80.1 ADAMS, Rick A.; Univ. Northern Colorado, Greeley; nick.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.

80.3 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.
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 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.

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.
These flows are generated by interaction between the wakes of the two wings and axial flows along the body axis and away from the bird. We propose that corresponding to each stroke. The region around the tail is dominated by the body axis. These results are consistent with a ring vortex pattern with respect to the bird are consistently from the periphery to directly underneath that flow oscillates between the forward and backward directions in response to the bird's kinematic patterns. 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 hummingbirds (Calypte anna) use complex tail kinematic patterns ranging in phase to antiphase movement with the wings, covering several phase shifts. Our hypothesis asserted that more resources permit continued growth after sexual maturity to an eventual larger body size; thus, adult Ilyanassa were predicted to allow a reduction in one phase of the developmental period (intrapractebral development) in favor of the presence 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.

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 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 battle to generate pitching moments that contribute to pitch stability.

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.

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

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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 projection 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 due to the development of their tongue projection mechanism, which has been shown to maintain tongue projection performance at a high level at low temperatures. 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 in cutting biological tissues. 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's 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.
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 individual’s 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.

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 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 nanoindentation 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.
Patterns of Variation in Chiropteran Wing Folding: With Special Attention to Differences in 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.

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 pagun) and species of the Athelgineae (Isopoda: Bopyridae: ?Athelges takahashimensis) 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. virescens 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 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.
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 aponeuroses 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 elastic energy storage.

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

The remarkable jumping ability of most frogs can not 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.
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.

Impact of stressor exposure on intestinal microbiota

Recent murine studies, exposure to a prolonged stressor (i.e., repeated restraint stress) led to a significant overgrowth of Gram-negative bacteria. In more recent studies, 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.

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 forebrain. 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 male 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.

87.1 BALTZEGAR, David A.; OZDEN, Ozkan; BORSKI, Russell J.; North Carolina State University, Raleigh; dbaltzegar@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: Cldr3c, Cldr28a, and Cldr30 in the Mozambique tilapia (Oreochromis mossambicus). Maximum likelihood phylogenetic analyses of tilapia Cldr28a and Cldr30 suggest distant homology to mammalian Cldn4, while Cldr3c is related to mammalian Cldn3. We found that the mRNAs of these Claudins were expressed in a tissue-specific distribution profile in freshwater (0-2 ppt) and seawater (2/3 SW; 25 ppt) fish. Expression of these genes is most abundant in gill and skin, with Cldr30 and Cldr3c also showing significant abundance in posterior intestine. In the gill, Cldr3c expression is significantly lower in seawater fish (p < 0.001) compared to freshwater fish. Cldr28a and Cldr30 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; mbaltzley@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 placenta development 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.
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 ailments (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 molluscs. 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 polygonal tablets tightly stacked to form a three dimensional brick wall. A.

Fracture of Nacre from Mollusc Shells

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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 ailments (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 molluscs. 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 polygonal tablets tightly stacked to form a three dimensional brick wall. A.
Lateral line-mediated prey detection in the Lake Malawi cichlid, Aulonocara hansbaenschii

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. hansbaenschii. 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. hansbaenschii: 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.

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 (CGV) 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 CGV 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, Atherinopsis 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.
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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. Lattitudinal 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, and deprived of food will enter deeper hypothermia

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

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.

58. BELYDEN, L.K.*; WOJDAK, J.M.; Virginia Tech, Radford University;

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 Ribeirioa 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.
of habitats through modulation of their locomotor kinematics. This implies 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 gonad.

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 gonad.

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 elogate 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.
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 Americocephalus magna. Surprisingly, we found 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.

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).
inability to move with pendulum-like mechanics. Flight-mode locomotor speeds for steady speed locomotion, more so than an locomotion in other small mammals may reflect their tendency to use the predominant use of spring-mass mechanics during steady speed forage for widely distributed prey. Our observations support a hypothesis that customarily at moderate to slow speeds, relatively undisturbed, as they unarmored mammals; instead, they may have been selected to move predominantly running mechanics in other small mammals. Mammals with mechanics at higher speeds. These observations are in contrast to the, although hedgehogs were also capable of moving with spring-mass 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.
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 hystric. 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. [...]
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 following 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 NA08MF4270416 to CWW)

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.
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.

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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.

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 vibrometry to measure and compare the resonant properties of the secondary feathers of the Club-winged manakin relative to other non-sounding 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 resonate at the 1500 Hz frequency. These results lend critical support to the resonant stridulation hypothesis of sound production in Machaeropterus deliciosus.

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 is 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.
Morphologies, feeding mechanisms and patterns of species richness.

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 parasitize fishes. Mussels may attract fish hosts by using lures that are modifications of the mantle or by releasing conglutinates of eggs 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.

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.

Effect of varying weight and inertia on maximum attainable running speed in humans.
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 Entophiliinae) 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 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.

