal fins that closely replicate key biological features of fish fins, and have also used a dual-flapping foil robotic device to examine the effect of fin surface flexibility on swimming speed. We constucted two different pectoral fin robotic models based on the fins of bluegill sunfish (Lepomis macrochirus): one that reproduces steady swimming kinematics, and a separate model that generates manuevering kinematics. An array of non-biological movement patterns were also studied for steady swimming, and fin kinematics, biaxial forces, and flow hydrodynamics were measured simultaneously during pectoral fin motion. During steady swimming, clear dual leading edge vortices were visible on the dorsal and ventral edges of the fin, on both the outstroke and instroke. Continuous accelerated flow was observed throughout the fin beat, as was a pattern of continous thrust generation during both outstroke and instroke. Movement of the dorsal half of the fin only reproduced thrust during the outstroke but generated very little thrust during the instroke.

67.5 TANNER, J. B.*; DUMONT, E. R.; SAKAI, S. T.; LUNDRIGAN, B. L.; HOLEKAMP, K. E.; UMass, Amherst, Michigan Sate Univ., E. Lansing, Michigan Sate Univ., E. Lansing; *jtanner@bio.umass.edu*

The role of the fronto-parietal sinus during bone-cracking in spotted hyenas

The ability to break open large bones has evolved independently in only three groups of carnivorous mammals, all of which have robust teeth, vaulted foreheads, and pronounced sagittal crests. One unusual skull feature, present in bone-cracking members of the family Hyaenidae, is a caudally elongated frontal sinus that extends into the parietal bone and along the length of the sagittal crest. It has been hypothesized that this sinus functions to resist bending and dissipate stress during bone-cracking. Here we used Finite element analysis (FEA) to examine patterns of stress distribution in the skull of a spotted hyena (*Crocuta crocuta*) during unilateral biting, and to inquire about the functional role of the fronto-parietal sinus in stress dissipation. We constructed and compared three FE models: 1) a normal model of an adult *Crocuta* skull; 2) a model in which the caudal portion of the fronto-parietal sinus was filled with bone; and 3) a model in which the sagittal crest was flattened to resemble the plate-like crests of other mammals. During biting, an arc of decreasing stress extended from the bite point up through the vaulted forehead and along the sagittal crest. Our results suggest that pneumatization of the hyenas skull both enhances its ability to resist bending, and together with the vaulted forehead, plays a critical role in evenly dispersing stress away from the facial region during biting. The highly specialized skulls of bone-cracking hyenas are thus able to meet the concurrent demands of generating large bite forces while distributing large stresses.

15.1 TAPPE, J.T.*; SANTHANAKRISHNAN, A.; MILLER, L.A.; University of North Carolina at Chapel Hill; *tappe@email.unc.edu*

Ciliary Transport and Flagellar Locomotion in Physical Models with Varying Reynolds Numbers

Swimming organisms have adapted varying methods of locomotion such as cilia, flagella, fins, and jet propulsion. Fluid environments with low Reynolds numbers are inhabited by many organisms such as bacteria. E.M. Purcell (American Journal of Physics, 1976) published research which showed that at very low Reynolds numbers reciprocal motion in which pumping or swimming is achieved by a reversible process is not an effective means of moving or moving through fluid. For the case of locomotion, results from an experimental investigation of flagellar locomotion using physical vessels modelled after biological organisms are examined over Reynolds numbers ranging from 10^{-3} to 10. For the case of fluid transport in the same range of Reynolds numbers, a physical model of a single cilium is examined. Quantitative and qualitative flow visualizations are used to understand the limit at which both flagellar locomotion in terms of forward velocity and ciliary transport in terms of volumetric transport are no longer efficient. Furthermore, the data obtained allows characterization of the efficiency as a function of Reynolds number and indicates whether the relationship is gradual, drastic, or intermediate. This provides insight as to the effects of scaling in organisms and why only the very small exhibit the features being investigated in this experiment.

S6.8 TASDEMIR, Deniz; University of London, London; *deniz.tasdemir@pharmacy.ac.uk*

From Secondary Metabolites to Drugs: Rationale, Purification and Biological Screening

Chemical compounds derived from plants, animals and microorganisms have formed the basis of most early medicines. Despite the significant advances in organic chemistry and the availability of large libraries of synthetic or combinatorial compounds, the secondary metabolites (SMs, natural products) are still the most prolific source for drugs because of their higher chemical diversity, biochemical specificity and other molecular properties, which make them superior to synthetic compounds as lead structures for drug discovery. This is believed to be due to the fact that SMs are structures, which have evolved through ecological pressures, such as competition and predation, for millions of years. So natural products can be viewed as privileged structures selected and optimized by evolutionary pressures to interact with a variety of proteins and other targets of the organisms predators, and thus possess a higher potential to interact with human proteins. The ability of a small molecule SM to bind or otherwise inhibit a certain macromolecule is the basic concept of drug discovery and explains the higher drug-like properties of SMs. In conclusion, the biological activity of SMs is of relevance for their ecological function, but is also the basis of their biomedical importance. Typical natural product drug discovery is a complex process. It includes the extraction and initial screening of natural material against a validated target, purification of its bioactive principle(s) by chromatography and structure elucidation of the active component(s) by spectroscopic methods. The selection of target protein/cell line and screening technique is crucial. This lecture will deal with high throughput screening, bioactivity-driven isolation and characterization of natural products from plants and marine invertebrates against established targets in cancer and malaria.

76.3 TAVERNIA, B.G.*; REED, J.M.; Tufts University; *brian.tavernia@tufts.edu*

Urbanization measures are not interchangeable: effects of spatial scale and habitat context

A wide variety of metrics is used to quantify features of urbanization in ecological studies. Successful integration of results across studies using different metrics, however, requires a strong relationship among the metrics. Additionally, it is important that the relationships remain consistent across spatial scales of biological interest and across habitat matrix types. We examined the strength and nature of relationships between eight urban metrics at 1105 sites, including: population, agriculture cover, forest cover, wetland cover, dense residential cover, impervious surface cover, road length and green space cover. Values were measured at five spatial scales (100 m, 250 m, 500 m, 1 km, 2 km) and at one spatial scale (1km) for 100 urban sites within each of three habitat context (salt marsh, forest, freshwater marsh) within Massachusetts, USA. We found generally weak correlations between urbanization measures, with only 26/140 mean correlation coefficients exceeding 0.70, and 70/140 <0.30. Spatial scale did not significantly affect the strength of correlations, but habitat context did, with lower average values in salt marsh habitat. Similarly, principal components analysis showed that spatial scale did not affect the nature (relative relationships among variables) of the relationships between urbanization measures, but habitat context did. Our results show that in our study area no single metric adequately characterizes urban settings, making multiple measures and multivariate statistically approaches an invaluable tool in assessing the influence of urbanization on ecological phenomena.

6.1 THACKER, R.W.*; GOCHFELD, D.J.; OLSON, J.B.; Univ. of Alabama at Birmingham, Univ. of Mississippi, Univ. of Alabama; *thacker@uab.edu*

Aplysina Red Band Syndrome: An emerging infectious disease of coral reef sponges

Disease is often implicated as a major factor contributing to continuing declines in the health of Caribbean coral reef communities. Most studies of coral reef diseases have focused on scleractinian corals, whereas sponge diseases have been less frequently documented. We are currently investigating *Aplysina* Red Band Syndrome (ARBS), which affects Caribbean rope sponges. Visible signs of disease presence include one or more rust-colored leading edges, with a trailing area of necrotic tissue, such that the lesion forms a contiguous band around a portion of or the entire sponge. Microscopic examination of the leading edge of the lesion indicates that filamentous cyanobacteria are responsible for its coloration. Although the presence of this distinctive coloration is used to characterize the diseased state, it is not yet known whether this cyanobacterium is the causative agent of this disease. ARBS is present throughout the Caribbean; surveys in Belize and the Bahamas revealed that up to 10% of *Aplysina cauliformis* individuals are infected. In laboratory aquaria, ARBS lesions expanded at a rate of up to 1 mm per day. Transmission studies in the lab and field demonstrated that contact with an active lesion's leading edge was sufficient to spread ARBS to a healthy sponge, suggesting that the etiologic agent is contagious. Population studies indicate clumping of diseased individuals on the reef, but the presence of affected individuals in isolation suggests that waterborne transmission is also likely. Studies to elucidate the etiologic agent of ARBS are ongoing. Sponges are an essential component of coral reef communities and emerging sponge diseases have the potential to impact benthic diversity and community structure on coral reefs.

6.2 THORNHILL, D.J.*; SANTOS, S.R.; Bowdoin College, Auburn University; *thornhill.dan@gmail.com*

Population genetic structure of symbiotic dinoflagellates associated with Caribbean reef-building corals, Montastraea annularis and M. faveolata.

Symbiodinium is a highly diverse genus of unicellular dinoflagellate symbionts that associate with a variety of marine protists and invertebrates, including reef-building corals. Although the diversity and phylogenetics of the *Symbiodinium* complex is now well-established, there has been surprisingly few data on fine-scale population structure and biogeography in these symbionts. Here, we present data regarding the population structure of *Symbiodinium* hosted by the Caribbean reef-building corals *Monastraea annularis* and *M. faveolata*. Tagged coral colonies were sampled from reefs in the Florida Keys and Bahamas from 2002 - 2006 and *Symbiodinium* diversity was assessed using denaturing gradient gel electrophoresis of the internal transcribed spacer 2 (ITS2) rDNA and three microsatellite loci specific for *Symbiodinium* belonging to Clade B. The majority of individuals at a site harbor were found to harbor an identical *Symbiodinium* ITS2 type and clone, suggesting low symbiont population diversity per host species per site. Additionally, *Symbiodinium* populations within a colony remained homogeneous through time, including a prolonged 2005 high-temperature bleaching event. Notably, symbiont populations were unique to each site, suggesting low genetic connectivity between them due to *Symbiodinium* having a limited dispersal capability in the environment. Interestingly, neighboring colonies of *M. annularis* and *M. faveolata* harbored differing *Symbiodinium* populations in the Florida Keys while, adjacent *M. annularis* and *M. faveolata* colonies in the Bahamas harbored indistinguishable symbiont populations. We hypothesize that this is due to differences in the genetics of the host corals between these two regions.

75.5 TIELEMAN, B.I.*; VERSTEEGH, M.A.; FRIES, A.; HELM, B.; DINGEMANSE, N.J.; GIBBS, H.L.; WILLIAMS, J.B.; University of Groningen, Ohio State University, Max Planck Institute for Ornithology, Ohio State University; *B.I.Tieleman@rug.nl*

Genetic modulation of energy metabolism in birds through mitochondrial function

The genetic mechanisms that determine energy expenditure in animals have largely remained unstudied despite their central importance for the evolution of physiological variation. We used quantitative genetics to confirm that both mass-specific and whole-organism BMR were heritable in a captive-bred population of Stonechats (Saxicola torquata spp.) founded on birds from three wild populations that differed in basal metabolic rate (BMR). Our results suggest that BMR is at least partially under genetic control by multiple unknown genes. We then tested for a genetic effect on BMR based on mitochondrial-nuclear coadaptation using hybrids between ancestral populations with high and low BMR, with different parental configurations within each combination of populations. Hybrids with different parental configurations have on average identical mixtures of nuclear DNA, but differ in mitochondrial DNA because it is inherited from the mother only. Differences in mass-specific BMR between hybrids with different parental configurations showed that the match between mitochondrial and nuclear DNA had consequences for metabolic rate. Our findings implicate mitochondrial function as important regulator of energy metabolism. In combination with the substantial heritabilities of metabolic rate, and corroborated by genetic differences in the mitochondrial genome, these results set the stage for further investigations of a genetic control mechanism involving both mitochondrial and nuclear genes determining metabolic rate at the whole-organism level.

11.4 TIMPE, E.K.*; KOZAK, K.H.; BONETT, R.M.; Univ. of Tulsa, Univ. of Minnesota; *elizabeth-timpe@utulsa.edu*

Exploring the Faunal Connection between the Ozark Plateau and the Appalachian Mountains: A Phylogeographic Study of the Long-tailed Salamanders of the Eurycea longicauda complex

The Ozark Plateau is a major geographic feature in eastern North America that harbors a wide diversity of endemic plants and animals. The colonization of this region is believed to have occurred from numerous independent invasions from adjacent areas, including the Appalachian Mountains and the Coastal Plain. Although in recent years there have been several detailed phylogeographic studies of eastern North American, few examine species groups that are distributed across the Ozarks and surrounding areas in order to test the origin and dispersal of fauna of this region. Long-tailed salamanders are relatively abundant and widely distributed throughout eastern North America, providing an ideal model system to investigate the faunal connections between these regions. Using a phylogeny based on mitochondrial (cyt b, ND2, 16S) and nuclear (Rag1) DNA sequences, we test the patterns and timing of dispersal of the *Eurycea longicauda* complex, to make inferences about the historical biogeography of the Ozark Plateau and the Appalachian Mountains. All phylogenetic analyses recover four major well-supported lineages, that represent each of the nominate taxa of long-tailed salamanders (*E. l. longicauda, E. l. melanopleura, E. guttolineata, and E. lucifuga*). Ozark long-tailed salamanders (*E. l. melanopleura* and some populations of *E. lucifuga*) are phylogenetically nested among Appalachian lineages indicating multiple colonization events from the Appalachian Highlands onto the Ozark Plateau. Divergence time estimates indicate that the *E. l. melanopleura* lineage has been in the Ozarks since the Miocene, whereas, Ozark populations of *E. lucifuga* appear to be the result of recent Pleistocene colonization.

105.2 TOBALSKE, B.W.*; WARRICK, D.R.; University of Montana, Missoula; *bret.tobalske@mso.umt.edu*

Where's the LEV? Aerodynamics of the hummingbird wing during hovering

Leading-edge vortices (LEVs) are considered essential features of wing aerodynamics during hovering in insects and have recently been reported to enhance lift production in a slow-flying bat (*Glossophaga soricina*). To test for similar patterns in hummingbirds, birds that are uniquely adept at hovering, we used digital particle image velocimetry (DPIV) and measured near-field flow ($\leq$ 5 mm from wing surface) about the wings of hovering rufous hummingbirds (*Selasphorus rufus*, 3.3 g, n = 5). We also measured a series of model wings and dried hummingbird wings spun as propellers. We mounted the propellers on a force plate to compare direct measures of lift (L) and drag (D) with estimates made using DPIV. In live birds, we found no evidence of sustained, attached LEVs during up or downstroke although a transient LEV was produced during the rapid change in angle of attack at the end of downstroke. In the propeller models, coefficients of L and D were $\leq$ 2.5 and maximum L:D ratios were $\leq$ 3.7. These L:D ratios were comparable with previously reported measurements for models of similarly-sized hawkmoth (*Manduca sexta*) wings but 4x < maximum L:D ratio previously reported for a dried, spinning hummingbird wing. We observed reasonable congruence between transducer measurements and circulation-based estimates of lift. The major conclusion from our research, novel in a comparative context, is that LEVs do not dominate the flow about hummingbird wings during hovering. NSF IOB-0615648.

79.4 TODD, Nancy E.*; NEFF, Matt; Manhattanville College; *toddn@mville.edu*

Reduction of bubble nest frequency and size by male Betta splendens after exposure to 17Estradiol

Betta splendens, known as the Siamese Fighting Fish, are notorious for their highly aggressive behavior toward each other. Males in particular have been selectively bred to enhance epigamic traits, such as bright colors and long, flowing fins. In addition to their aggression as an attractant for females, males build elaborate bubble nests to house fertilized eggs collected from the female. Many environmental estrogens are now present in aquatic ecosystems, resulting from pesticides, waste chemicals from factories, and other non-point sources. In the wild, these fish live in flooded rice paddies and other stagnant bodies of water in Asia, environments that are potentially susceptible to contamination by estrogenic compounds. The effects of these estrogens is beginning to emerge in studies of other species of fish that have reduced fertility, or undergo sex changes and transitions. In this study, male *Betta splendens* were exposed to 5ul of 17B estradiol for 28 days to evaluate the effect on their aggressive behavior and bubble nest construction. Behavior was examined pre-treatment, and 28 days after treatment, and the presence/absence of a bubble nest and its size was recorded. While the males were highly variable compared to each other and between behaviors, males that were exposed to 17B estradiol made significantly smaller bubble nests, or none at all, after treatment. More aggressive males made smaller bubble nests, while the less aggressive males made larger nests on average, but few made nests after exposure to 17B estradiol. These results highlight the potential effects of environmental estrogens on reproductive behavior in *Betta splendens*.