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 adult 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.
Evolution of physical interactions among the transcription factors HoxA-11 and FOXO1α 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 FOXO1α. 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, FOXO1α 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.

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.

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-glucose) 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.
Activity of intestinal carboxydases responds to multiple dietary signals in nesting 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 a 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, 66% 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 significantly almost doubled in birds fed diet with starch. But, on diets with similar starch content (B and C), summed carboxydases 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 carboxydases activities were thus consistent with the adaptive modulation hypothesis, but high oil had a counteracting effect on carboxydase 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.
Physiological and behavioral responses of molting house sparrows to protein stress

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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.
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 sparrowsex 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, and we did not have an effect on antibody formation to KLH in males 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.
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-gonadal 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.

**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.
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 osteoglossomorphs) 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, osteoglossomorphs 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).

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 (lg) 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 jawed vertebrates, appears to play a particularly widespread role in metazoan immunity, as recent reports have also implicated Ig domains in the early cleavage embryo to ultraviolet radiation. Increasing solar ultraviolet radiation (UVR, 290-400 nm), especially ultraviolet B (UVB, 290-320 nm) is reaching Earth's surface due to ozone depletion and global climate change. Embryos of the purple sea urchin, Strongylocentrotus purpuratus, provide an ideal system for modeling the proteomic 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 887 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.
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 Enteropneusta; 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.

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 platyrhynchos) 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.
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-acetylglicosamine, 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.
**16.2 CECILE, Helmettetter; 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 hyptrophy 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.

**94.3 CHAPPLE, T.K.*; JORGENSEN, S.J.; ANDERSON, S.D.; VAN SOMMERAN, S.; KLINLEY, A.P.; BOTS福德, L.W.; BLOCK, B.A.; University 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 localized movement data. A combination of these two tagging technologies and altricial species appear to have enlarged their telencephalon by altering neurogenesis onset (stage22/ED5). We also found that telencephalic neurogenesis onset in precocial species occurs earlier than in altricial species. Therefore, precocial species appear to have enlarged their telencephalon by altering different developmental parameters.

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**Connectivity Patterns of Two Hawaiian Marine Gastropods Possessing 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.

**58.3 CHARVET, C.J.*; 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.

January 3-7, 2009, Boston, MA
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 killfish) have smaller ovaries and testes, lower sex steroid hormone concentrations, and are more likely to be reproductively repressed 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-β-hydroxytestosterone (11-OHT) supplied as precursor, hypoxia did not change 11KT production, suggesting that hypoxia specifically inhibits 11-β-hydroxylase (CYP11B1), the enzyme that converts T to 11 OHT. Inhibition of the terminal steps of gonadal 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.

Hypoxia alters gonadal androgen synthesis in the estuarine fish Fundulus grandis

Alkylphenols, anthropogenic estrogenic endocrine disruptors, were found in new cuticle of 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 14C-tyrosine during shell hardening in the presence and absence of the alkylphenol, and found that it inhibited tyrosine incorporation by 59.43±7.7%. This process was phenoloxidase dependent, since it was inhibited with phenylthiourea by 79.29±4.4%. The cold tyrosine inhibited 14C-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.

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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.
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-standing 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.

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 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 pregnant Siberian hamster.

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 polygenieity 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.

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.
73.5 CHI, K.; SCHMITT, D.; ROTH, V. L.; Duke University and National Chung-Hsing University, Taiwan, Duke University; kchi@physics.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; damp 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.

57.2 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 vertebral 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 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.

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 analogous 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.

57.4 CLARK, A*; 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 retractive forces.
4.1 

CLIFFORD, Andrew B.; Andrew_clifford@brown.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 Anna's Hummingbird. I filmed diving male Anna's 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.

8.8 

CLARK, 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 (spears) 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 (spears) 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 

CLIFORD, Andrew B.; 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 interosseous 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.

January 3-7, 2009, Boston, MA
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 known 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.

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Correlated evolution of feeding morphology in piscivorous versus non-piscivorous centrachid 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 data better than the single rate matrix model, in which a single rate matrix was assumed to prevail for all centrachid 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.
TPCs of reversible phenotypes in multiple environments. The first use of the template mode of variation (TMV) method for examining chief in these two directions. As far as we are aware, this study represents results suggest that TPCs for reversible performance traits in vary 66% of the total variation in swimming TPCs and 95% for feeding rate. Our thermal optimum and the performance maximum of TPC but not the width. Thermal performance of burst swimming and feeding rate between 8-38°C. 30°C) and day-length (10:14, 12:12, 14:10 L:D) cues and examined the acclimated to reliable and contrasting seasonal temperature (16 and 19°C) and day-length (10:14, 12:12, 14:10 L:D) cues and examined the TPC of a 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 30°C) and day-length (10:14, 12:12, 14:10 L:D) cues and examined the thermal performance of burst swimming and feeding rate between 8-38°C. Acceleration 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.
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 as 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.

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.

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 (raellids), 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 raellids, but cetaceans later exapted the limb for aquatic locomotion by evolving a lift-generating hydrofoil.

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 and threat display, and contest duration. The slopes of these regressions were statistically indistinguishable between winners and losers. In both winners and losers, we found a significant, positive relationship between lactate accumulation in the caudal muscle and 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.
mutations that cause deafness in humans are likely to reduce the breaking may be the gating spring. In addition, we find that cadherin 23 in series with a dimer of protocadherin 15. We have used steered extensible. Tip links are most likely composed of a parallel dimer of cadherin with the channels. Although tip links were initially thought to be this spring, micromechanical measurements, propose an elastic gating spring in series parallel and independent. Theories of transduction, confirmed by separate by <10 nm even for very large deflections. Channels are thus in between stereocilia, then the channels are mechanically in parallel. We have found with high resolution stroboscopy 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.

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 anodromous 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.

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 stroboscopy 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.
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 -20°C. 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.

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.
**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).
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, but also serve as beacons for predatory sea stars and other echinoids. Here, we present data 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.
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.
87.5 CUNNINGHAM, C; SCHILLING, N; ANDERS, C; CARRIER, D*; Univ. of Utah, Salt Lake City, Friedrich-Schiller-Univ. Jena, Univ. Hospital Jena; carricer@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.

8.3 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 dispersal 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 elephants 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 elephants: 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.; SORENSEN, M.D.; Boston University, University of Michigan; dacosta@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$^6$ 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$^6$ years ago, consistent with a model of sympatric speciation through host shift.

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 larva since the fish never swam in normal viscosity water: maximum turn angle ($\theta$) 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; suneetra.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.

35.6 DANLEY, Patrick; 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.
the relative volume and orientation of the bony pits. The volume and orientation of the mandibular symphysis completely during development. Initial results suggest that unfused, whereas the hairy-legged vampire bat, *Diphylla ecaudata*, fuses its symphysis. The symphyses of the common vampire bat, *Desmodus rotundus*, demonstrate differences in fusion of the two dentary bones at the mandibular incisors. In spite of these apparent dietary and morphological similarities, upper incisors project into bony pits in a mandibular shelf behind the lower tips of the extremely large upper central incisors. When the jaw is closed, the unique characteristics is a protruding jaw which extends beyond the anterior tooth row and is characterized by a highly specialized cranial morphology. Among other unique characters which extend 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 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.

**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 characters which extend 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 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.

**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), adjointed 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 isotress model of a composite beam in bending shows tilting 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.

S5.10 DEARING, M. D.; MAGNANOU, E.; MALENKE, J.; SKOPEC, M. S.; University of Utah, CNRS - Université P et M Curie, Webber 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 osteo perforata) 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. Q10 values over 5-20°C 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.

January 3-7, 2009, Boston, MA
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.

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 that 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 is currently documented in the literature.

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.
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.

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 cheliotistome 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.

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.
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.

**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.

**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 for 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-phase 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-phase 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.

**Phylogenetic Analysis of Mammalian Maximal Oxygen Consumption**

We compiled data from the literature on maximum oxygen consumption during forced exercise (VO2max), 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 VO2max varied in relation to domestication or measurement method. We used in 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 VO2max in small mammals or between domesticated and wild animals. Considering all 73 “species” (including subspecies or species populations within species), both log10 body mass and residual log10 VO2max showed highly significant phylogenetic signal (P < 0.001). Conventional (non-phylogenetic) analysis indicated an allometric scaling exponent of 0.957 (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
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 toughness and 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.
The physiological costs of fish gill remodeling following infection by freshwater mussel larvae.

Larval freshwater mussels (glochidia) 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 ionic regulatory balance and other hematological effects in infected bluegills. 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.

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 the high flapping frequencies of the remaining wing pair, an effect most clearly evidenced by the elytra of Coleoptera and the halteres of Hymenoptera. 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.

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.
8.8 DUMONT, E.R.; GROSER, 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, 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.

5.4 DURANT, S.E.; HEPPE, G.R; MOORE, I.G; HOPKINS, William A; Aubur; durant@vt.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; HEPPE, Gary R; MOORE, Ignacio T; HOPKINS, Britney C; HOPKINS, William A; Virginia Tech, Blacksburg, Aubur; durant@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 hatching 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 ducks nests (35.0, 35.9, and 37.0°C). 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 37.0°C had 43% higher growth rates than ducklings incubated at 35.0°C. 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 37.0°C 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 (<1.0°C) in the incubation environment can have important consequences for physiological traits important to fitness.

8.0 DURANT, S.E.; HEPPE, Gary R; MOORE, Ignacio T; HOPKINS, William A; Virginia Tech, Blacksburg, Auburn Univ, Auburn; durant@vt.edu
Consistent behavioral and life history variation within clones of the killfish 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 killfish, 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 killfish clones. We also determined whether individuals exhibit consistent behavioral and endocrine variation over a time span of up to one year. Individual killfish 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 killfish. 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.
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 sympatic species. Results demonstrate that animal-eating bats living in large colonies have relatively large olfactory bulbs, while plant-eaters that live at higher degrees of sympathy 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 sympathy 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.