97.6 TOMANEK, L.*; VALENZUELA, J. J.; HITT, L. R.; California Polytechnic State University, San Luis Obispo; *ltomanek@calpoly.edu*

The proteome response of Mytilus congeners to salinity stress

The marine mussel *Mytilus galloprovincialis* is an invader along the Pacific coast of North America and competes with the native *M. trossulus*. Interspecific differences in temperature and salinity tolerance are thought to contribute to limiting their distribution ranges and to determining the competitive advantages of the two congeners. Of the two species, *M. trossulus* is more tolerant towards low salinities in comparison to *M. galloprovincialis*. Here we studied the global changes in protein expression of both congeners in response to hyposaline stress using two-dimensional gel electrophoresis and mass spectrometry. Exposure to hyposaline conditions (85% and 70% sea water) for 4 h and subsequent recovery at a 100% for 24 h led to greater changes in global protein expression in gill tissue in *M. trossulus* (11% of the 477 detected protein spots) than in *M. galloprovincialis* (6%). After cluster analysis of the expression profiles we found that these differences are mainly due to a smaller number of proteins being down-regulated in *M. galloprovincialis*. In contrast, the number of proteins that were up-regulated in response to hyposaline stress was similar (15 versus 16) for both congeners. Half of those spots have the same molecular mass and isoelectric point on a 2D gel image in both species. Principal component analysis shows that the protein response to hyposaline conditions is much more distinct in *M. trossulus* than in *M. galloprovincialis*. We are currently using matrix-assisted laser desorption ionization (MALDI) - tandem time-of-flight mass spectrometry to identify proteins of interest.

S5.1 TORDAY, John/S*; REHAN, Virender/K; Harbor-UCLA Medical Center; *jtorday@labiomed.org*

Cell-Cell Signaling Drives the Evolution of Complex Traits: Introduction- Lung Evo-Devo

Physiology is biologic assimilation with the environment through multi-level cell-cell communications. We deconvoluted (Torday and Rehan 2004) lung evolution through Gene Regulatory Networks (GRNs) mediating cell-cell interactions for all lung biology-development, homeostasis, regeneration, and aging. This cell-cell communication model predicts other aspects of vertebrate physiology as adaptational responses. For example, the oxygen-induced differentiation of alveolar mesenchymal stem cells into adipocytes was necessary for the evolution of the lung in land dwelling animals adapting to Phanarezoic oxygen (12-35%). Alveolar adipocytes prevent oxygen radical injury (Torday et al 2001), and produce leptin, augmenting pulmonary surfactant to accommodate increasing alveolar surface area, limited by high systemic vascular pressure, which is compensated for by the evolution of the adrenomedullary beta adrenergic receptor mechanism (AR). Evolution of peripheral adipocytes fostered endothermy, also driven by the AR, ratcheting up selection pressure for both respiratory oxygenation and metabolic demand. Combined positive selection for the lung, endothermy and AR generates further positive selection pressure for the heart, which becomes progressively more complex phylogenetically in tandem with the lung. Increasing heart complexity and size impinge on the gut mesoderm to induce the liver, a regulated source of glucose necessary for the evolution of the neocortex. Neocortical control furthers the integration of these physiologic systems. Such a cell-to-tissue-to-organ-to-systems physiology evolutionary integration through cross-talk between intrinsic and extrinsic factors facilitates the translation of genomics into biology. We will elucidate this evolutionary cell biologic approach, tracing metazoan evolution from sponges to man. Funded by NIH Grants HL055268 (JST) and HL075405 (VKR).

59.2 TORREGROSSA, A-M*; AZZARA, A. V.; DEARING, M.D.; University of Utah, Salt Lake City, UT, Bristol Myers Squibb, Princeton, NJ ; *torregrossa@biology.utah.edu*

Specialist and generalist herbivores regulate food intake on diets containing novel plant compounds

Specialist herbivores are predicted to have evolved biotransformation pathways that can process large doses of the preferred plants secondary compounds (PSCs), however, specialization is thought to limit an herbivores ability to ingest novel PSCs. In contrast, generalists are predicted to regulate intake of PSCs by alternating the plants that they consume thereby decreasing the possibility of over-ingestion of any particular PSC. Because generalists ingest a mixed diet, it has been hypothesized that generalist herbivores would be better able to maintain body mass on a diet containing a novel toxin than specialists. We further hypothesized that both species would regulate toxin intake by decreasing meal size in a dose dependent manner. We tested these hypotheses by comparing the feeding behavior of two herbivorous rodents: a juniper specialist, *Neotoma stephensi*, and a generalist, *N. albigula* on a novel PSC diet of phenolic resin from creosote (*Larrea tridentata*). Animals were fed diets with increasing resin concentrations (0-4%) for three days per concentration. Animals that lost more than 10% of starting body mass were removed from the trial. Specialists were significantly more likely to be removed from the trial (5 of 12) than generalists (1 of 11). In addition, although the specialist and generalist both regulated phenolic resin intake via meal size on the 4% diet, only the generalist showed regulation on the 2% diet. The ability of the generalist to regulate at a lower concentration may provide an advantage over the specialist. These data provide evidence for the hypothesis that the foraging strategy of specialists results in a trade off in the ability to consume novel PSCs.

55.7 TOUCHON, Justin C.*; WARKENTIN, Karen M.; Boston University, Dept. of Biology; *jtouchon@bu.edu*

Morphological Responses to Abiotic and Biotic Factors: Temperature Effects on Predator-Induced Phenotypes in a Neotropical Treefrog Tadpole

Predator-induced phenotypic plasticity is well-known. However, the adaptive value of induced defensive phenotypes can vary. Abiotic factors affect larval growth rate, changing how long prey are vulnerable to predators and the relative value of investment in growth or defense. Thus, larval investment in predator-specific defensive phenotypes may be affected by abiotic conditions. Tadpoles of the Neotropical treefrog *Dendropsophus ebraccatus* change tail shape and coloration in response to predators. We studied the influence of growth rate, affected by pond temperature, on the development of predator-induced defensive phenotypes of *D. ebraccatus* tadpoles. First, we obtained realistic estimates of variation in growth rate by raising tadpoles in cages in sunny and shaded areas of four ponds, spanning a range of water temperatures. We monitored tadpole growth every week until metamorphosis and correlated growth rates with pond temperature. Tadpole growth rates varied both between sunny and shaded sites within ponds and between ponds. Using temperatures from our field study, we conducted a 2 X 2 factorial experiment in the lab, crossing slow and fast growth rates with the presence or absence of a caged larval predator. We conducted the experiment twice, using early and late larval-stage predators (Libellulid and Belostomatid, respectively). We measured the onset and outcome of phenotype induction by digitally photographing tadpoles at three intervals during each experiment. Tadpole morphology varied with both predator exposure and temperature, and predator effects differed with temperature. Natural variation in both abiotic and biotic factors thus generates a diversity of functionally different tadpole morphologies.

97.7 TRACY, C.R.*; BETTS, G.; CHRISTIAN, K.A; Charles Darwin University; *chris.tracy@cdu.edu.au*

Condensation onto the skin as a means of water gain by tree frogs in tropical Australia.

The savannas of tropical northern Australia present a challenge for frogs attempting to maintain water balance because there is often no free water available for several months during the dry season. However, green tree frogs (*Litoria caerulea*, Hylidae) can be found active during the cool dry season despite the fact that free water is not available and environmental temperatures can be as cool as the critical minimum temperature for this species (11 &degC). We hypothesized that dry season activity may reflect a strategy to obtain water by being active in cool conditions and having condensation form on the body when frogs return to a warm, humid tree hollow. Therefore, we measured the mass gained when a tree frog moves from a cool outside environment into a tree hollow, using both a natural hollow, and a simulated hollow in the laboratory. Even with a relatively small temperature difference between frog body temperature and air temperature in the hollow, frogs gained mass. With a large (15 &degC) difference in temperature, frogs were able to gain about 0.5% of their body mass in water condensed onto their skin. In areas with extended periods with no access to free water, even small gains in water would be advantageous to frogs, thus the use of condensation as a means of water gain may be a significant source of water uptake.

60.8 TRUMBLE, S.J.*; HAWKE, T.J.; PEARSON, L.E.; KANATOUS, S.B.; Baylor University, York University, University of Alaska Anchorage, Colorado State University; *stephen_trumble@baylor.edu*

Skeletal muscle lipids in Weddell seals (Leptonychotes weddellii): Differences in age class and possible response to resource limitations

In this study, we investigated the intramuscular triglyceride (IMTG) profiles and oxidative metabolism substrates of a deep diving mammal, the Weddell seal. We sampled pups (4-6 wks), juveniles (12-15 mo) and non-lactating adults (> 15 mo) and tested for age-class, gender and yearly differences. No gender differences were observed in IMTG or oxidative metabolism substrates. While pup (6g/100g) muscles had consistently three times the IMTG stores than juveniles (2g/100g), no differences were observed between yearly IMTG stores. No yearly differences were found in citrate synthase (CS) and COX activity among age classes. However, differences were detected among age classes and between years in lactate dehydrogenase (LDH), lipoprotein lipase (LPL) and fatty acid synthase (FAS) from skeletal muscles sampled. Interestingly, IMTG stores of 2006 sampled adults (2g/100g) decreased 550% from 2005 levels (11g/100g). This finding appears to correlate with the receding ice coverage in the McMurdo Sound area and its impact on the population density of adults (increase of 62% in adult numbers in 2006). Assuming breeding aged or lacatating females had similar IMTG values implies these adult animals may be faced with a physiological bottleneck similar to that of juveniles. This suggests that numbers of Weddell seal adults may increase into the McMurdo Sound area with warmer ice-free conditions, impacting future reproductive success.

13.4 TULENKO, FJ*; KUSAKABE, R; KURATANI, S; BURKE, AC; Wesleyan University, Kobe University, RIKEN Center for Developmental Biology;
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Body Wall Formation in Lamprey

Patterning of the musculoskeletal system from embryonic mesoderm has diverged considerably over more than 350 million years of vertebrate evolution, resulting in extraordinary morphological variation across taxonomic groups. In vertebrates, skeletal muscle derives from somitic mesoderm. Whereas most axial musculature is primaxial and forms from somitic cells that differentiate in a somitic environment, muscles of the limbs, diaphragm, and abdominal body wall are abaxial and derive from somitic migratory cells that enter the lateral plate. The lateral somitic frontier (LSF) marks the interface between the primaxial and abaxial domains. Although the LSF has been mapped in mouse and chick, its position in anamniotes is unknown. Lamprey lack jaws and paired fins, and diverged from other vertebrates prior to the radiation of gnathostomes. Thus, lamprey are a key model system for gaining insight into the ontogeny of basal vertebrates and the evolutionary innovations of gnathostomes. We use DiI to label presumptive lateral plate cells in the Japanese River Lamprey (*Lethenteron japonicum*) to determine if a boundary consistent with our definition of the LSF exists in an agnathan vertebrate. Embryos were injected shortly after somitogenesis and fixed at various developmental stages, up to and including ammocoetes. Myotomes were labeled with the skeletal muscle marker MF20. Preliminary results indicate that DiI labeled cells contribute to the lining of the body coelom and invest the ventral margin of the growing myotome, but do not mix with somitic myofibers. These data suggest that the primaxial myotome displaces the lateral mesoderm ventrally, and lateral plate cells do not contribute to the post-branchial lateral body wall. This supports the hypothesis that the primitive vertebrate trunk was primaxial, and paired appendages evolved as an innovative expansion of the abaxial domain.

58.5 TURNER, Ashby C.*; COOPER, Robin L.; Univ of Kentucky, Lexington;
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The Effects of an Altered Dopaminergic System on Behavior, Development, and Physiology in Drosophila melanogaster

Neuromodulators play a vital role in developing and controlling the Central Nervous System (CNS) but all of their attributes to development and behavior are not completely understood. One neuromodulator, dopamine, has been seen to have devastating effects if the concentrations are altered. Cocaine causes excess amounts of dopamine in the synapse.Dopamine levels are associated with Parkinson's disease and its effects on motor control. Drosophila were fed different concentrations of Alpha-METHYL-DL-p-TYROSINE-METHYL-ESTER (AMVT), a tyrosine hydroxalase inhibitor, at a range of doses in a variety of development stages. Development and larval behaviors were monitored for the effects of reduced dopamine. Adult flies administered AMVT at different concentrations were also studied for stress tolerance, locomotive behavior, and sensory to motor coordination. AMVT appears to have little impact on time of development. Decreased pigmentation was seen in pupated adults fed AMVT. Preliminary stress tests in adults have shown a decreased tolerance to heat stress after being fed AMVT when compared to controls as well as non-stressed pharmacological animals. Electrophysiological recordings measuring CNS recruitment of motor neurons when exposed to exogenous dopamine indicated a decreased frequency in rhythmic bursts for the larvae fed AMVT. Resting heart rate was reduced and the sensitivity of the heart to dopamine was enhanced in larvae fed AMVT.

37.5 TYTELL, E.D.*; COHEN, A.H.; Univ. of Maryland, College Park;
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Nonlinear integration of proprioceptive inputs to the lamprey central pattern generator for locomotion

When animals move, they receive feedback from numerous proprioceptive sensors. These sensors relay information on body movement to the spinal cord and brain, which must then integrate all of the signals and produce an appropriate response. The lamprey central pattern generator (CPG) for locomotion is a well studied system for examining proprioception and its effect on the locomotory pattern. In the lamprey, much of the proprioceptive input comes from mechanosensory neurons called edge cells that are located in the spinal cord along its full length. The CPG receives these spatially distributed inputs, but it is not known how the timing and distribution of multiple inputs affects the swimming pattern. Many mathematical models assume that inputs are independent, that their effects sum linearly, and that they do not affect the swimming frequency. However, these assumptions have not been tested empirically. To examine how the CPG integrates multiple proprioceptive inputs, fictive swimming was induced in lamprey spinal cords. First, the spinal cord was bent at the rostral or caudal end to stimulate the edge cells. Changes in burst period, burst amplitude, and phase lags were assessed for several cycles after the stimulus. Then, three types of double stimuli were tested: (1) two stimuli at different locations simultaneously, (2) two stimuli at the same location with a time lag between them, and (3) two stimuli at different locations with a time lag. Preliminary results indicate that the effect of simultaneous stimuli at two locations may sum nonlinearly. Additionally, stimuli may shorten burst periods for several cycles after the stimulus, which may invalidate one of the assumptions underlying many mathematical models of the CPG.

86.1 USHERWOOD, JR; The Royal Veterinary College;
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Compass-gait mechanics constrains walking speed in bipeds

The constraints to maximum walking speed and the underlying cause of the walk-run transition remains controversial. However, the motions of the body and legs can be reduced to a few mechanical principles, which, if valid, impose simple physics-based limits to walking speed. Bipedal walking may be viewed as a vaulting gait, with the centre of mass passing over a stiff stance leg (an inverted pendulum), while the swing leg swings forward (as a pendulum). At its simplest, this forms a compass gait walker, which has a maximum walking speed constrained by simple mechanics: walk too fast, or with too high a step length, and gravity fails to keep the stance foot attached to the floor. But how useful is such an extremely reductionist model? Here, we report forceplate-derived measurements on a range of bird species. Ducks represent relatively unspecialized, non-planar, crouch-limbed walkers; turkeys, guinea fowl, pheasants and emu may be viewed as more competent cursors. These measurements are compared with the theoretical predictions derived from compass gait mechanics. Ducks walked as inverted pendulums with near-passive swing-legs up to relative velocities around 0.5, remarkably consistent with the theoretical model. In contrast, top walking speeds (around 0.7) in guinea fowl - as for humans - *cannot* be achieved with passive swing legs: more specialist cursors, while still constrained by compass gait mechanics, extend their envelope of walking speeds by using relatively high step frequencies. Therefore, the capacity to drive the swing leg forward by competent walkers may be an important and previously little considered specialization, allowing near-passive vaulting of the centre of mass at walking speeds 4/3 that possible with a passive (duck-like) swing leg.