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 octocpes, 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.

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 metabolobuc receptor signalling system. Application of glutamate induces contractions in a dose dependent manner and application of GABA induces rapid twitches of the choanoosome. Nitric oxide induces the contraction of the osculum and nitric oxide synthase has been localized in mesenchyme cells of the apical pinacoderm, choanoocytes and in cells surrounding eurrent 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).

Muscle fibre 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, hindlimbs 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, 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.
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 (\( \delta^{13}C=12.8 \%_{\text{VPDB}} \)) which is very distinct from other (C3) resources available at this time of the year (\( \delta^{13}C=24.9 \%_{\text{VPDB}} \)). 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.

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.
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.
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 HS differently. We identified a series of HS protein (HSP) 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 HSP72 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. 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.
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.

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.

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, hypochondral 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 myomers 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.
context of other information-processing systems. Sine waves (n = 15 cells) to estimate the bit rate as a function of frequency, to 133 bits per second, significantly higher than the rate found in many visual afferents. Many haltere primary afferent cells while mechanically stimulating the haltere stimulus and the resulting spike train. We recorded the activity of more than 30 haltere primary afferent cells while mechanically stimulating the haltere mechanoreceptors respond to stimuli with extremely high temporal precision. They can be used to locate 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 (discrepancy 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 reused 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 will the more general problem of identifying the influence of gene variants in pharmacological studies with wild herbivores.

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 temporal precision, suggesting that they are associated with the transmission of information at very 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.
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.
and the roles they may have played in the history of life on Earth.

The talk I will provide some insights into the evolution of IF-based materials human keratinocytes, hagfish slime, wool, and whale baleen. At the end of functions. Examples will include work we have done on the biomechanics of mechanical properties of IFs can be modified for particular mechanical examples, I will also discuss some of the mechanisms whereby the ways that they are suited to their use in life. Using a variety of illustrative 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.

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.

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.

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.
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.

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

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 (VO2). However, the original formulation of the model left unclear if the postulated selection (and VO2) sustained over extended periods. Subsequently, most studies testing the model have yet 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.

Internarial timing differences steer sharks

Eighties 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 headphones 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.

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 (VO2). However, the original formulation of the model left unclear if the postulated selection affected short-term maxima (VO2 max) or activity (and VO2) sustained over extended periods. Subsequently, most studies testing the model have focused on short-term VO2max 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) VO2max elicited by swimming (VO2swim) and (2) body mass-corrected BMR. Experiment (1) resulted not only in significant between-line differences in VO2swim but also in the VO2max elicited by forced treadmill running (VO2run) 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 VO2max 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 VO2max and suggest that the high BMR of endotherms evolved as a by-product of selection for long-term energy expenditures, rather than short-term VO2max.

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.

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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. Contrariwise, 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. Therefore, force generation of muscles 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 dorsal-ventral direction, with a mean difference of 8.8°C (a max of 10°C; n = 7) across 5 mm, and (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.

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

The pikilike fish *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 unicuspide 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), *Hybostoma* (swordfish), 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. 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.
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.
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 chemosynthetic 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 chemosynthetic 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.
Hormonal regulation of sexual dimorphisms in Lichtenfelder’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 precloacal pore structure, yet these traits have become evolutionarily 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).

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 hazards, and risk-induced alterations of hatching timing are effective treatments 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).

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.
The mechanical properties of the ear.

Hearing is a multi-step process that starts with the conversion of acoustic energy into mechanical vibrations (stimulus reception), the funneling 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 fly’s 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.

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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 funneling 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 fly’s 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.

S7.6 GORB, Stanislav N.; Zoological Institute, Department of Zoology; Functional Morphology and Biomechanics, University of Kiel, Kiel, Germany; s.gorb@fmf.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 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 substratas. 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.

S4.3 GORB, Stanislav N.; Zoological Institute, Department of Zoology; Functional Morphology and Biomechanics, University of Kiel, Kiel, Germany; s.gorb@fmf.mpg.de
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 substratas. 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.

S3.10 GOYMAN, Wolfgang; Max-Planck-Institut fuer Ornithologie; goymann@orn.mpg.de
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 mate 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); ggrabowsky@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.

82.5 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 reproducitively 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.

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

51.2 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; mridiapp@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. Odorana 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 pharyngeal 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 lie prey in the mouth.

January 3-7, 2009, Boston, MA
Evolution of phalangeal formula in gymnothyalid 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 pentaactyl 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 gymnothyalid lizards that 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 Gymnothyalidae. 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 Gymnothyalidae likely lays on molecular mechanisms of developmental genes.

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 H2O2, 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).
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.
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 bacterial film 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.

Mixes with bacterial exopolymers in the biofilm to secure the larva more firmly 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.
Social transmission of immunity in the carpenter ant Camponotus pennsylvanicus

Social insects exploit microbiologically-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 (troughallaxis). These ants store nutrients in their crop and engage regularly in troughallaxis, 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 troughallaxis 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 troughallaxis. Future research will include SDS-PAGE assays of hemolymph, fat tissue, and salivary glands to pinpoint the source and identity of these proteins.

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. 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.
Mechanical and Behavioral Constraints on Neural Encoding in the Rat Vibrissal/Trigeminal Pathway

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, basic analyses of whisker mechanics have 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.

Expression of Ectodysplasin in Tabby-Mice

Expression of Ectodysplasin in Tabby-Mice

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.

Biological screening assays for plant secondary metabolites

Biological 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 intended 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.
5.2 HAU, M; Max Planck Institute for Ornithology, Germany; mhaui@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.

5.5 HEALY, Jessica E*; DIAZ, Yvonne; FLORANT, Gregory L; Colorado State University, New Mexico State University; jhealy@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), hawksmoths (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.
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.
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 basicapital 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.

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 char 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.

S5.4 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.

January 3-7, 2009, Boston, MA
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: Seguenzioida 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 fragmentation 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.
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 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).

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.
**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 them. 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, Kabatariina patternsoni Cressey & Boxshall, a parasite found on the gills of a fossil teleost fish, Cladocyclops 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.

**A new perspective on the echinoderm nervous system: abundant histaminergic and FMRFamnergic-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 FMRFamnergic-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.

**Self-grooming response of meadow voles to the odor of opposite-sex conspecífics 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 conspecífics 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.
35.4 HOFMANN, C.M.; SEEHAUSEN, O.; CARLETON, K.L.; University of Maryland; chohma1@umd.edu
Light environment limits gene expression in rapidly evolving cichlid radiations
Sensory adaptation to the light environment has been repeatedly demonstrated in opsins 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.

35.5 HOLZMAN, Roi*; WAINWRIGHT, Peter; Univ. of California, Davis; raholman@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, rather than velocity magnitude, seems to be an important adaptation to fish avoidance in zooplankton.

35.10 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.
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 gait cycles, 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.

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

Dragonflies move each wing independently and therefore may alter the phase difference between 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.

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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.
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 treefrogs (Agalychnis callidryas) 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.
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.

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.
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.

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 8 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.
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.

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.

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 between 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.

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 fgfl0a 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.
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 asymmetrical flapping, quadrupedal crawling, have high wing-loading (WL, 162±14 N m⁻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 N m⁻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 N m⁻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.

Molecular phylogeny 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, 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. penicillus and O. mendoncinae is found 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.

Spatial and Temporal Patterns of Contamination by Endocrine-Disturbing 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.
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 30 min period between collections to allow T elevation. Response to the GnRH challenge was compared to melanin-based ornamentation (face mask) and nesting 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 nesting 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.

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.

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 O2 and high-energy phosphate (HEP) molecules on the scaling with body mass of the post-exercise whole animal rate of O2 consumption (VO2) 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 (Palaeomonetes 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 O2 and HEP molecules were greater in larger animals. The body mass scaling exponent, b, for post-tail-flipping VO2 (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 O2 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 PO2 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, W.M.; University of North Carolina, Chapel Hill; ajohnsen@duke.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.

53.2 JOHNSEN, S.*; KIER, W.M.; Duke Univ., 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.

53.3 JOHNALDER, H.B.*; COX, R.M.; HAENEL, G.J.; SMITH, L.C.; Rutgers Univ., New Brunswick, NJ; 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.

53.5 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 (14.9°C 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 °C 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.

January 3-7, 2009, Boston, MA
85.5. JOHNSON, S.L. *; BROCKMANN, H.J.; University of Florida; shelujohnson@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. JOHNSON III, W. M. *; BALTZEGAR, D. A.; BORSKI, R. J.; North Carolina State University, Raleigh; wjjohnst@funity.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, mineralocorticoids, 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 been identified. We also cloned a 510 and 536 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 discrete 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 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 1°C 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 Electrosonory System Morphology

Electrosonory 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 electrosonory 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 electrosonory system morphology of three stingray species: the benthic round stingray, Urobatis halleri, benthopelagic bat ray, Myliobatis californica, and the pelagic stingray, Pteroplatytrygon (Dasystes) 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 electrosonory anatomy with behavioral differences in the detection capabilities of batoid fishes.
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 mohckid, 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).

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 photosymbiotic 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 photosymbiotic 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.
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, 30°C) and salinities (0, 15, 35 ppt) 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 advesive 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.

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.

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 (intromission sexual 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.

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.
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.
**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 (Poecliiids) 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 Ik 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 body weight) to non-reproductive females in a simultaneous choice paradigm they exhibited a protactive 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.

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**Mammalian and Sarcopterygian Long Bones: A Comparative Analysis of Allometric Relationships and 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 biomechanically/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.