102.4 VAGLIA, J.L.*; BABCOCK, S.K.; WHITE, K.; CASE, A.; SMITH, K.; DePauw University; *jvaglia@depauw.edu*

Tail Elongation and Patterns of Regional Growth in Salamanders

While the morphology and function of the vertebral column are conserved across vertebrate groups, it exhibits variation in the number of vertebrae comprising the different axial regions. Typically the number of vertebrae an organism will have post-embryonically is determined during embryogenesis via the development of paired somites. However, studies show that salamanders (Amphibia:Urodela) add caudal vertebrae throughout life. Our research investigates the phenomenon of continual axial elongation in salamanders, with current emphasis on two species of the genus *Eurycea* (Plethodontidae), *E. cirrigera* and *E. longicauda*. Our goals were to 1. determine whether and to what extent *Eurycea* adds vertebrae through the life cycle, 2. assemble centrum length profiles of tail vertebrae, and 3. build upon our understanding of axial elongation in plethodontids. Larval, juvenile, and adult specimens were collected from field sites in central Indiana. Whole specimens were cleared and stained for bone and cartilage. Data collected include snout-vent length (SVL), tail length (TL), vertebral counts and centrum lengths. Both *Eurycea* species had TLs that surpassed SVL following metamorphosis. Increased TLs were associated with increased numbers of caudal vertebrae. Posterior to the base, tails exhibited regional variation in centrum lengths, similar to patterns observed for other salamander species (Babcock and Blais, 2001). Variation amongst species at the tail base might reflect phylogenetic history and/or design changes accompanying tail autotomy and elongation. Patterns in SLV/TL, caudal numbers and centrum lengths also varied across the life cycle. This suggests that metamorphosis represents an important transition in mechanisms that enable elongation of the posterior body axis.

42.2 VAN SANT, MJ*; OUFIERO, CE; HAMMOND, KA; Univ. of California, Riverside; *mvans001@ucr.edu*

A Comparative Analysis of Evaporative Water Loss in Mammals

Organisms must acquire sufficient water and energy from the environment to maintain cellular function and support maintenance, growth and reproduction. Water is easily lost across body surfaces and in waste products. Terrestrial environments are the most challenging environments for maintaining water balance with deserts, in particular, being extremely challenging. Animals living in deserts face desiccating conditions and low water availability. Despite these challenges, many species of mammals thrive in deserts. Thermoregulation may be difficult for mammals living in deserts where environmental temperatures are often higher than body temperature and water must be lost for thermoregulation. Evaporation of water from the respiratory tract and skin often constitute the greatest sources of water loss for terrestrial mammals. Hence, it is likely that natural selection has provided terrestrial species mechanisms to reduce total evaporative water loss (TEWL) within the thermal neutral zone, especially in species exposed to highly desiccating conditions. We collected mean values of TEWL from the literature for 127 species of mammals ranging from 8 g to 3570 kg. We compared rates of TEWL to determine if mammals living in deserts have lower rates of TEWL than mammals living in more mesic conditions. Preliminary analysis with conventional statistics suggests that desert species do have lower rates of TEWL than mesic species. Due to evolutionary relatedness datasets containing values for related species cannot be considered independent and identically assorted. We corrected for phylogenetic relationships by using standardized phylogenetic independent contrasts as well as using a phylogenetically generalized least squares approach. Results of the phylogenetically corrected statistics will be discussed and compared with results from the conventional statistics.

1.4 VAN UITREGT, B. O*; WILSON, R. S; The University of Queensland; *v.vanuitregt@uq.edu.au*

Costs and benefits of predator induced behaviour in larvae of the urban mosquito (Aedes notoscriptus)

Prey often exhibit behavioural and morphological responses that convey greater survival in the presence of predators. The evolution and maintenance of such responses requires a functional trade-off between alternate phenotypes. That is, predator-adapted phenotypes must be beneficial in the presence of predators but costly in their absence. While the cost/benefit trade-off of prey responses seem intuitive, they are often difficult to demonstrate empirically. In this study, we examine the costs and benefits of the behavioural response of larval mosquitoes *Aedes notoscriptus* to fish predators. Larval *Ae. notoscriptus* reduce activity in the presence of predator chemical cues from Eastern mosquitofish, *Gambusia holbrooki*. We will test the adaptive benefits of the behavioural response by entering predator-exposed and -naive larvae into predation trials with *G. holbrooki*. Fitness costs will be measured by comparing longevity and lifetime fecundity of predator-exposed to predator-naive females. We predict that larvae exposed to predator chemical cues throughout development will avoid detection from *G. holbrooki* for longer, but suffer a shorter adult life span and/or reduced lifetime fecundity. We will discuss the findings of these experiments and the potential use of aqueous predator chemical cues as control agents of pest mosquitoes.

10.5 VAN WASSENBERGH, S.*; BRECKO, J.; HERREL, A.; VAN DAMME, R.; AERTS, P.; Univ. Antwerpen, Belgium; *sam.vanwassenbergh@ua.ac.be*

Hydrodynamics of prey capture in forward striking piscivorous snakes

Aquatic snakes generally use fast, frontally directed strikes to capture prey under water. The prey is typically approached with a relatively wide gape, without making use of suction. A potential problem with this mode of prey capture is the generation of bow waves that tend to push prey away from the rapidly approaching, open-mouthed snake. However, the magnitude and importance of bow-wave effect for feeding performance remains unknown. Here we studied the hydrodynamics of forward striking in a specialist fish-eating species *Natrix tessallata* by means of computational fluid dynamics (CFD). To do so, 3D laser scans of preserved specimens were made and a finite volume mesh was created and imported into Fluent software. Flow patterns and hydrodynamic effects on a spheroid-shaped prey approached by the snake model at steady speeds, and at constant accelerations were studied for a range of different gape angles. Our results show that pushing of the prey occurs, but is generally restricted to the zone in between the jaws of the snake. A larger gape does not result in increased pushing of the prey, but strongly increases the drag to be overcome by the snakes locomotion system to reach a given approaching speed. The effect of different strike kinematics and mouth opening and closing will be discussed as well.

S4.6 VANDENBROOKS, J. M.*; KAISER, A.; HARRISON, J.F.; Arizona State University, Midwestern University; *john.vandenbrooks@asu.edu*

Tracheal Systems and the Evolution of Insects

Most insects respire via an air-filled tracheal respiratory system. Tracheal systems appear in the three related clades of Ecdysozoa that achieve large size and terrestriality, and within all three higher subclades of Arthropoda, suggesting that the characteristics necessary for tracheation are fundamental to Ecdysozoa. However, the apparent evolution of multiple terrestrial arthropod clades from marine ancestors suggests independent evolution of tracheal systems in hexapods, myriapods and chelicerates. Members of all extant hexapod groups, including insects, possess tracheae, supporting a common terrestrial ancestor of this group. Insects may be excluded from marine environments because possession of a tracheal respiratory system limits physiological function in a marine environment. Possession of a tracheal system is a key characteristic in the evolution of flight, providing an important factor in the great biodiversity of insects. In addition, tracheal systems support the highest rates of oxygen consumption in the animal kingdom and tremendous tolerance to hypoxia/anoxia. However, accumulating data support the hypothesis that possession of a tracheal system limits insect body size, and that historical variation in atmospheric oxygen influenced maximal insect size. Larger insects have a greater fraction of their body devoted to tracheal system, perhaps to overcome gas exchange limitations associated with blind-ended tracheal tubes. Rearing studies under different oxygen levels in the lab have shown strong effects on insect respiratory structures, average body size, and development rates in a variety of insect groups, suggesting that changes in atmospheric composition in the past may have influenced insect ecology and evolution. Supported by NSF IBN 0419704 and EAR 0746352.

103.5 VANHOOYDONCK, B*; HERREL, A; GABELA, A; PODOS, J; Univ. of Antwerp, Harvard University, Univ. Massachusetts, Amherst, Univ. Massachusetts, Amherst; *bieke.vanhooydonck@ua.ac.be*

Beyond the beak: wing shape variation in Darwins finches.

Wing design in birds is subject to a suite of interacting selective pressures. As different performance traits (e.g. manoevrability, aerodynamic efficiency, speed) are favoured in different ecological settings, a tight link between variation in wing morphology and variation in ecological parameters is generally expected. Here, we document aspects of variation in wing morphology in the medium ground finch (*Geospiza fortis*) on Isla Santa Cruz in the Galagos. We compare variation in body size, simple morphometric traits (body mass, wing chord, wing length, wing width and wing area) and functional traits (wing loading and wing aspect ratio) across years, among populations, and between sexes. Functional traits are found to covary across years with differences in climatic conditions (i.e. amount of rainfall), and to covary among populations with differences in habitat structure. Sexes differ in wing loading, with males having lower wing loadings than females. Lastly, in contrast to functional traits, we found little inter-annual or inter-site variation in simple morphometric traits.

101.6 VAUGHN, D.; Univ. of Washington; *dvaughn@u.washington.edu*

Sand Dolly: The adaptive significance of predator-induced cloning and size reduction in Dendraster excentricus plutei

Predator-induced cloning (asexual reproduction), and reduced size as a consequence of cloning, suggests a novel adaptation to the threat of predation. Although cloning is a common reproductive strategy of many plants and animals, cloning in response to stimuli from predators has, at present, only been documented in the pluteus larvae of the Western sand dollar, *Dendraster excentricus*. Other studies report larval cloning in echinoderms under optimal conditions of food and temperature. A burst of asexuality should be favored when environmental conditions are conducive to growth, but it is less clear that cloning is advantageous when conditions indicate risk from predators. This study tests the hypothesis that the small size of predator-induced clones reduces vulnerability during direct encounters with planktivorous fish. As in an earlier study, cloning was induced by exposing the early stage plutei to stimuli from fish predators (i.e., external mucus). Cloning was inferred by an increase in larval density, a reduction in larval stage and size, and limited direct evidence of cloning by budding. All clones were smaller than uncloned sibling larvae, suggesting an advantage against visual predators. Pair-wise predation trials demonstrated that predatory fish ate more uncloned sibling plutei than clones. These results offer a new ecological context for asexual reproduction: *rapid size reduction as a defense*.

64.2 VENDETTI, J.E.; Univeristy of California, Berkeley; *jannv@berkeley.edu*

The fossil neogastropod genus Bruclarkia in the Eastern Pacific: investigations of its endemism and speciation

The extinct buccinid gastropod genus *Bruclarkia* Trask in Stewart, 1927, includes thirteen species from the Paleogene and Neogene of California, Oregon, Washington, Vancouver Island, and Alaska. Genera in the family Buccinidae are common and abundant throughout the active margin of the Pacific Rim, and *Bruclarkia* is noteworthy in that it is a genus endemic to the East Pacific. This genus first appears during the Eocene in the Keasey Formation of Oregon and is last seen in the Oregon Astoria Formation of the middle Miocene. A radiation of *Bruclarkia* species occurred in the early Oligocene after a local extinction near the Eocene/Oligocene boundary in the Pacific Northwest wiped out more than ninety percent of mollusk species. The genus went extinct about 20 million years later, with no *Bruclarkia* species giving rise to any extant neogastropod. In this study, more than 200 *Bruclarkia* fossils were analyzed and seventeen character states of shell morphology were identified. By polarizing morphological characters and correlating species with stratigraphic data, a suite of derived *Bruclarkia* shell characters was identified. To further elucidate the evolutionary history of this genus, the original and steinkern-preserved protoconchs of Bruclarkia were examined to infer larval developmental mode, and the shell morphology associations with substrate and inferred depth.

93.5 VENESKY, M.D.*; PARRIS, M.J.; The University of Memphis; *mvenesky@memphis.edu*

Effects of Batrachochytrium dendrobatidis Infections on Larval Foraging Performance

There is evidence of pathogen induced modifications in host behavior, including alterations in foraging behavior or foraging efficiency, which may compromise host fitness indirectly by reducing growth and development. Chytridiomycosis is an infectious disease of amphibians caused by the pathogenic fungus *Batrachochytrium dendrobatidis* (*Bd*) and has played a role in the worldwide decline of amphibians. In larval anurans, *Bd* infections may result in reduced developmental rates; however, the mechanism(s) responsible for these changes are unclear. We examined the effects of *Bd* on larval foraging time and efficiency of Grey Treefrogs (*Hyla chrysoscelis*) and Fowlers Toads (*Bufo fowleri*). If *Bd* infections reduce activity, we predicted that infected larvae will spend less time foraging compared to non-infected larvae. Additionally, if *Bd* induced oral deformities inhibit foraging efficiency, we predicted that infected larvae will forage less compared to non-infected larvae. To test these hypotheses, we conducted two experiments that ran concurrent with each other. In the first experiment, we tested for differences in foraging activity. In a second experiment, we tested for differences in the short-term ingestion rates by examining the amount of food in their alimentary track after a 3 hour foraging period. We found that in both species, infected larvae forage less often and were less efficient at obtaining food than non-infected larvae. However, we found interspecific differences in when *Bd* affected their performance. These data suggest that reduced larval growth rates observed in previous experiments with these species may be from *Bd* induced changes in foraging ability.

81.2 VENTURA, T.*; MANOR, R.; AFLALO, E.D.; WEIL, S.; GLAZER, L.; SAGI, A.; Ben-Gurion University of the Negev; *sagia@bgu.ac.il*

Insulin-like gene in prawn sexual differentiation

Androgenic glands (AGs) are unique endocrine glands regulating male sexual differentiation and growth in crustaceans. In the prawn *Macrobrachium rosenbergii* complete sex reversal was achieved by AG grafting or removal in females and males, respectively. In the prawn *M. rosenbergii* AG cDNA subtractive library was constructed. Screening of this library revealed an AG specifically expressed gene, termed *M. rosenbergii* insulin-like AG factor (*Mr-IAG*). The predicted mature Mr-IAG peptide (B and A chains) showed high similarity in its cysteine backbone to other crustacean AG specific insulin-like peptides with low sequence homology. *Mr-IAG* was found to have a prominent expression comprising 55% of the library sequences. Using real-time RT-PCR *Mr-IAG* transcript level was found to be higher in the sexually active morphotypes relative to its level in the sexually less active morphotype. *In vivo*, *Mr-IAG* dsRNA injections to young males temporally prevented the regeneration of male secondary sexual features accompanied by a delay in molt and growth parameters. Moreover, prominent histological changes were observed following *Mr-IAG* silencing: arrest of spermatogenesis in the testis, absence of spermatozoa in the sperm duct and a dramatic effect on the AG manifested by hypertrophy and hyperplasia. These results indicate that Mr-IAG might be an AG hormone responsible not only for male sexual differentiation but also for maintenance of male hood.

31.3 VERSTEEGH, MA*; HELM, B; GOYMANN, W; TIELEMAN, BI; University of Groningen, Max Planck Institute for Ornithology; *m.a.versteegh@rug.nl*

Energetics, immunology and corticosterone response of four subspecies of stonechats in winter

The balance between current and future reproduction is one of the foundations of life history theory. If adult survival is high, investment in current reproduction is expected to be low, while if adult survival is low current reproduction is expected to be high. Tropical stonechats from Kenya produce fewer offspring per year than their temperate conspecifics. Also, they are resident birds in contrast with stonechats from Central Europe or Kazakhstan, which are migrants, and Irish birds, which are partial migrants. Because tropical stonechats invest less in current reproduction then temperate stonechats, we expect them to invest more in self-maintenance, thereby increasing their survival chances. To obtain insights in the physiological differences among the four subspecies of stonechats, we measured basal metabolic rate, several measures of the innate constitutive immune system, and baseline and stress induced corticosterone levels during winter. Individuals from all four subspecies were kept in captivity in a common garden set up. We hypothesized that mass-specific basal metabolic rate and immune function were inversely related with life expectancy, although we realized that pathogen pressure may strongly influence immune function as well. The results suggest that metabolic and corticosterone measures depend on migratory strategy, while immune measures depended more on the environment that free-living stonechats animals would have experienced during winter. Pathogen pressure is thought to be high in the tropics and low in temperate regions, and birds might well have adapted their innate constitutive immune system to these varying threath levels.

1.3 VITOUSEK, Maren N.*; TARLOW, Elisa; WIKELSKI, Martin; University of Colorado, Boulder; *vitousek@colorado.edu*

A physiological basis for island tameness

Island tameness is a widely documented phenomenon in which island species, particularly those that have been isolated for much of their evolutionary history, show a greatly reduced behavioral response to novel predators. This insufficient escape response has led to widespread population declines among many island species exposed to novel predators, and has become a serious conservation problem. Despite its prevalence, the cause of island tameness is not known. We compared the physiological stress response of the classically tame Galapagos marine iguana *(Amblyrhynchus cristatus)* when approached by a novel potential predator (human) with that elicited by a native predator (the Galapagos hawk: *Buteo galapagoensis*). Although iguanas initiated flight from an evolutionarily novel potential predator, they showed no evidence of the cardiovascular stress response that facilitates successful escape. In contrast, when approached by a native predator, marine iguanas displayed the typical highly conserved vertebrate stress response and markedly increased heart rate prior to initiating escape, which is indicative of epinephrine release upon visual contact with a native predator. Our findings suggest that escape behavior in predator-naive species may be constrained by an inappropriate physiological stress response. This altered physiological response could explain why many island species have difficulty adapting to novel predators.