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**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 sarcopterygian 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 0802846 to MEH.
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.

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 regulatory networks to novel to deep mollusk regulatory networks to

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.
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 dissacharidases (maltase and sucrase) than those 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.
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 Nototenia coriceps 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.

Low landslides 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 Phesitlia 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.

SICB 2009 Annual Meeting Abstracts
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.

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.
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 km² 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.

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.

55.4 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.

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.
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 (chondrichthysans, 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 chondrichthysans: Basking shark (Cetorhinus), 11.8 meters and 17.3 tonnes; whale shark (Rhynocodon), 12.2 meters and 12.7 tonnes., Very large aquatic 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.

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.
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 their antennae. The studies presented here summarize both field tethering trials and mesocosm-free-ranging trials. In 1-hour 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 2 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.

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.

The Scaling of Critical \( P_{\text{co2}} \) 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 \( P_{\text{co2}} \) values do not increase with body size in insects. The lack of a positive correlation between body size and critical \( P_{\text{co2}} \) 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 \( P_{\text{co2}} \) 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 \( P_{\text{co2}} \) 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 size at both normoxic and hypoxic conditions; and as oxygen levels decreased, mean \( CO_2 \) output for all species decreased. Critical \( P_{\text{co2}} \) 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.
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 -10°C invoke an 8-fold increase in metabolic rate during torpor and a shift toward metabolism of glucose and amino acids. We divided S. parryii hibernating in captivity at 2°C into two thermal regimes, -10°C (thermally regulating) and 2°C (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 -10°C 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.
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.

55.3 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 function 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 Institute 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 < ω < 30 rad/sec and material preparation (packing fraction 0.58 < Φ < 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) 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, 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 v and reveal that v is a sensitive function of both parameters. For fixed > 0.6 and increasing , displays a maximum at a frequency ~1/ ). beyond which decreases rapidly with increasing . For < 1, the robot walks using a pendulum-like gait and for > 1 it swims using a paddling motion.
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.

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, neurogenesis 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 morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years. Has the evolution of morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years. Has the evolution of morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years. Has the evolution of morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years. Has the evolution of morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years. Has the evolution of morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years. Has the evolution of morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years. Has the evolution of morphological and behavioral phenotypes, with almost 2000 unique species having evolved over a period of just 10 million years.

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.
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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 semi-diurnal 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.

50 foot long fish.

Symphysial tooth whorl translates into an approximately 1 meter in length or diameter. Tooth arches or whorls of the Edestoids 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 parasympyphal and sympyphal cartilages are found in modern holocephalans, which are also found 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 cochlodont holocephalans are hypothesized to be parasymphysial elements fused to the neurocranium. While multiple upper and lower whorls or families are found in some innoterigynians, the basic eucharichthystran 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.

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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 ecomorphological disparity. In this study, we compare the extent of morphological variation. We demonstrate that mainland anoles occupy overlapping portions of morphological space. Comparison between mainland and island anoles indicates that the habitat specialist-stemmed ecomorphs that have evolved repeatedly in the West Indies 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

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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 adrenaline. 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.
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 melanin 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.
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 doesn’t). We speculate that C. saepepallens represents a first step toward obligate mutualism, B. curacao a second step, and N. longus the final step.

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.
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 vertebrate versus elongation (or shortening) of individual vertebrate (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 liability? 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.

THE ADHESIVE DISC AND ITS FUNCTIONAL CAPACITY IN NORTERN CLINGFISH Gobiesox maenadicus: Gobiesocidae) AND TIDEPOOL SNAILFISH (Liparis florae: Liparidae): SCALING OF MORPHOLOGY AND SUCTION FORCE

In the intertidal environment, Northern clingfish, Gobiesox maenadicus, 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. maenadicus 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.

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 (Linganonea 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.

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 8 wk, 16 wk, and 26 wk 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.
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.

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/rexin 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.

Corticosteroid-binding globulin levels decrease 24 hours after an acute stressor in Japanese quail

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.
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.

Bilaterian animals (protostomes and deuterostomes) sense light through the use of visual opsins, seven-pass transmembrane receptors of the Rhodopsin family that show that cnidarians were the earliest phyla to possess phototransduction. Opsin diversity and extra-ocular photoreception in the Metazoa

Bilaterian animals (protostomes and deuterostomes) sense light through the use of visual opsins, seven-pass transmembrane receptors of the Rhodopsin family. The long-term endurance of the entire community at relatively high latitudes despite enormous demographic change.

N. 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 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 N. vectensis (an 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 rhodobacter and ciliary photoreceptor cells. In addition, we find previously undescribed opsin diversity in the lophotrochozoan Capitella sp.1 (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 (an 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.

Notch signaling during embryogenesis in the cnidarian Nematomastella vectensis

Nematomastella 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.
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.

Ecological immunology: an adaptationist perspective on the vertebrate immune system

TBA

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.

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.*; MCLURE, 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 silversides, 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 hatchling 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 hatchling 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 *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. The Harderian gland of the red-sided garter snake sexual attractiveness pheromone 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 parietalis gland. The Harderian gland of the red-sided garter snake, *Thamnophis sirtalis parietalis*, is a secretory structure that plays a role in the vomeronasal system.

31.7 MATSON, K.D.*; HORROCKS, N.P.C.; VERSTEEGH, M.A.; TIELEMAN, B.L.; 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 lipopolysaccharide (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.
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 gamenite species pairs from tropical America, which have known differences in egg size between gamenites. 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 gamenite pair. When corrected for volume, however, the EP species have significantly and substantially higher protein densities than their WA gamenites. 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.

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 composition.

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 silvery 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.
survival and the timing of life history switch points. Results highlight the importance of density dependence for determining both processes in later stages magnify or reduce variation earlier in ontogeny. Our cohort density and phenotype can affect how size- and density-specific importance of density- and size dependence in vital rates on survival and switch points as a function of size-specific growth and mortality in each stage subsequent switch point phenotypes. While previous models predict optimal size- and density-dependent processes and variation 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 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.

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 hypsymbiotic. Hypsymbionts are poorly represented within 26 members ( 8.6%) of the Pinnotheridae (20 species in the subfamily Pinnotherinidae and 6 species in the Pinnotherellinae). Parastic hypsymbionts 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 hypsymbionts involving ecosymbionts 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 live other species of pinnotherids. Some other ecosymbionts are stalked ciliates, hydroids, polychaetes, bivalve mollusks, balanomorph barnacles, harpacticoid copepods, and urochordates. Factors influencing our meager knowledge of hypsymbioses in the Pinnotheridae are discussed, among them the inaccessibility of crab hosts and research emphasis on taxonomy within the family.
Large species of Macropodoidea, the superfamily containing kangaroos and wallabies, have the amazing ability to decouple oxygen consumption from 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.

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.

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 (r²=0.91), plantaris tendon area (r²=0.91) and combined tendon area (r²=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 therefore could likely hop in a similar manner to modern kangaroos.

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 phylogeographic 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.
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 experimental 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.

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 ontogenetic 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 degrees > 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 Halodule wrightii, drift algae Acanthophora sp., mummichug Fundulus granulis, 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.
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. We here 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.

**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.

**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.
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 implication of this work is that dinosaurs had neither UCP1 nor canonically this event occurred no later than the saurian ancestor of birds and lizards, an degradation of UCP1, after it separated from the mammalian lineage. Since mammals, and that its thermogenicity was lost in the avian lineage, with the mammals. Furthermore, ABALC induction resulted in strong transcription development of these cells is also under control of beta-ARs, as is the endogenous one in adipose tissue. The main function of WAT is to store energy; in contrast, 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.

10.9 METZGER, KA*; BAIER, DB; LIN, A; HARPER, CJ; HERRING, SW; BRAINERD, EL; Touro University College of Medicine, Brown University; 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.

55.5 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~r$. 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.
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.

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.

Long-term reconstructions of limpet body temperatures allow estimation of the frequency and severity of stress events, and reveals 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.

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\textsubscript{2} 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.
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 natural 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.

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<0.0015). 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.
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@svccon.net

Syminx 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 (lpm), 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.

January 3-7, 2009, Boston, MA
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 8% 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.

**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.

**Mechanical Regulation of Skeletal Healing**

An intimate relationship exists among the structure, mechanical function, and environmental regulation of skeletal tissues. The ability of these tissues which include bone, cartilage, tendon, and ligament to 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 macro- and macroscopic structure of the healing tissues.
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, Diposaurus dorsalis, Acanthodactylus macularius) 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 Diposaurus. 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.

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.
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.

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$_3$ grasses and cacti versus C$_4$ 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 performance, 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.

59.1 NAUWELAERTS, S.*; MALONE, S; CLAYTON, HM; Michigan State University, East Lansing; nauwelaes@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 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 glyocalyx 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.
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.
Life-history trade-offs in a fish. This is the first study that examines differential stress responses in relation to levels of the parental males after a standard restraint stressor. In a second of parental care, and subsequently measured the cortisol and testosterone age. In an initial set of experiments, we manipulated brood size at the onset expenditure and parental investment both in relation to brood size and brood. For animals with multiple lifetime reproductive opportunities, the value of a current brood will influence optimal trade-off decisions between the current and future reproductive opportunities. One of the key mechanisms underlying these trade-offs 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.

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 to consider variation in breeding time at the individual level in studies of natural populations.

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 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.
Ocean acidification alters skeletalogenesis 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 CO₂, 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 CO₂ 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 CO₂ conditions based upon IPCC emissions scenarios. Morphometric analysis showed significant effects of enhanced CO₂ on both size and shape of larvae; those grown in a high CO₂ environment were smaller, and with a more triangular body than those raised in normal CO₂ conditions. Gene expression profiling showed that numerous genes central to energy metabolism and biomineralization were down-regulated in the larvae in response to elevated CO₂, 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 CO₂ levels has consequences for physiological function as shown by changes in the larval transcriptome.
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 activating 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.