25.11 VOGEL, S.; Duke University; *svogel@duke.edu*
A heat-conserving ventilator for buildings based on nasal countercurrent exchangers
Respiratory ventilation in warm-blooded animals causes loss of both heat and water. Small mammals and birds commonly minimize such losses cyclic storage and release of heat plus condensation and evaporation of moisture during exhalation and inhalation respectively. Such single-passage, reciprocating flow, countercurrent exchangers can recover well over 80 percent of exhaled heat and water according to measurements done long ago by Schmidt-Nielsen and his collaborators on small desert rodents. Well-insulated, sealed buildings in cold places face an equivalent problem of heat and moisture loss through ventilators; unfortunately, as constant volume systems, they cannot use directly analogous devices. A biomimetic version for a building is nevertheless applicable, one based on paired exchangers operating in opposite phase at opposite ends of the structure. A very crude model house, consisting of a 0.8-m styrofoam box heated up to 50° C above room temperature, permitted exploration of at least the thermal aspect of the problem. Ventilating it at opposite corners were paired exchangers, 5.0 cm square by 41 cm long, in which air passed between 20 closely-spaced, parallel, aluminum plates 0.61 mm thick, drawn by small electronic cooling fans at their outer ends. With a full cycle about every 10 seconds and an average air exchange time (flow relative to box volume) of 250 seconds, the device recovered somewhat over 25 percent of the heat that would have been lost were ventilation unidirectional. Changing the operating conditions pointed to poor thermal interaction between moving air and aluminum plates as the chief limitation of this particular model.

82.2 VOLTZOW, J.; Univ. of Scranton; *voltzowj2@scranton.edu*
Back to the Origin: Incorporating Darwin in Introductory Courses
The year 2009 marks the 200th anniversary of Charles Darwin's birth and the 150th anniversary of the publication of *On the Origin of Species*. Many of Darwin's writings were widely read by a non-specialist public interested in natural history and thus are easily understood by undergraduate students. I have developed exercises that incorporate readings and short writing projects from the *Origin*, *The Voyage of the Beagle*, and other works by Darwin. These exercises give students first-hand experience with the richness of his writing and provide them with a strong foundation in natural history, natural selection, and the origins of modern evolutionary theory.

29.2 WACKER, D.W.*; WINGFIELD, J.C.; DAVIS, J.E.; MEDDLE, S.L.; University of Edinburgh, University of California, Davis, Radford University; *dwacker@staffmail.ed.ac.uk*
Seasonal differences in aromatase (cyp19) mRNA expression in the brain of the free-living male song sparrow, Melospiza melodia morphna
Male song sparrows go through three annual life history stages. In the breeding stage, circulating testosterone (T) is elevated and birds are aggressive. During molt, circulating T is basal and birds show little or no aggression. Aggression returns in the non-breeding stage despite low circulating T. Male song sparrows were captured on their territories in the early breeding, molt, and non-breeding stages at multiple sites in Washington State, and brains were collected to assess aromatase (cyp19) expression in nuclei putatively associated with the regulation of aggression. In situ hybridization using an oligoprobe custom created from an existing cyp19 sequence for the Zebra Finch, *Taeniopygia guttata* was utilized. Male song sparrows had higher levels of cyp19 mRNA in the preoptic area and medial preoptic area/medial division of the bed nucleus of the stria terminalis during breeding as compared to non-breeding and molt. This is consistent with the idea that these areas are involved in estrogen-mediated changes in sexual behavior. Cyp19 mRNA expression did not vary significantly across life history stage in nucleus taeniae or the caudomedial nidopallium. Levels of cyp19 mRNA were higher in the ventromedial hypothalamus in breeding and non-breeding versus molting males, suggesting that this area may be involved in the seasonal regulation of aggression in this species. Together, these finding support a role for cyp19 in the seasonal regulation of reproductive and aggressive behavior in free-living male song sparrows.

12.6 WAGNER, Gunter P.*; KOHLSDORF, Tiana; GRIZANTE, Mariana; KIN, Koryu; Yale University, Universidade de S Paulo; *gunter.wagner@yale.edu*
A molecular footprint of limb development in the HoxA-13 gene: implications for the origin of urodele limb development
Transcription factor genes can undergo adaptive changes in their coding sequence when recruited into a novel developmental context. We use this fact as a rational to search for a molecular footprint of limb development and limb loss in the limb developmental gene HoxA-13. This gene is expressed during limb development in the prospective autopodium, male and female reproductive track, kidney and body axis. We sequenced a fragment of exon 1 of HoxA-13 genes from various squamates amphibians and fishes and compared the inferred amino acid sequences using the random forest method to search for amino acid residues that are indicative of the presence or absence of the autopodium. The classification of sequences in those from species with autopodium and those without reliably identifies all fishes and snakes as limbless, and all classical eu-tetrapods as limbed (turtle, alligator, anuran, mouse, chicken etc). We use this sequence signature to test the idea that urodele limb development is different from that of other tetrapods because of a transient period of limb loss in the stem lineage of uroldeles. Urodeles have several unique features to their limb development: the sequence of digit development is from anterior to posterior, the gene HoxA-11, normally restricted to the zeugopod, is expressed in developing digits, the gene HoxD-11, normally strongly expressed in the developing autopod, is only weakly expressed, and Shh, normally expressed long the posterior edge of the autopod, is restricted to a small spot in the posterior margin of the limb bud. We sequenced a large sample of amphibian species to compare their HoxA-13 sequences with that of clearly limbed and limbless and discuss the implications for the origin of urodele limb development.

49.4 WAGNER, C.E.*; MCCUNE, A.R.; Cornell University; *cew35@cornell.edu*

Contrasting effects of substrate on population genetic structure in sympatric rock-dwelling cichlids

The cichlid fishes of Lake Tanganyika in Eastern Africa are a celebrated example of both ecological and species diversification. Because population subdivision is likely to play an important role in the speciation process, understanding how habitat features interact with species demographic, behavioral and ecological attributes to influence gene flow and population divergence may help explain the causes of high species richness in this and other systems. Here, we test the roles of isolation-by-habitat and isolation-by-distance in generating fine-scale population structure in three sympatric species of habitat-restricted cichlids in Lake Tanganyika. Using multi-locus microsatellite genotypes, we contrast patterns of population differentiation in these habitat specialists along a mosaic coastline of both favorable and unfavorable habitat. Despite their close phylogenetic relationship and shared habitat affinity, the species show striking differences in their pattern of genetic subdivision in the same geographical region, suggesting substantially different patterns of gene flow. In particular, two trophically specialized species exhibit much more restricted gene flow over sandy habitat than a trophically opportunistic species. This result suggests that ecological and behavioral traits have a strong influence on the scale and degree of population subdivision, a finding which has potentially important implications for understanding differential propensities for diversification among lineages and phylogenetic patterns of diversity.

71.3 WAINWRIGHT, P.C.*; HOLZMAN, R.A.; MEHTA, R.S.; HULSEY, C.D.; Univ. of California, Davis, Univ. of Tennessee, Knoxville; *pcwainwright@ucdavis.edu*

Integrated diversification of suction feeding performance in centrarchid and cichlid fishes

Suction feeding ability has been shown to have a complex underlying basis with numerous avenues of musculoskeletal biomechanics and behavior leading to higher performance. In this study we explored the degree to which this complexity was integrated during the diversification of two groups of predatory suction feeding fishes, centrarchids and the heroine cichlids of Central America. We focus on the magnitude of hydrodynamic forces the fish can exert on the prey as a measure of performance. These forces are partly due to the ability to generate high velocity, high acceleration water flow during suction feeding, which can be estimated from cranial morphology with Suction Index. Fish can also increase the water flow in the prey frame of reference with faster jaw protrusion and appropriate timing of strike kinematics. We measured Suction Index and jaw protrusion speed in 17 centrarchid species and 14 heroine cichlids, and asked how tightly correlated the evolution of these features were during the diversification of the two groups. In both groups there is a significant relationship between independent contrasts of Suction Index and jaw protrusion speed. These results show that structurally independent determinants of suction feeding performance were integrated during these two radiations. We suggest that the mechanical trade-off between the ability to exert high suction forces on prey and the ability to capture large volumes of water is a dominant axis of diversification in fish feeding systems.

74.4 WAKELING, James M*; BLAKE, Ollie; Simon Fraser University; *wakeling@sfu.ca*

Maximizing power and efficiency from a limb during cyclic contractions

Maximizing the power output from a muscle, from the single fibre to the whole belly level, involves: (a) maximizing the level of activation (mainly during the concentric phase) with zero activation elsewhere and (b) allowing the sarcomeres to shorten at their optimal strain rate as predicted by the Hill relation. But how is the power output from a whole limb maximized? In a multisegmental limb there are many muscles and only a fraction of these are considered primary power producers. Muscles additionally function to control joint stiffness, transfer power between joints and move the limb between power producing stages. High power production requires the coordinated action and distributed function of all the muscles in a limb. Indeed, it was hypothesized that power output would be limited by the muscle coordination. Muscle activity (EMG) was measured from ten muscles in the leg while subjects cycled on a stationary dynamometer at the highest effort they could sustain for hour. Every minute the load and target velocity (pedal cadence) were altered and this varied the power output that could be achieved. The mechanical power output was recorded for every pedal cycle. The total EMG intensity across all muscles was calculated as a proxy of metabolic activity. The EMG intensities for all muscles were grouped together for each pedal cycle to form a pattern of coordination, and these patterns were decomposed using principal component analysis. Submaximal power outputs could be achieved with a range of coordination patterns and these occurred with a range of total EMG intensities. Maximum power outputs were achieved with a more limited set of coordination patterns and these corresponded to the more efficient patterns during submaximal power cycling. The maximum power from a limb thus requires specific coordination between all its muscles.

92.2 WALKER, A.A.; DEVADI, R.; RILEY JR, L.G.*; California State University, Fresno, California State University, Frenso; *lriley@csufresno.edu*

Temperature and Fasting Differentially Regulate Glucose Metabolism and Ghrelin Levels in the Tilapia (Oreochromis mossambicus)

Glucose is an essential source of energy. However, glucose metabolism/clearance is slow in fish. The discovery of ghrelin, a novel stomach hormone, has broadened our understanding of the regulation of energy homeostasis in vertebrates. In mammals, ghrelin has been shown to be an important endocrine peptide that links the gastrointestinal system, brain, and peripheral tissues in regulating food intake and energy expenditure. Furthermore, it has been suggested that ghrelin may play a role in preventing catabolism in mammals. The goal of this study was to investigate the effect of glucose on ghrelin production and growth regulation in the tilapia (*Oreochromis mossambicus*) under two catabolic states; acclimated to a sub-optimal temperature (20ºC) and fasting. Groups of animals were acclimated to either 20ºC or 30ºC. After 4 weeks of fasting; fed (control) and fasted animals were given a single intraperitoneal injection of glucose (2 g/kg) or saline (control) 6 h prior to sample collection. Glucose treatment significantly elevated plasma glucose levels 6 h post-injection in all treatments except in fed animals at 30ºC. At 30ºC, fasted tilapia given glucose had significantly lowered plasma ghrelin levels, whereas there was a significant increase in plasma ghrelin at 20ºC. Fasting alone did not alter plasma ghrelin levels at either temperature, indicating that the response of ghrelin in glucose-treated and fasted animals is temperature dependent. This pattern was not reflected in stomach ghrelin mRNA levels. These results suggest that the mechanisms regulating glucose metabolism and energy balance are temperature dependent in the tilapia. Acknowledgements: Supported by California Sea Grant (NA04OAR4170038 R/A-122PD) and the NSF (IOS-0639771) to LGR.

64.6 WARWICK, A.R.; HOPKINS, M.J. ; BERENDZEN, P.B. ; THURMAN , C.L. *; University of Northern Iowa, *University of Chicago ; *thurman@uni.edu*

Morphological, Physiological, and Genetic Variation in the Red-Jointed Fiddler Crab, Uca minax (Le Conte)

Due to its absence on peninsular Florida, *Uca minax* is unusual in having a disjunct distribution along the southeast coast of the United States. To understand the impact of isolation, we examined carapace morphology, osmoregulation, and gene sequences for cytochrome oxidase-1 (CO1) and internally transcribed sequence (ITS-1) across the species range. Osmoregulation and mean hemolymph isotonic concentrations were identical for both Atlantic and Gulf populations. The variation of 23 carapace landmarks was assessed by principal components analysis. Although Goodall's F-test indicates a significant difference between Gulf and Atlantic populations, the magnitude is small. The average difference is less than species with contiguous populations and is much smaller than the differences between *U. minax* and its sympatric relatives *U. longisignalis* and *U. pugnax*. Samples of CO-1 and ITS-1 genes from 15 sites revealed 72 unique CO-1 and 42 ITS-1 haplotypes. Phylogenetic analyses were performed on haplotypes and topologies constructed using Bayesian analyses for each gene. No genetic difference between the Gulf and Atlantic populations was found. Although haplotypes are shared, no geographic structure was evident. Most variation in CO-1 and ITS-1 was explained by differences within populations rather than among Gulf and Atlantic populations. Analyses of demographic parameters indicate a greater effective population size for the Atlantic population and separation of the two populations occurred only recently. This suggests a common *refugium* population in Floridia during Pleistocene glaciation. Following retreat of the ice, populations diverged and migrated to their current distribution. These findings suggest that although *U. minax* populations are disjunct, they are currently not substantially different in morphology, physiology or genetics.

75.6 WATERS, James S.*; HOLBROOK, C. Tate; FEWELL, Jennifer H.; HARRISON, Jon F.; Arizona State University, Tempe; *james.waters@asu.edu*

Allometric scaling of whole colony metabolic rate in Pogonomyrmex californicus

Across all the kingdoms of living organisms and a vast range of body sizes, an organism's metabolic rate scales with mass by a power between 0.66 and 1, most often near 0.75. The mechanistic basis for the reduced mass-specific metabolic rate in larger animals remains controversial. The social efficiency hypothesis suggests that evolution of sociality may be facilitated by increased efficiency of task performance in larger groups, suggesting that metabolic rates might scale with mass to an exponent less than 1 in whole social groups, as occurs in individual organisms. We tested this possibility by investigating the scaling of metabolic rates of whole, functioning ant colonies. The metabolic rates of lab reared colonies of a monomorphic seed-harvester ant species, *Pognonomyrmex californicus*, were non-invasively measured with flow-through respirometry. Larger colonies expended less energy per ant than smaller colonies: whole colony metabolic rate scales with colony mass to the power of 0.75, suggesting that the colony is metabolically more like a "super-organism" than a collection of individuals. Investigating the mechanisms driving the scaling of metabolic rates in social groups such as ant colonies may reveal insight to the evolution of sociality as well as fundamental principles of scaling that also apply to organisms. This research was partially supported by a Sigma Xi Grant In Aid of Research and a NSF Graduate Research Fellowship to JSW and NSF IBN 0419704 to JFH.

6.5 WATERSON, Tyler*; BARSHIS, Daniel; STILLMAN, Jonathon; San Francisco State Univ., Univ. of Hawaii, Manoa; *waterson@sfsu.edu*

Microarray analysis of the effects of symbiont type and microhabitat on heat stress responses in the coral Acropora hyacinthus

In the face of climate change and the worldwide decline of coral reefs coinciding with rising sea surface temperatures, it is important to understand how corals may be able to cope with extreme temperature environments. In the back reef lagoon of Ofu, American Samoa, corals thrive in a diverse range of temperature microclimates including extremely fluctuating pools (28-36 C), and moderately fluctuating pools (28-32 C). Previous studies found that colonies of the scleractinian coral *Acropora hyacinthus* from extreme pools host only clade D *Symbiodinium*, while conspecifics in a moderate pool host both clade C and D *Symbiodinium*. While clade D is generally considered to confer heat tolerance, the specific effects of symbiont clade on host physiology are poorly known. To study the relative effects of symbiont type and microhabitat on the heat stress response of this coral, we exposed nubbins from 17 different colonies representing both pools to a control (constant 28.5 C), and two heat-ramp treatments. All aquaria were held at 28.5 C for one hour, after which the two treatment tanks were heated at a constant rate for 4 hours to 32 C and 34 C, respectively. After two hours of exposure to the maximum temperatures, nubbins were sampled and frozen at -80 C for genotyping and microarray analysis. Genotyping by RFLP analysis of the 18S ribosomal subunit was used to confirm symbiont clade prior to microarray experiments so that corals hosting clades C and D could be compared. Microarray analyses of transcriptome profiles were performed using a 4,980 gene microarray developed for *Acropora palmata* by the Medina lab at UC Merced. Supported by USGS BRD GCC program

S9.11 WEIL, Z.M.*; NORMAN, G.; DEVRIES, A.C.; NELSON, R.J.; Ohio State University; *zacharymweil@gmail.com*

The Injured Nervous System: a Darwinian Perspective

Much of the permanent damage that occurs in response to nervous system damage (trauma, ischemia, etc.) is mediated by endogenous secondary processes that can contribute to cell death and tissue damage. For humans to evolve mechanisms to minimize secondary pathophysiology, selection must occur for individuals who survive such insults. Two major factors limit the selection for beneficial responses to CNS insults: for many CNS disease states the principal risk factor is advanced age and virtually all severe CNS traumas are fatal in the absence of medical intervention. An alternative hypothesis for the persistence of apparently maladaptive responses to CNS damage is that the secondary exacerbation of damage is an unavoidable evolutionary constraint. That is, the CNS could not function without the mechanisms that caused secondary damage in response to injury. However, some vertebrates inhabit environments (e.g., hypoxia in underground burrows) that could potentially damage their CNS. Yet, neuroprotective mechanisms have evolved in these animals indicating that natural selection can occur for traits that protect animals from CNS damage. Many of the secondary processes that exacerbate injuries likely persist because they have been adaptive over evolutionary time in the healthy CNS. Therefore, it remains important that researchers consider the role of these processes in the healthy CNS to understand how they become dysregulated following injury. For instance, death from cardiovascular disease in humans peaks during the winter. Siberian hamsters housed in short day lengths (simulating winter) are more prone to hippocampal cell death than hamsters housed in long days after experimental ischemia. Proinflammatory cytokine expression is elevated following cardiac arrest in short- but not long-day, hamsters suggesting that there is a tremendous opportunity to investigate human disease patterns in a comparative context.

7.4 WEINSTEIN, S.B.; Univ. of California, Berkeley; *Batrachoseps@gmail.com*

Individual and population level effects of a pathogenic chytrid fungus on the terrestrial salamander Batrachoseps attenuatus.

The pathogenic amphibian chytrid fungus, *Batrachochytrium dendrobatidis*, infects populations of the fully terrestrial California Slender Salamander, *Batrachoseps attenuatus*. Histological analysis of museum specimens shows that this pathogen has been present in wild populations for at least 35 years, and while infected individuals collected in the wild exhibit 100% mortality when maintained in the laboratory, wild populations apparently remain stable. Infected salamanders frequently can be identified by such symptoms as caudal autotomy, excessive shedding, and dark spots on the ventral surface. Housing salamanders in a wet environment results in high mortality rates, while infected salamanders maintained in a relatively dry environment recover from infection. Histological examinations of both shed and sectioned skin from infected salamanders suggests that shedding, combined with dry environmental conditions, may represent a mechanism by which the salamanders can recover from chytridiomycosis. Although *B. attenuatus* remains widespread with dense local populations, other members of the family Plethodontidae are experiencing marked declines. An understanding of the relationship between the chytrid fungus and *Batrachoseps* may be applicable to patterns of declines and persistence in other species of plethodontid salamanders and amphibians in general.

22.1 WEISBECKER, Vera*; SANCHEZ-VILLAGRA, Marcelo R; Cambridge University, Universitaet Zuerich; *vwei07@esc.cam.ac.uk*

Monotreme postcranial ontogeny and the evolution of mammalian skeletal development

Mammalian postcranial diversity and development is often discussed with view to a potential relationship of mammalian reproduction with postcranial ontogeny. However, data on monotremes, representing the earliest diverging extant mammalian clade, are lacking. Using micro-CT, I collected the first data on monotreme postcranial ossification to assess postcranial ontogeny in the earliest mammals, and to relate marsupial ossification patterns to the ancestral therian condition. Event-pair coded ossification sequences from 5 platypus and 5 echidna juveniles were added to previously obtained data of 27 therians and 3 sauropsids, and analysed with the Parsimov program and phylogenetic analysis using PAUP. The latter yields monophyletic monotremes within monophyletic Marsupialia, retrieving no other currently accepted clades. Monotremes are virtually unique in 14 characters, and 6 are unique in echidnas; cervical and lumbar vertebrae and the coracoid ossify like in non-mammalian amniotes. Parsimov analysis indicates delayed ossification of scapula and stylopods relative to axial and zeugopod elements in monotremes. Echidnas show a unique ossification shift of the lower spine with respect to stylopods and scapula. Parsimov results confirm that marsupial ossification patterns are derived compared to the therian ancestor. The derived ossification patterns in monotremes, which are not assignable to either those of marsupials or placentals, agree with recent suggestions that monotremes display a mosaic of traits. This, and the differences between echidnas and platypuses, also prevent determination of ancestral mammalian ossification patterns. The late ossification of both stylopods in monotremes points is congruent with hypotheses of modularity between mammalian limbs.

37.3 WEISSBURG, M.J*; DICKMAN, D.B.; PAGE, J.L; WEBSTER, D.R.; Georgia Inst. Technology; *marc.weissburg@biology.gatech.edu*

Simultaneous correlation of odor-plume structure and behavior: II. Signal contrast at walking legs elicits steering in tracking blue crabs

Animals may use different sensor populations to regulate specific tasks during guidance. To directly discern the role of particular sensors in chemosensory searching, we used three-dimensional laser-induced fluorescence (3DLIF) to collect chemical concentration data simultaneously with movement in actively tracking blue crabs (*Callinectes sapidus*). Our data indicate that mechanosensory input, combined with input from chemosensors on walking legs, allows continued contact with the odor plume. Crab movement is adjusted to maintain a direct upstream heading (presumably using mechanosensation), with corrections toward the source modulated by chemical cues. Like moths, crabs are thus able to make numerous subtle corrections toward the source in the presence of frequent stimuli. The relative transverse bias of signals arriving at the legs mediates turning; animals receiving signals with directional bias in the transverse direction move in the direction of greatest signal intensity. Interestingly, crabs often face obliquely upstream so that legs on one side span the transverse direction and the legs on the other side are in their wake. Animals still execute appropriate turns when receiving biased signals across legs on one side, suggesting that CNS processing does not require bilateral (e.g. L-R) contrast to encode directional bias. Rather, the inputs from each sensor-bearing leg seem be preserved such that any contrast in the transverse direction provides steering information.

60.7 WELCH, KC*; KEENEY, BK; ALTSHULER, DL; Univ. of California, Riverside; *kenwelch@ucr.edu*

Anatomy of the hummingbird flight motor

Both small size and the ability to hover distinguish hummingbirds from other avian groups. Some of the unique features of the hummingbird musculoskeletal system have been described as important adaptations to their mode of flight. However, we still know comparatively little about how the hummingbird flight motor, particularly the ultrastructure and neuroanatomy of motor elements in the wing, differs from that of other birds. Here we describe the gross anatomy, fiber composition, and the spinal motor pools of the pectoralis and several muscles of the proximal wing of the Anna's hummingbirds (*Calypte anna*). These data are compared to data from zebra finches (*Taeniopygia guttata*), also obtained in our laboratory, as well to published data from other bird species. All flight muscles examined in both the Anna's hummingbird and zebra finch were found to be uniformly composed of fast oxidative glycolytic (FOG; type IIa) fibers. Although the homogeneity of fiber type composition (FOG) of the pectoralis muscle of small, volant bird species has long been appreciated, the homogeneous fiber type composition of all other examined muscles in the wing of the zebra finch and Anna's hummingbird stands in stark contrast to studies on even slightly larger birds, such as the English sparrow. The distribution and quantity of motoneurons innervating the pectoralis, and a control muscle, the extensor metacarpi radialis, within zebra finches and Anna's hummingbirds are highly similar. These findings indicate that specialization for flight in the smallest bird species corresponds with distinct differences in the design of the flight machinery, compared to larger species. However, these results also reveal relative similarity between these two small species with respect to the functional design of the flight machinery, despite striking differences in the modes of flight employed by hummingbirds and finches.

85.1 WELCH, A.M.*; SMITH, M.J.; GERHARDT, H.C.; College of Charleston, SC, Arthur Rylah Institute, Victoria, AU, Univ. of Missouri, Columbia; *welcha@cofc.edu*

Heritability and genetic correlation of call duration and condition in gray treefrogs: a test of genic-capture

Genetic variation in male sexual displays is a key ingredient in sexual selection, fueling the evolution of more attractive displays, allowing choosy females to gain the benefit of attractive sons, and facilitating correlated evolution of female preference and male display. What prevents sexual selection from quickly eroding genetic variation in display attractiveness? The genic-capture model suggests that this variation persists because condition-dependence of display traits translates genetic variation in condition into genetic variation in the display. We tested this model in gray treefrogs (*Hyla versicolor*). Male gray treefrogs produce energetically expensive advertisement calls, and females prefer long-duration calls. To test the predictions of genic-capture, we assessed genetic variance in call duration and in body condition, as well as genetic covariance between condition and call duration. Offspring from artificial fertilizations were raised to maturity in the laboratory, body condition was measured at several points during development, and calls of male offspring were recorded in a controlled acoustic environment. We find significant heritability in both body condition and call duration, but no significant genetic correlation between the two. Heritability of call duration demonstrates the potential for this trait to evolve in response to sexual selection. In addition, females mating with males that produce longer calls are expected to benefit via enhanced sexual attractiveness of their male offspring. However, a lack of genetic correlation between call duration and condition suggests that the ample genetic variation in call duration is likely maintained by some mechanism other than genic capture.

S6.4 WHALEN, Kristen*; HOFMANN, Gretchen; STEINBERG, Peter; Univ. New South Wales / Univ. of California, Santa Barbara, University of California, Santa Barbara, University of New South Wales, Sydney, Australia; *kwhalen@whoi.edu*

Transcriptome profiling in the sea urchin: understanding allelochemical modes of action and marine herbivore cellular defenses

As marine ecologists struggle to explain the vast differences in herbivore tolerance to plant allelochemicals, a key piece of the puzzle requires understanding the cellular and molecular responses underlying diet choice. Since herbivore biochemical and molecular adaptations are likely to be complex, genomic-based approaches are poised to accelerate our understanding of the physiological underpinnings controlling an herbivores response to dietary chemical stressors. Specifically, we are investigating the transcriptome-level response to varying algal diets and specific secondary metabolites in Australian sea urchin species. Sea urchins grazers dominate shallow seas worldwide and have had the most impact of any marine herbivore on structuring populations and communities of benthic macroalgae. This interaction has no doubt influenced the evolution of seaweed chemical defenses, and in turn, the coevolution of herbivore detoxification genes. Working with colleagues in the Hofmann lab, we have designed a custom sea urchin oligo microarray containing over 2000 genes involved in xenobiotic biotransformation/efflux, signal transduction, metabolism, oxidative stress and chemoreception. This technology will allow us to determine the cellular targets of algal secondary metabolites and identify those genes involved in xenobiotic resistance essentially creating a transcriptomic fingerprint of an organisms stress response. Discussion will focus on the use of the sea urchin microarray as a tool for understanding the coordinately-controlled xenobiotic defense gene network in marine herbivores using a toxicogenomics framework.

10.10 WHITENACK, L.B.*; MOTTA, P.J.; Univ. of South Florida; *whitenac@mail.usf.edu*

Performance of Shark Teeth during Puncture and Draw: Implications for the Mechanics of Cutting

The performance of an organisms feeding apparatus has obvious implications for its fitness and survival. In this vein, a number of recent studies of elasmobranch functional morphology have specifically addressed feeding, though the role of teeth has largely been ignored. Here we report the results of performance testing of teeth in puncture, which mimics biting, and unidirectional draw, which mimics lateral head shaking behavior for ten species of extant shark and three extinct sharks. Teeth were mounted to a MTS 858 MiniBionix II universal testing system with a 5 kN load cell and moved through the prey item at 400 mm/s. For puncture teeth were tested on five prey items representing a range of material properties (*Elops saurus, Haemulon plumieri, Archosargus probatocephalus, Sphyrna tiburo, Callinectes sapidus*), and force to puncture, maximum puncture force, and energy to puncture were measured. Draw testing was limited to *H. plumieri*, and maximum force during draw was recorded. Overall, forces required for puncture were low, averaging 6.7 to 21.4 N for fish prey and 47.7 N for crab prey. Differences in puncturing performance occurred among different prey items and among tooth morphologies, though no discernable pattern was found for the latter. No differences in draw performance occurred among tooth morphologies. When considering both biological roles, the majority of the teeth did not perform better in puncture versus unidirectional draw. These results as well as an independent morphometric analysis do not support the functional classification of shark teeth as either tearing and cutting morphotypes suited for various prey types. These results have implications for studies of fossil chondrichthyans, where typically tooth morphology is used to predict feeding ecology in the absence of behavioral data.

53.5 WIERSMA, P; RO, J; WILLIAMS, JB*; Ohio State Univ.; *wiersma.6@osu.edu*

Small organ size contributes to the slow pace of life in tropical birds

Previously we have shown that lowland tropical birds have a reduced basal metabolic rate (BMR) and peak metabolic rate (PMR), induced by cold exposure or exercise, compared with temperate species. Here, we test whether reduced mass of central organs contributes to a reduction in BMR in tropical birds, and whether smaller flight muscles might contribute to reduced peak metabolic rates. In addition, we searched for correlations of metabolic rate and organ masses within tropical birds. For 14 species of tropical birds, BMR was positively correlated with mass of pectoral muscle, heart, and lungs. PMR as elicited by cold correlated positively with mass of skin, intestines, liver and kidneys (n=14). When we compared organ masses of tropical birds with those of temperate birds, using body mass as covariate, we found 13 to 34% lower mass of heart (n=424 species), liver (n=65), kidneys (n=60) and flight muscles (n=304) in tropical species. Mass of lungs (n=47), spleen (n=34), and gizzard plus intestine combined (n=35), showed similar trends. No such trend was visible in size of the brain (n=154). In a separate analysis, we paired tropical and temperate species by genus and compared heart mass. This analysis confirmed lower heart masses in tropical species. If organ masses are reduced in tropical birds, after correcting for body mass, other structures must be larger. To explore this idea, we analyzed the skeletal mass of 60 museum specimens from both tropical and temperate locations. We found that mass of the skeleton was 17% higher in tropical species. In combination, our results indicate that the benign tropical environment has relaxed selection on high levels of sustained metabolic performance, permitting species to reduce the size of organs that are costly to maintain, which results in a lower BMR in tropical species.

79.6 WILCOXEN, T.E.*; SCHOECH, S.J.; BRIDGE, E.S.; BOUGHTON, R.K.; REYNOLDS, S.J.; University of Memphis, Oklahoma Biol. Survey, Archbold Biological Station, Univ. of Birmingham, UK; *twilcoxn@memphis.edu*

Changes in Reproductive Hormones with Age in the Florida Scrub-Jay (Aphelocoma coerulescens)

Analysis of fifteen years of data from our study population of Florida Scrub-Jays reveals a quadratic relationship between female breeder age and number of fledglings produced, with the youngest and oldest birds having the lowest reproductive success. A similar pattern holds for male breeders and fledgling production. In most vertebrates, production of reproductive hormones wanes with age, co-occurring with the decline in reproductive output. Measurement of these hormones can serve as a key marker of the onset of reproductive senescence. We collected blood samples from jays during the breeding season and used radioimmunoassay for luteinizing hormone (LH), estradiol (E_2), and testosterone (T). We hypothesized that concentrations of circulating reproductive hormones will change with age, and predicted declines in reproductive hormones with age in breeding jays. Samples were grouped according to the capture date in relation to the day the first egg was laid in the territory, and analyses were performed within each group to control for naturally occurring changes in circulating hormones during different stages of the breeding season. Male breeders LH and T concentrations follow a quadratic pattern, with low titers in young, maximum concentrations in middle aged, followed by a decline in plasma levels in the oldest birds. This distribution parallels the relationship between male breeder age and fledgling production, which mirrors the female pattern, and suggests that decreased T may reflect reproductive senescence. Interestingly, data for LH, E_2 and female breeder age reveals no age-based differences.

83.6 WILGA, Cheryl D.; Univ. of Rhode Island; *cwilga@uri.edu*

Hyoid And Pharyngeal Arch Function During Ventilation And Feeding In Elasmobranchs

The hypothesis that the mandibular and hyoid arches evolved from anterior pharyngeal arches to increase ventilation performance and subsequently became adapted for feeding is widely accepted. As jaws evolved, the morphology of the hyoid arch changed notably from that of a pharyngeal arch. Furthermore, hyoid arch morphology varies considerably among extant elasmobranch taxa and has been shown to be related to feeding style. Thus, the goal of this study is to determine whether the function of the hyoid and pharyngeal arches is altered between ventilation, the basal behavior, and feeding, the derived behavior. Four elasmobranch species with different hyoid arch morphologies are examined: *Chiloscyllium plagiosum* (CP), *Squalus acanthias* (SA), *Leucoraja erinacea* (LE), and *Mustelus canis* (MC). The hyoid arch is oriented more posteriorly while the pharyngeal arch is oriented more laterally in all of the species. CP has lateral and slightly anterior directed hyomandibulae (HY), SA has lateral and slightly posterior directed HY, LE has anterior directed HY, and MC has posterior directed HY. The epibranchial of the pharyngeal arches is the homolog of the HY and are directed posteriorly in all of the species. The kinematics of the hyoid and third pharyngeal arch during ventilation and feeding are quantified using sonomicrometry and the associated pressure generated at the arch is quantified using pressure probes. As expected, hyoid and pharyngeal arch vertical depth increases during ventilation and feeding in all species. However, hyoid and pharyngeal arch width and pressure differs among the species relative to hyoid arch orientation and feeding style. Hyoid and pharyngeal arch kinematics remain the same in some taxa but are altered in different ways in other taxa. Pressure varies between feeding style and ventilation.

41.5 WILLIAMS, J. D.*; AN, J.; Hofstra Univ., New York; *biojdw@hofstra.edu*

First report of Orthione griffenis Markham, 2004 (Isopoda: Bopyridae: Pseudioninae) from China and comparison with types specimens and collections from the west coast of the United States

Orthione griffenis Markham, 2004 was originally described from thalassinid mudshrimp hosts collected in Oregon. Subsequently, *O. griffenis* has been cited as a nonindigenous species in the Northwest Pacific (NWP); however, no taxonomic work has provided evidence that specimens from the NWP and any foreign locality are conspecific. We report the first record of *O. griffenis* from Chinese waters based on collections made in the late 1950s, which pre-date any records of the species from the NWP by at least 20 years. Females of the Chinese specimens match the original description except in the number of articles on antennae 2 (6 and 5 articles in the Chinese and NWP samples, respectively). Although males of *O. griffenis* from Oregon were originally described as having second antennae with 5 articles, reexamination of the allotype showed that antennae 2 were damaged and missing terminal articles. Thus, the number of articles in the second antennae of males is 6, as found in both the Chinese and new NWP samples. SEM of males from the NWP and China revealed curled setae at distolateral uropod margins, which were not reported in the original description. In China the species is found on the hosts *Austinogebia wuhsienweni* Yu and *Upogebia* sp. from Shandong province, whereas along the west of coast of the United States the species extends from California to British Columbia on *Upogebia macgniteorum* Williams and *U. pugettensis* (Dana); the species has also been reported from Japan. SEM studies on the morphology of the epicaridium larvae will be presented, along with additional notes on the reproduction and natural history of the species.

45.2 WILLIS, Mark/A.*; AVONDET, Jennifer/L.; Case Western Reserve University; *maw27@case.edu*

Behavioral context modulates the loss of local feedback sensors on flight in the moth Manduca sexta.

Information from local feedback sensors is known to have profound effects on flight motor patterns, and has been shown to affect maneuvering in freely flying insects. Much of what we know in this area is from studies on the locust, whose front and hind wings beat out of phase with each other. However, little is known about the role of local feedback in the Lepidoptera, whose front and hind wings are physically linked and appear to function as one. We removed the tegulae, a sensory structure known from locusts to signal maximum down stroke position, from the fore and hind wings, separately and in concert to determine their role in moth flight. The performance of these experimentally manipulated animals was compared to that of normal controls when challenged to take flight in still air and when asked to track a plume of an attractive odor upwind. In still air, moths with no tegulae took significantly longer to warm-up, a lower percentage took flight, and those that took flight flew for shorter times than intact controls. However when challenged to track a plume of attractive wind-borne odor the performance of the moths without tegulae were similar to that of the controls. We now need to understand how loss of the tegulae affects the flight motor patterns and wing kinematics underlying flight and maneuvering in these different behavioral contexts. Supported by AFOSR #FA9550-07-1-0149.

80.3 WILLIS, P.M.*; SYMULA, R.E.; RYAN, M.J.; Univ. of Texas, Austin; *pmwillis@mail.utexas.edu*

Ecological correlates of hybridization in wood warblers (family Parulidae): a mate choice perspective

Variation in mate choice can arise through changes in ecological conditions, such as mate availability, that affect the cost of finding and evaluating potential mates. Little is known, however, of the role such conditions play in promoting hybridization. Hybridization is frequently recorded among the wood warblers, and a lack of conspecific mates is often implicated as a causal factor. Competition among warblers for breeding sites may also increase the cost of continued mate search and contribute to heterospecific pairing. We investigated whether hybridization among North American wood warblers correlates with various estimates of the availability of conspecific mates (e.g. population size), or the availability of suitable breeding habitat (e.g. breeding range size). We generated mtDNA-based phylogenetic trees for the family, and conducted phylogenetic comparative analyses of North American species. In contrast to earlier observations, we found hybridization to be greatest between sympatric species, and between close relatives. Results to date suggest that smaller populations produced proportionately more hybrids than larger ones, as did those with smaller breeding ranges relative to those with larger ones. While the observed correlations may arise through alternate mechanisms, our findings suggest that a low availability of either conspecific mates or breeding habitat may facilitate wood warbler hybridization by increasing permissiveness in mate choice. More generally, this study suggests that variation in environmental conditions relevant to mate choice may have important consequences for reproductive isolation between taxa, particularly where the genetic costs of hybridization are mild.

70.4 WILLIS, D.J.*; RISKIN, D.K.; SWARTZ, S.M.; PERAIRE, J.; BREUER, K.S.; Univ. Massachusetts, Lowell, Brown Univ., Massachusetts Institute of Technology; *david_willis@uml.edu*

Computational modeling of the aeromechanics of a bat (Cynopterus brachyotis)

Bat flight represents a complex interaction between unsteady fluid flow and the material that composes the wing. Here, we explore bat flight aeromechanics using a computational model that exploits accurate, high resolution, in flight kinematics recordings of a bat (*Cynopterus brachyotis*). Using accurate reconstructions of the wing geometry, we apply a computational aerodynamics panel method to model the flow around the wings and in the wake region of the bat to hypothesize aerodynamics forces, wing surface pressure distributions, and wake vorticity distributions. As a first check of our results, we compare the time series of lift forces from our model to the accelerations of the bat body, estimated by taking into account wing inertial effects. The force predictions from the computational aerodynamics model and the estimated center of mass accelerations are compared and are found to be in good agreement. Our methods produce a hypothesized flow structure behind the bat consisting of a wake that is composed of discrete vortex rings, suggesting a down-stroke dominated flight strategy. The main difference that was observed between fast and slow flight was the change in the pressure jump distribution over the wings. In slow flight, the predicted loading is greater in the distal regions of the wing, while in fast flight the predicted loading tends to be closer to the proximal regions of the wing. This shift in loading is accompanied by large forward-aft flapping motions in slow flight and reduced forward-aft excursions in fast flight.

18.6 WILMOT, Michael*; KOSUGI, Takayoshi; FREAMAT, Mihael; SCHULTZ, Bernadine; SOWER, Stacia A.; University of New Hampshire, Durham, University of New Hampshire Durham; *sasower@cisunix.unh.edu*

IDENTIFICATION OF A GLYCOPROTEIN HORMONE ALPHA SUBUNIT IN THE SEA LAMPREY, PETROMYZON MARINUS

The pituitary glycoprotein hormone family in gnathostomes consists of the gonadotropins (GTHs), luteinizing hormone (LH) and follicle-stimulating hormone (FSH), and one thyroid-stimulating hormone (TSH). The alpha subunit of FSH, LH, and TSH is common within a single species, while the beta subunit is unique to each and confers specificity. Another heterodimeric glycoprotein hormone was recently discovered and termed thyrostimulin for its ability to stimulate TSH receptors in the thyroid (Nakabayashi et al, 2002). However, the thyrostimulin alpha subunit (GPA2) is not identical to the alpha subunit (GPA1) of FSH, LH and TSH. In the lamprey, an agnathan (jawless vertebrate), a gonadotropin beta subunit cDNA was cloned (Sower et. al, 2006). It is proposed from these studies that lampreys, a basal vertebrate, have only one pituitary gonadotropin. The objective of this study was to identify and clone the cDNA of the GTH alpha subunit. Thus far, a 292-nucleotide portion of a cDNA encoding a putative glycoprotein hormone alpha 2 (GPA2) subunit has been cloned by PCR from lamprey pituitary cDNA. Gene-specific primers were used to amplify a portion of the sequence identified from the lamprey genome (Pre!Ensembl, www.pre.ensembl.org), following TBLASTN searches with known GPA1 and GPA2 subunits. Comparison of this partial, translated sequence with known alpha sequences shows a higher similarity with GPA2 rather than GPA1 subunits. These data suggest that GPA2 may be the ancestral alpha subunit of the glycoprotein hormone family. Supported by a UNH UROP grant to MW and a NSF # 0421923 and USDA Hatch #332 to SAS.

25.9 WILSON, R S*; OLIVER, J; GOLDIZEN, A; BLOMBERG, S; Univ, of Queensland, Univ. of Queensland; *r.wilson@uq.edu.au*

Unreliable signals of strength in male slender crayfish (Cherax dispar): costs of enlarged claws and the importance of resources during disputes

Unreliable signals of weapon strength are considered problematic for signalling theory and reliable signals are predicted to be the dominant form of signalling among conspecifics in nature. Previous studies have shown males of the Australian freshwater crayfish (*Cherax dispar*) routinely use unreliable signals of strength during simple experimental confrontations. We investigated the possibility that functional trade-offs associated with enlarged weaponry may be important in reducing any benefits for unreliable signaling. We found swimming speed was negatively correlated with chela size for males, but not females, suggesting a functional trade-off exists for males only. Decreases in swimming speed with increases in weapon size, suggest there could be important fitness costs associated with larger chelae. In addition, we examined whether unreliable signals of strength remain effective during confrontations in the presence of two different perceived resources (shelter and territory). Like previous studies of *C. dispar*, chela size was the most accurate predictor of the decision to engage in a fight and of eventual dominance. However, males whose chelae represented an unreliable signal of strength (i.e. poor strength for a given chela size), were less likely to decide to fight when in the presence of a shelter. Overall, territory ownership and the presence of shelter significantly decreased the probability of males deciding to fight; whereas these factors did not significantly affect the likelihood that males established dominance.

4.2 WILSON-RICH, N.*; HESTER, F.; STARKS, P.T.; Tufts University; *noah.wilson_rich@tufts.edu*

Innate immunocompetence in Polistes dominulus: A critical test of the haploid susceptibility hypothesis

The order hymenoptera is characterized by a haplodiploid mode of genetic inheritance, whereby males are typically haploid and females are typically diploid. The 'haploid susceptibility hypothesis' assumes that since male haploids have only one allele at any given locus, they will be more susceptible to disease than female heterozygous diploids. We critically tested this hypothesis by examining multiple metrics of innate immunocompetence (IC) in the paper wasp, *Polistes dominulus*, an invasive species to North America which produces mutant, diploid males. The inclusion of haploid and diploid males controls for sex effects (i.e., the effects of being male) and allows for a critical test of the haploid susceptibility hypothesis without confounding ploidy with gender. Haploid susceptibility predicts that haploid individuals (reproductively-viable, haploid males) will possess low IC, while diploid individuals (reproductively-viable females and sterile diploid males) will possess high IC. The encapsulation response and phenoloxidase activity did not differ between haploid and diploid males, contradicting the haploid susceptibility hypothesis. Surprisingly, differences in IC were found across female castes -- non-reproductive workers had low IC and reproductive gynes had high IC, while males fell in between. These differences may be driven by caste dissimilarities with regards to reproductive viability and/or lifespan.

S1.3 WINDSOR, Shane; University of Auckland; *s.windsor@auckland.ac.nz*

Hydrodynamic imaging in blind Mexican cave fish

Blind Mexican cave fish (*Astyanax fasciatus*) lack a functioning visual system but are capable of moving through complex environments without colliding with obstacles. They do this by using their mechanosensory lateral line system to sense how the flow field that they create while swimming is altered by the presence of nearby objects; an ability termed hydrodynamic imaging. Little is known about the fluid mechanics involved with this ability. Automated digital video analysis was used to measure the swimming kinematics of the fish as they explored novel environments. Particle image velocimetry (PIV) was then used to measure the flow fields around the fish in similar situations. A series of computational fluid dynamic (CFD) models were created in order to estimate the stimulus to the lateral line. The fish reacted to avoid head-on collisions with a wall at a remarkably short mean distance of 0.09±0.01 body lengths (BL). This agreed with the PIV and CFD results, where the stimulus to the lateral line was estimated to be sufficient for the fish to be able to detect the wall at 0.10 BL, but decreased rapidly at increasing distances. Interestingly, the swimming velocity of the fish was not correlated with the distance at which they reacted to walls. This was supported by the CFD models, which indicated that the relative change in the stimulus to the lateral line was nearly independent of the velocity of the fish. The combined results of these three methods showed that hydrodynamic imaging is a short range sensory ability and suggest that it may not be enhanced with higher swimming velocity.

91.1 WOJCIECHOWSKI, M.S.*; JEFIMOW, M.; PINSHOW, B.; Nicolaus Copernicus University, Torun, Poland, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University, Israel; *mwojc@umk.pl*

Blackcaps use torpor and huddle while resting at a stopover site during migration.

For small endothermic animals, daily torpor serves as an energy-saving mechanism for survival in challenging environments, and it may also accelerate fat accumulation in animals preparing for fuel-demanding activities. While monitoring body temperatures (T_b) of blackcaps (*Sylvia atricapilla*), freshly-caught at a stopover site in the Negev, we found that they entered shallow torpor at night, reducing T_b by 5°C, or more, below normothermic resting levels. We estimated that such reductions in T_b can lead to overnight energy savings of approximately 30% compared to birds remaining normothermic. In addition to using shallow torpor, blackcaps huddled while roosting at night, which likely represents an additional avenue for energy savings. This occurred in spring migration in the Negev Desert and in autumn migration in central Poland. Since migratory flight brings about atrophy of muscles and other organs potentially involved in thermogenesis, we hypothesize that the observed deviations from normothermy, as well as huddling at night, may be associated with decreased capacity for thermoregulatory heat production attributable to reduced organ size. Since torpor, as seen in blackcaps, may lead to significant energy savings and more rapid fuel deposition at stopover sites, we predict it to be common among small migrating passerines. This study was funded by US-Israel Binational Science Foundation grant number 2005119 to BP and Scott R. McWilliams, and by the Polish Ministry of Science and Higher Education grant number N304 048 31/1811 to MSW.

92.7 WON, E.T.*; BALTZEGAR, D.A.; PICHA, M.E.; BORSKI, R.J.; North Carolina State University; *etwon@ncsu.edu*

Cloning and regulation of hepatic leptin mRNA expression by nutritional status in hybrid striped bass (Genus Morone)

Leptin is an anorexigenic peptide hormone that regulates energy homeostasis. In mammals it is produced predominantly by white adipose tissue and circulates in proportion to energy reserves. Teleost leptin has been characterized in a few fish species, but its regulation is not well understood, particularly in response to nutritional status. We cloned a putative leptin in striped bass (*Morone saxatilis*). Striped bass and the commercially valuable hybrid striped bass (HSB, *M. chrysops* X *M. saxatilis*) leptin coding sequence showed only 65% homology with pufferfish, 52% with rainbow trout and 46% with mouse. PCR showed that leptin mRNA was exclusively expressed in the liver, and not adipose or other tissues. We then evaluated whether the metabolic status of HSB might alter leptin gene expression. Juvenile HSB (100 g) subjected to three weeks of food deprivation had significantly lower levels of hepatic leptin mRNA expression than fed controls, as measured by quantitative PCR. In a separate experiment HSB were initially subjected to 3 weeks feed deprivation followed by 3 weeks of refeeding. Fasting for 3 weeks again reduced leptin mRNA levels relative to fed controls. Leptin mRNA levels then increased upon refeeding, albeit levels were not completely restored to those seen in control fish fed throughout the study. This study represents the first characterization of leptin in a Perciforme, the largest Order of fish. We show that the liver predominantly produces leptin and that leptin gene expression changes with feeding state, decreasing under catabolic states. These results are consistent with a potential role for leptin as a regulator of energy reserves in teleosts.

19.4 WONG, R.Y.*; CUMMINGS, M.E.; University of Texas at Austin; *ryan.wong@mail.utexas.edu*

Brain regions associated with female preference behavior in a poecillid fish, Xiphophorus nigrensis

Individual variation in female preferences for a mate can be seen in a wide range of taxa. Yet little is known about the underlying proximate mechanisms behind this variation despite the potential important evolutionary consequences. Here we present our findings on brain regions that may underlie female mate choice behavior in a poecillid fish, *Xiphophorus nigrensis*. Females (n=30) were subjected for 30 min. to one of three treatment conditions in a classic dichotomous choice setup: mate choice, a female social control, and an asocial experimental handling control. We recorded the association time and female behaviors exhibited during the trials in order to assign preference and activity scores. After the behavior trial, females were immediately sacrificed, cryosectioned onto serial series, and prepped for nonradioactive *in situ* hybridization. Through optical density measurements, we measured the localized expression of a neural activity marker (*egr-1*) and two previously identified candidate genes for mate preference behavior (*neuroserpin* & *neuroligin-3*) in several brain nuclei. Utilizing the individual variation in female preferences in this species, we show preliminary evidence that the area dorsomedialis (Dm) and area dorsolateralis (Dl) of the telencephalon have a significant positive relationship between optical density and preference only in mate choice conditions. This suggests that these telencephalic nuclei may play a more important role in preference behavior.

82.1 WONG, G.K.; Quinnipiac University; *Gene.Wong@quinnipiac.edu*

Creating Interactive Instructional Experiences By Utilizing Technology To Enhance Student Learning

The traditional teaching involves the instructor at the front of the room while students watch, listen, and take notes. Afterwards, students review their notes and textbooks to study for the examination. This format can make it difficult for an instructor to gauge student understanding of the material presented during class. The gradual incorporation of different technologies in a two-semester Comparative Anatomy & Physiology course, and Developmental Biology course provided methods that allow students to learn and review material in a variety of ways. The technologies include student remote response systems used in the classroom, and online resources that include pre-recorded audio/visual lectures, lecture outlines, wikis, online review quizzes and games, and electronic flashcards. Many of the online resources were also made available off-line to students, converted so that they were usable in iPods. In general, students having access to these materials have demonstrated better performance on examinations and overall final grades in the course. Students surveys also noted a high degree of satisfaction with the resources provided to them. This presentation will demonstrate how these technologies are incorporated into a two-semester Comparative Anatomy & Physiology course, and how it has helped students learn and comprehend the large volume of material.

91.3 WOODS, S.B.*; BARNES, B.M.; HUMPHRIES, M.M.; Natural Resource Sciences, McGill University, Institute of Arctic Biology , University of Alaska Fairbanks; *murray.humphries@mcgill.ca*

Resource-dependent cold climate heterothermy in free-ranging red squirrels

Although not as dramatic as daily or prolonged torpor expression, shallow reductions in body temperature (T_b) expressed by so-called homeothermic endotherms may be a significant contributor to their energy conservation during daily or seasonal periods of energy shortage. We documented T_b variation of a cold climate population of free-ranging red squirrels (*Tamiasciurus hudsonicus*) during winter using surgically implanted data loggers. Among the 24 individuals successfully monitored, minimum, average and maximum recorded T_b was 34.1, 38.1, and 42.3 ºC, respectively. T_b was higher during activity than when in the nest and during the day than at night, with an average daily range of 3.5 ºC (range 2.2-6.5 ºC). Daytime T_b was positively related to ambient temperature(T_a), which ranged from -38 to -3 ºC during the study period. Half of the monitored individuals that were provided with ad libitum food prior to and during T_b measurements were characterized by slightly but significantly warmer T_b than controls (38.3 vs. 37.9 ºC) across the range of encountered T_a. Although T_b does not vary by much within and among individual red squirrels, its responsiveness to both ambient temperature and food availability demonstrates that shallow reductions in T_b are facultatively employed by red squirrels during cold periods of food scarcity.

17.3 WOODS, W. A. Jr.*; TRIMMER, B. A. ; Tufts University; *william.woods@tufts.edu*

Effects of temperature on dynamic properties of active and passive caterpillar muscle: Q_{10} less than 1?

Caterpillars are soft-bodied terrestrial climbers that accomplish a wide variety of complex movements over a broad range of ambient temperatures using several hundred muscles. We examined temperature dependence of passive and dynamic characteristics of *Manduca sexta* ventral interior longitudinal muscle, a comparatively large muscle known to serve alternately as a locomotor and as a damper during each crawling strain cycle. At temperatures of 20 to 30 °C, we recorded passive tension at resting length, peak force after stretching, and peak force under tetanic stimulation of individual muscles in saline mimicking hemolymph. Surprisingly, all changes in these parameters were inversely related to temperature. Resting tension declined linearly by 25% as temperature increased (Q_{10} = 0.75). Under linear stretching from 90 to 110% of resting length, peak force dropped by similar percentages at all strain rates from 0.1 to 1.6 lengths s^{-1} as temperature increased (Q_{10} = 0.54). Peak force reached during 4 s tetanic stimulations diminished by fivefold over the same temperature range. To examine how these unexpected temperature responses might affect stimulus patterns required for crawling at different temperatures, we subjected muscles *in vitro* to strain cycling and stimulation similar to those previously determined during crawling *in vivo* at 23-25 °C. As preparation temperature was reduced from 25 to 20 °C, the portion of the strain cycle where positive work was done shifted in the same manner as when stimulus duration was increased at a fixed temperature. These results raise the possibility that crawling caterpillars may employ different stimulus patterns at different temperatures.

6.3 WULFF, Janie; Florida State University; *wulff@bio.fsu.edu*

Context-dependency of growth rate and vulnerability to predators of Caribbean coral reef sponges

Sponges play key functional roles on coral reefs, including filtering the water column, gluing live corals to the reef frame, protecting exposed carbonate skeletons from excavating organisms, and facilitating regeneration of damaged reefs. Concerns that these roles could be lost due to declines in sponges, or, conversely, that sponges could overgrow reef surfaces with detrimental effect, impel understanding of factors that control sponge distribution and abundance. Relative importance of top down versus bottom up trophic factors was evaluated by comparing size changes and survival of 12 common species of Caribbean coral reef sponges in three linked habitats that differ in spongivore abundance and taxa and in water column productivity. Sponge pieces of the same size and genotype were attached to stable solid substrata inside cages and next to, but outside of, cages on the reef and in the seagrass, and on PVC pipes suspended among mangrove roots. Growth and survival were monitored at intervals for 1-3 years. For most sponge species, growth and survival were indistinguishable inside and outside of cages on the coral reef, but in the seagrass most species did not survive outside of cages. Curiously, both growth and survival of the coral reef sponges were highest among the mangrove prop roots.

1.1 WUND, Matthew A.*; FOSTER, Susan A.; BAKER, John A.; Clark University; *mwund@clarku.edu*

Predation history and the evolution of antipredator behavior in threespine stickleback fish

Isolated populations of threespine stickleback fish encounter various predator assemblages, and thus might exhibit substantial variation in antipredator behavior, and the underlying endocrine stress response. Ancestral, oceanic stickleback populations encounter many predators, including predatory fish, while derived, freshwater populations typically experience reduced predator assemblages. In particular, many lakes contain native predatory fish while others do not, and in many Alaskan lakes historically lacking predatory fish, game trout have recently been introduced. We are investigating whether these differences in predation history have led to differences in antipredator behavior and baseline and post-stress cortisol levels among stickleback populations. Preliminary results indicate that antipredator behavior covaries with predation regime in wild-caught fish, but this relationship is diminished in laboratory reared fish, suggesting a prominent role for learning. We are currently exploring whether cortisol levels differ among populations, and if this variation relates to predation history.

33.1 WYETH, R.C.*; CROLL, R.P.; St. Francis Xavier Univ., Dalhousie Univ.; *rwyeth@stfx.ca*

Peripheral sensory cells in the cephalic sensory organs of the pond snail Lymnaea stagnalis

The study of nervous systems in gastropods has focused primarily on central and motor systems, with sensory systems receiving less attention. In particular, peripheral sensory neurons have been only erratically studied across several species. Yet peripheral sensory cells play a crucial role in the neural control of behavior. We are attempting to fill this gap in our understanding of gastropod neuroethology by mapping the peripheral sensory cells in the cephalic sensory organs of *Lymnaea stagnalis* using backfills, immunohistochemistry, and vital stains. We have found evidence for ciliated catecholaminergic sensory cells, ciliated histaminergic sensory cells, and two classes of nitrergic sensory cells, at least one of which appears to not be ciliated. The histaminergic cells project centrally while the nitregic cells without cilia have no projections. Mapping the projections of the remaining nitrergic cells and the catecholaminergic cells is complicated by the possibility of further classes of non-sensory peripheral neurons with similar neurotransmitters. All four classes of sensory cells have distinctive, non-uniform distributions over the surface of the cephalic sensory organs. None of the morphologies or distributions leads to an obvious hypothesis for either a chemosensory or mechanosensory role. Our next step will thus be to use optical recording experiments to test the cells responses to mechanical and chemical stimuli, and thus link sensory cell morphology to modality for the first time in gastropods. This work opens the possibility of further comparative studies of the peripheral nervous system across gastropods, and can also guide studies of sensory systems roles in the neural control of behavior in *Lymnaea* and other gastropods.

24.5 WYNEKEN, Jeanette; Florida Atlantic University; *jwyneken@fau.edu*

Structure and Function of theTurtle Heart Through In Vivo Imaging of Blood Flow

Cardiac structure is quite varied within nonavian sauropsids (reptiles) including shape of the heart, extent of separation of the three intraventricular compartments, degree of development of the intraventricular muscular ridge, and the trabecular network. Species with short or round ventricles tend to have many trabecular ridges compared with those that have elongate ventricles. The structural variations are important in defining major functional differences in reptiles. In species whose hearts lack distinctive intracardiac specializations, how pulmonary and systemic blood flows are maintained by the structure remains as speculation. The hearts of turtles tend to be round, have many densely packed trabeculae, and have less pronounced muscular ridge development when compared with other reptiles. In some suaropsids the muscular ridge is important in separating high O_2 vs. low O_2 intracardiac flow. The implications of this structural arrangement are that blood flow from the pulmonary and systemic circulation should mix easily in the ventricle. Published physiological studies do not support such a conclusion. In this study, noninvasive imaging was used to trace blood flow in marine turtles. These turtles have relatively large hearts that are relatively easy to view during imaging. To better understand the functional roles of the intracardiac structure in turtles, blood was traced from the sinus venosus to the right atrium and through the interconnected ventricular compartments that are typically viewed as parts of the single pumping system. The results of *in vivo* functional anatomical imaging suggest that in marine turtles, flow streams from the systemic circulation may be partially maintained structurally by the trabecular networks along with the muscular ridge and also are separated temporally by the intraventricular compartments.

54.7 YEATES, Laura C.*; WILLIAMS, Terrie M.; TINKER, M. Tim; Univ. of California Santa Cruz; *yeates@biology.ucsc.edu*

The Challenge of Energetic and Thermal Balance in Aquatic Environments: a simple bioenergetic-behavioral model for sea otters

Because of its high surface to volume ratio, elevated metabolic demands, and reliance on fur insulation, the sea otter represents an extreme example of the energetic and thermal challenges of marine living by mammals. To assess daily activity patterns and budgets, twenty two adult sea otters (6 males,16 females) were captured and tagged using temperature sensitive VHF radio transmitters. Additionally, two captive adult sea otters were used to measure energetic costs of foraging, grooming, swimming and resting. Data from daily activity budgets, behavior specific energetic costs and the relationships between core body temperature and behavior were used to develop an integrated bio-energetic behavioral model for wild otters. The model was used to address the importance of maintaining an elevated core body temperature while living in water, how changes in the proportion of the day spent performing energetically costly behaviors affect energy stores, and how the caloric value of prey impacts the cost to benefit ratio. In simulation 1, thermal stability was dependent on the heat increment of associated with a predictable schedule of meals occurring throughout the day and night. Engaging in energetically costly behaviors such as swimming to different areas to obtain food quickly put the sea otter into an energy deficit, although body temperature could be maintained. In simulation 3, the availability of high quality food resulted in a surplus of energy and cost benefit ratio of 2.5 while poor quality or dispersed food resulted in cost benefit ratio of 0.7. Using a relatively simple bioenergetic-behavioral approach can provide insight into the vulnerability of this small, recently evolved marine mammal to such perturbations and may applicable to other mammals as well.

15.6 YEN, J.*; CATTON, K.; WEBSTER, D.; Georgia Institute of Technology, Biology, Georgia Institute of Technology, Civil and Environmental Engineering; *jeannette.yen@biology.gatech.edu*

The Hydrodynamic Wake of Two Species of Swimming Krill

Krill are often found in unorganized swarms or coordinated schools depending on the species. To test if group organization is related to the hydrodynamic wake produced by swimming krill we quantified the flow structure in the wake of Euphausia superba, a schooling Antarctic krill, and Euphausia pacifica, a swarming Pacific krill. In this study, we used infrared Particle Image Velocimetry (PIV) to analyze the structure of the hydrodynamic disturbance of free-swimming individual specimens. The downward directed jet produced by E. pacifica has a lower maximum velocity (3.4 +/- 1.1 cm/s vs. 6.2 +/- 1.3 cm/s), has a steeper wake angle (59 +/- 20 degrees vs. 48 +/- 14 degrees), and decays faster (0.3 s vs. 0.6 s) than the jet of E. superba, which suggests that the wake is less persistent for signaling in the smaller krill species (E. pacifica). Time record analysis reveals that the wake flow is very weak beyond 0.5 body length for E. pacifica and beyond 1 body length for E. superba. Since E. superba separation distances within a school range from 1 to 3 body lengths (from previous data), it appears that E. superba may not be using solely the hydrodynamic signal to facilitate schooling.

73.2 YOO, E/H*; LEE, D/V; BIEWENER, A/A; Harvard University, University of Nevada Las Vegas; *eyoo@oeb.harvard.edu*

Actuation and compliance of goat foreleg during landing jumps

Using high-speed video and force plates, we collected foreleg kinematics and ground reaction force data in three adult male African Pygmy goats (*Capra hircus*) performing landing jumps from a 1.3 meter platform. External moments and work were calculated for elbow, wrist, and metacarpophalangeal joints. We then model each joint as a serial actuator and spring and calculate the spring constant that minimizes total actuator work using experimental joint moment and joint angle data. We expect calculated spring/actuator work data from our model to be consistent with differences observed in muscle-tendon anatomy of proximal vs distal joints.

S10.5 YOSHIMURA, T.; Laboratory of Animal Physiology and Avian Bioscience Research Center, Graduate School of Bioagricultural Sciences, Nagoya University; *takashiy@agr.nagoya-u.ac.jp*

Molecular and Endocrine Mechanisms of Vertebrate Photoperiodic Response

Animals living outside the tropics use changes in photoperiod to adapt to seasonal changes in environment, but the molecular mechanisms underlying photoperiodic response are not fully understood. The Japanese quail is a robust model for the study of these mechanisms because of its rapid and dramatic response to changes in photoperiod. Local thyroid hormone catabolism within the mediobasal hypothalamus (MBH) by thyroid hormone-activating enzyme (DIO2) regulates the seasonal reproduction. Rapid induction of *DIO2* gene expression in the ependymal cells (EC) lining ventrolateral walls of third ventricle of the MBH was the earliest event yet recorded in the photoperiodic signal transduction pathway. To address the identity of the photoperiodic transduction pathway, we have dissected the molecular dynamics of gene expression regulating photoinduced thyroid hormone catabolism using a chicken high-density oligonucleotide microarray. We identified two waves of gene expression. The first was initiated ~14 h after dawn of the first long day and included increased thyrotropin (TSH) beta subunit expression in the pars tuberalis of the pituitary gland; the second occurred ~4 h later and included increased *DIO2* expression. TSH receptor was found in the EC of the MBH and intracerebroventricular administration of TSH to short day quail stimulated gonadal growth, and expression of *DIO2*. This TSH induced expression of *DIO2* was shown to be mediated through a thyrotropin receptor-cAMP signaling pathway by the promoter analysis. Increased pars tuberalis TSH therefore appears to trigger long day photoinduced seasonal breeding.

103.2 YOUNG, N.M.*; FONDON III, J.W.; University of California, San Francisco, University of Texas at Arlington; *nathan.m.young@gmail.com*

Artificial Selection, Developmental Constraints, and Craniofacial Variation in the Feral and Domesticated Pigeon (Columba livia)

The relative importance of selection and constraint in evolution is one of the oldest questions in biology. While selection determines the fate of alleles, biases in the pattern of variation define selection's sphere of influence. Observed phenotypic variation consequently is the product of both processes, yet disentangling their relative contributions can be difficult since selection reduces diversity. This discordance between observed and potential variation confounds investigations of developmental constraints, mutation bias, or other factors impacting phenotypic variance. In contrast, organisms often exhibit greater phenotypic variation under domestication, but it is unclear what relationship this variation has to that found in their wild counterparts. Here we hypothesize that domesticated breeds of the common pigeon (*Columba livia*) represent extensions of variation found in the feral pigeon shape space. To test this hypothesis we compared craniofacial variation in feral pigeons (N=40) to that of 43 domesticated pigeon breeds (N=63) using Principal Components Analysis of 3D shape coordinates acquired by CT. Results reveal that the principal components of variation are essentially identical between feral and domestic pigeons, and that domestic pigeons are effectively exaggerations of the same types of variation appearing in feral pigeons. These results suggest that domestic pigeon breeds represent a high signal-to-noise system that is a potentially powerful model for measuring morphological covariance and constraint by enabling the dissection of the basic axes of natural craniofacial variation.

12.2 YOUNG, R. L.*; CAPUTO, V.; GIOVANNOTTI, M.; KOHLSDORF, T.; WAGNER, G. P.; Yale University, University of Ancona; *rebecca.youngbrim@yale.edu*

Molecular evidence of a digit identity frameshift in the Italian Three-toed Skink (Chalcides chalcides)

While modifications of trait development are required for evolutionary change in phenotypes, evolutionary persistence of phenotypes across taxa does not require maintenance of developmental pathways. Several studies of digit reduction exemplify this phenomenon by calling into question the homology of the remaining digits. In birds, the debate results from a conflict between embryological and anatomical evidence of digit identity. The avian hand contains three digits. Morphologically the digits resemble ancestral digits I, II, and III; however, embryological data reveals that these structures develop from digit condensations II, III, and IV. Extensive investigations of developmental and molecular mechanisms of digit formation in the avian hand have resolved this conflict by providing evidence of a digit identity frameshift during development. In this case, the properties of development critical for generating digits I, II, and III are shifted onto digit condensations II, III, and IV. In the Italian Three-toed Skink (*Chalcides chalcides*), a similar conflict between anatomical and embryological evidence of digit homology has been described. Here we ask whether the same mechanism, a homeotic frameshift in digit identity, can resolve the conflict between the developmental origins and adult morphology of digits in both the fore- and hindlimb of *Chalcides chalcides*. We first detail the anatomical and embryological evidence of digit homology in this system. Second, we examine expression patterns of posterior HoxD genes with known expression and function in digit identity determination. Finally, we discuss the implications of our findings for the role of the frameshift as a mechanism of dissociation of character identity and morphology and the importance of this mechanism for character evolution.

104.3 YOUNG, B.A.; University of Massachusetts at Lowell; *Bruce_Young@uml.edu*

Anaconda locomotion: Gait transitions and a novel form of terrestrial locomotion

Snakes have traditionally been divided into "sit and wait" ambushers and active foragers. The former group is typified by slow moving heavy-bodied snakes that rely on venom (vipers) or constriction (pythons) to capture their prey. The primary goal of this study was to document the locomotor kinematics and gait transitions of a species that presumably has no specializations for terrestrial locomotion. The anaconda (*Eunectes*) is a relatively basal taxa, primarily aquatic, predominantly a sit and wait ambush forager, and is among the largest snakes in the world. This study incorporated a combination of standard and high-speed digital videography, as well as force plate analysis, to explore the terrestrial locomotion. Four distinctive gaits were documented; gait sequuence and the velocity at gait transition were highly influenced by substrate and environmental factors. These snakes exhibited a previously undescribed form of high-speed locomotion, herein termed collateral locomotion. Using this form of propulsion, these heavy bodied snakes were able to move at rates of several body lengths per second.

8.4 YUND, P.O.*; KREGTING, L.J.; BASS, A.L.; AVENI-DEFORGE, K.; TILBURG, C.J.; THOMAS, F.I.M.; Univ. New England, Univ. New England; Univ. Hawaii, Univ. Hawaii; *pyund@une.edu*

Flow and Fertilization in Sea Urchins: A Combined Flume and Field Approach

Past work on the ecology of fertilization in sea urchins has tended to assume that gametes are quickly diluted upon release and immediately enter free-stream flows, with eggs either quickly fertilized in the water column, or advected out of the sperm plume. Yet the biology and physics of urchin fertilization do not appear to be consistent with these assumptions. Gametes are released in viscous fluids that resist dilution and remain on the aboral surface for hours, concentrated sperm are continuously advected downstream, and eddies that form downstream of females may entrain gametes and increase mixing and the probability of sperm:egg contact. Consequently, we have been employing a combined laboratory flume and field approach to explore how variation in flow affects where fertilization occurs and the probability that eggs are fertilized. In both unidirectional and oscillatory flows, fertilization decreased with increasing Reynolds stress, and many eggs were fertilized either on the aboral surface, in the downstream eddy, or on the substrate. At two field sites, Reynolds stress above sea urchins could be predicted with wave height data from oceanographic buoys 13-17 km away. We then used these regression equations to predict the distribution of Reynolds stress during sea urchin spawning season from the distribution of wave heights. Our results suggest that fertilization is not necessarily a water column process, and that sea urchin fertilization may be less limited by sperm availability than previously believed.

1.7 ZAMZOW, J.P.*; AMSLER, C.D.; MCCLINTOCK, J.B.; BAKER, B.J.; Univ. of Alabama Birmingham, Univ. of South Florida; *jzamzow@gmail.com*

Hiding in the bushes: Structural and chemical determinants of habitat choice in Antarctic amphipods

Amphipods are important components of near-shore marine environments of the Antarctic Peninsula. Population densities are much higher on highly structured, chemically defended algae (e.g., *Desmarestia menziesii*) than on simply structured, non-chemically-defended algae (e.g., *Palmaria decipiens*). Habitat preferences of two Antarctic amphipod species were determined in pair-wise experiments. Fresh thalli and artificial analogues of *D. menziesii* and *P. decipiens* were used to elucidate the relative contributions of structure and chemistry to amphipod host-alga choice. Trials were performed in both fresh seawater and water containing chemical cues of the abundant nearshore fish predator *Notothenia coriiceps*. In fresh seawater, the amphipod *Prostebbingia gracilis* preferred *D. menziesii* to all other alternatives. If *D. menziesii* was not available, *P. gracilis* preferred fresh *P. decipiens* over its plastic analogue, and preferred the highly structured analogue to the simple one. In contrast, the amphipod *Gondogeneia antarctica* preferred *P. decipiens* over all other alternatives. If *P. decipiens* was not available, the only preference displayed was for fresh *D. menziesii* over its plastic analogue. In seawater containing predator cues, preferences of *P. gracilis* did not change, but *G. antarctica* preferred fresh thallus of *D. menziesii* to *P. decipiens*. In predation experiments using *N. coriiceps*, more *P. gracilis* survived on the highly structured *D. menziesii* and its analogue than on the simply structured habitats. There was no difference in survivorship on fresh thalli vs. their plastic analogues, indicating that structural complexity is sufficient to provide some refuge from predation for *P. gracilis*.

2.4 ZANI, P.A.*; ROLLYSON, M.E.; Lafayette College; *zanip@lafayette.edu*

Influences of short- and long-term climate fluctuations on ectotherm life histories revealed by biophysical modeling of lizards

Global climate change continues to impact the seasonal timing of events such as the onset of favorable and unfavorable growing seasons. By examining past changes in climate one may understand how future changes will impact organisms. We created a biophysical model that predicts spring emergence, onset of reproduction (oviposition), and winter retreat for an ectotherm, the side-blotched lizard (*Uta stansburiana*), using temperature and day-length data as well as assumptions about activity and preferred body temperatures. Following verification of the model using multi-year life-history data from a lizard population in eastern Oregon, we used meteorological data for the past 70 years to test the hypothesis that spring emergence and oviposition have been advanced (earlier onset) and that winter retreat has been delayed due to changing climate. Results indicate that for this Pacific Northwest population spring emergence is actually later in recent years, oviposition is unchanged, and the onset of winter is progressively earlier. Further investigation revealed a significant correlation between short-term climate fluctuations (El Nino-Southern Oscillation [ENSO]) and oviposition (but not emergence or retreat) such that warm, dry winters (positive ENSO) in the Northwest result in the early onset of oviposition. Interestingly, long-term climate fluctuations (Pacific Decadal Oscillation [PDO]) are correlated with retreat (but not emergence or oviposition) such that warm periods (positive PDO) result in the earlier onset of winter in this population. Thus, in order to understand the effects of climate change on the life histories of organisms it may be necessary to take into account the influences of regional climate as well as short- and long-term climate fluctuations.

22.4 ZELDTICH, M.L.*; SWIDERSKI, D.L.; WOOD, A.R.; Univ. of Michigan, Ann Arbor; *zelditch@umich.edu*

Modularity and integration of mandibular size and shape

The mammalian mandible is a developmentally modular, functionally integrated system. Whether morphological integration can evolve to match functional integration may depend on the developmental origin of integration, specifically, on the role played by direct epigenetic interactions, which are hypothesized to be conservative and therefore potentially constraining. Using the prairie deer mouse and fox squirrel mandibles as model systems, we examine patterns of integration in size and shape, isolating direct epigenetic interactions by analyzing correlation structure of fluctuating asymmetry (FA). In both species, we find shapes of adjacent parts to be correlated along the proximodistal jaw axis whereas more distant ones generally are not. Species differ in relationships between dental alveoli and muscle-bearing parts of the jaw, with the molar alveolus linked to more parts, and the incisor alveolus to fewer, in deer mice than squirrels. Size is more highly integrated for both symmetric and FA components, even in conditional independence graphs. Dental alveoli are typically as highly integrated with muscle-bearing parts of the jaw as with each other, arguing against the several hypotheses that regard them as separate developmental and/or functional modules. For size, the structure of integration is similar between symmetric and FA components, although the two components differ more in conditional independence relationships. The two species are moderately similar in both components, slightly less so in conditional independence relationships for FA. The structure of integration suggests that the mandible is a single connected unit, a result consistent with its functional integration. The weak similarity in structure of conditional independence relationships for FA argues against direct epigenetic interactions being constraints.

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Molecular identification of a sclerotome in lampreys and sharks: implications for the origin of the vertebral column

Origin of the vertebrae is one of the central stories of vertebrate evolution. Vertebral elements first appeared in the jawless fish, although their embryonic origin remains unclear Early comparative and embryonic data suggested it may be derivative of the sclerotome, similar to the situation in amniotes. The only molecular data on lamprey Pax1/9 suggested sclerotome may not present in lampreys. While, the major cartilage matrices in jawless fishes have been reported to be non-collagenous, instead their cartilage is made of elastin-like molecules, named lamprin and myxinin. Thus the embryonic origin of the lamprey axial skeleton, termed arcualia, remains a puzzle. Very recently we demonstrated that agnathans cartilage matrix is composed type II collagen like gnathostomes. Concurrently, Col2a1a is expressed in the paraxial mesoderm. This led us to hypothesize that lampreys may possess a sclerotome that might contribute to the development of arcualia. We investigated seven sclerotome marker genes and their expression patterns in lamprey. We also re-examed the PmPax1/9A expression patterns in four lamprey species including the Japanese lamprey, along with a new cloned Pax1/9 homologous gene, PmPax1/9B. Except PmPax1/9B , all the sclerotome marker genes including the PmPax1/9A are expressed in the medioventral part of the somite, which is the position of sclerotome in amniotes. Ontogenetically, our data strongly suggested that lamprey do possess sclerotome and that it contributes to the development of arculia, the earliest vertebral elements. The phylogenetic analysis of these sclerotome markers revealed that all of them underwent a gene duplication event, probably as a part of whole genome duplication. And the origin of these sclerotome markers may account the phylogenetic origin of vertebral columns.

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Aerodynamic effects of wing flexibility in flapping flight

Wings of insects are flexible structures. Although there has been much recent progress in the area of insect flight aerodynamics, very little is known about how wing flexibility influences aerodynamic forces during flapping flight. We investigated this question using a dynamically scaled mechanical model of insect wings. Using a suite of wings with varying flexural stiffness (EI) values, we generated aerodynamic polar plots to characterize the force coefficients of flexible wings. These polar plots showed that the aerodynamic performance of the wings varied with wing flexibility. In general, aerodynamic force production decreased with increasing flexibility. Both lift and drag coefficients of wings were greater when wings were more rigid. However, at very high angles of attack, flexible wings generated greater lift than a rigid wing. In addition, the ratio of lift-to-drag also decreased with increasing flexibility. In both rigid and flexible wings, the measured center of pressure showed little variation. These data show that flexible wings offer no aerodynamic advantage over a rigid wing under steady state circumstances. Because wing material in insects is usually flexible but reinforced by wing veins, we tested the hypothesis that wing veins enhance the aerodynamic performance of wings by increasing their effective stiffness. Our data suggests that even a very basic framework of appropriately placed wing veins can substantially increase the functional rigidity of the wings thereby enhancing its aerodynamic performance.

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An additional role for molt-inhibiting hormone in the mature female blue crab Callinectes sapidus as a vitellogenesis stimulating hormone

Molting and reproduction in crustaceans are hormonally controlled by the family of crustacean hyperglycemic hormone (CHH) neuropeptides. To test the role of these neuropeptides of CHH and molt-inhibiting hormone (MIH) in the control of vitellogenesis in the female Callinectes sapidus, we profiled the expression levels of these genes and hemolymph titers during the reproductive cycle and their direct effect on vitellogenesis in vitro. The concentrations of MIH in hemolymph were higher at ovarian stages 2 and 3 than those at stage 1, while CHH remained constant. The data indicates that despite the females at terminally anecdysis, MIH is being expressed and secreted in a vitellogenic stage dependent manner. Tested in-vitro, MIH caused a 60% decrease in vitellogenin (VtG) mRNA, but stimulated the secretion of VtG by two folds as well as the transcription of heterogeneous nuclear VtG RNA (HnVtG) by 2.5 folds. Our results demonstrate that MIH has a stimulatory role in vitellogenesis in the female C. sapidus at the levels of transcription and translation of VtG in hepatopancreas. Furthermore, to ensure the hepatopancreas as being a target tissue of MIH, a preliminary binding study was carried out using the membranes of hepatopancreas of the vitellogenic females and [125I] MIH, together with Y organs as a reference tissue. Both tissues exhibited the specific binding sites, but with the differences in the values of KD and BMAX. Overall our data suggests that the functions of MIH in the regulation of molt and vitellogenesis are mediated through tissue specific receptors with different kinetics and signal transduction.

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Food for thought: the effects of roasting and mechanical tenderization on food material properties, masticatory force production and comminution.

Can *Homo* facial and dental size decreases be attributed to the adoption of food processing techniques? This study experimentally tests the extent to which roasting and mechanical tenderization of meat and root vegetables (tubers) affect food material properties and subsequently masticatory force production and comminution efficiency. The toughness, modulus of elasticity and fracture stress of each food was determined. 15 subjects chewed size-standardized samples of the raw, roasted or mechanically tenderized food. EMG signals from the balancing side masseter were collected and calibrated to masticatory force using a force transducer. Comminution (fragmentation) performance was assessed by measuring the particle size distribution of unswallowed food boluses. Preliminary results suggest that processing affects masticatory performance differently depending on the type of food and processing technique used. Roasting increases meat toughness, modulus of elasticity and masticatory force production, but decreases those same parameters for tubers. Roasting also appears to affect the degree to which meat, but not tubers, are fractured in the oral cavity. Mechanical tenderization of meat does not affect comminution, however subjects chewed these samples less than those that were raw or roasted, resulting in a net decrease of total masticatory force production. Although data regarding the effects of tenderizing tubers still needs to be analyzed, these initial results suggest that food mechanical tenderization may have played an important intermediate step in hominid cranio-dental evolution prior to the advent of cooking.