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 binary character states 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.
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 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.

### 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.

### 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 bento-pelagic, possess fantastic features (i.e. novel bioluminescent apparatus, 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.
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 argulids seem to transmit the viral parasites on fish and crabs. Using real-time polymerase chain reaction analysis, we show that the viruses can occur in the crustacean embryos, 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.
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 Earth's 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 P_O2, 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 Bauplans arose, we argue it is necessary to study heart/lung development in order to better understand how the current diversity of cardiopulmonary development 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, hatching 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.

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.

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/permability 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 gills slits 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.

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.
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. Hatching 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.

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 sphencephala, 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. sphencephala 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.

20.2 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.
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 across 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.

35.5 PARNELL, N.F.*; STREELMAN, J.T.; Georgia Institute of Technology; gnh877n@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 G-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 analyses provides insight into how communities may be structured in highly diverse, dispersal-limited vertebrates.

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 20°C. Fish were introduced to experimental tanks immediately upon hatching, and their movements were monitored day and night with video cameras. Rearing fish at 10°C caused development to slow and delayed the onset of dispersal. Fish in the 10°C group had a single peak of dispersal lasting 8 days. Increasing the temperature (15 and 20°C) 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 20°C treatments required a similar number of degree-days to become larvae, but fish in the 15°C group took more degree-days to begin dispersal than fish in the 20°C group. Fish in the 10°C 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.

3.8 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 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.
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 bamboo 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.

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 nutritional 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 correlated (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.

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 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; kaspop@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; 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.
Evolutionary constraints play a significant role in marsupial brain size. Comparisons between marsupials and eutherian mammals are underway to determine whether developmental constraints play any role in marsupial brain size. These results suggest that the selective pressures associated with brain size were sufficient to allow variation due to adaptive measures, suggesting that these pressures were strong enough to allow variation due to adaptive measures, suggesting that there were no significant size effects, but there were significant differences in size 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.

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 < 0.0001) with NW forms (Didelphimorphia, Pauchtuberculata and Microbiotheria) possessing larger brain sizes than OW (Dasyuromorpha, Diprotodontia and Peramelemorpha). These results suggest that the selective pressures associated with brain size were sufficient to allow variation due to adaptive measures, suggesting that these pressures were strong enough to allow variation due to adaptive measures, suggesting that there were no significant size effects, but there were significant differences in size 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.
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 (RhG) 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 were 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 RhG 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.

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.
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 kogid thorax may potentially undergo larger changes in volume than that of the bottlenose dolphin. However, kogids 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 kogid 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 kogids. Interestingly, the kogid 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 kogids possess smaller lungs than the shallow diving bottlenose dolphin, and will experience reduced pressure-induced changes in both lung and thoracic volumes at depth.
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 (Amphithoidae) 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.

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.

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.
93.7 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 Thriostrepton. 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 for the role of fungal communities in nest site selection, and the influence of fungal pressures on the evolution of termite nest architecture.

97.9 POWERS, DR*; GETSINGER, PW; WETHINGTON, SM; TOBALSK, 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 (REW L) 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 IOS-0615648.
Hymenochirus curtipes sacrourostylic complex, which helps maintain a streamlined position during increases stability for swimming and digging. Further rigidity in the (especially a bicondylar one) between the sacrum and urostyle constitutes Xenopus laevis. A moveable articulation multiplicata and the aquatic fused sacrum and urostyle, which is characteristic of the burrowing Discoglossus sardus. The ontogenetic pathway that forms the adult sacrum and urostyle have appeared concomitant with the origin of the group and the move toward of the most unusual specializations of the anuran skeleton, and seems to involve gene expression and environmental variability.

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 Post sacral 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 Post sacral 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 sandus. 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 salatorial 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.

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.

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 hydrochloric acid to the antennae significantly reduced the activity of P. clarkii antennae of P. clarkii sp. in the 10 minutes following application of the stimuli, but applying 6M hydrochloric acid to the antennae of P. clarkii also caused no change in behavior 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.

Do crayfish like spicy foods? and other tests of crustacean nociception

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 animal 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.

Self-Medication in Domestic Herbivores

Animals manage their health and well-being through behavioral interactions influenced by history, necessity, and chance such that at any time an animal 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.

Summary of the talk: We proposed to investigate the hypothesis that crustaceans have nociceptors that 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 hydrochloric acid to the antennae significantly reduced the activity of P. clarkii antennae of P. clarkii sp. in the 10 minutes following application of the stimuli, but 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, G.J.*; SIM, S; FEDER, J.L; HAHN, D.A; 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 Ragoletis 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.

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 coracohyo-mandibularis (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 hyomandibula 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 coracohyo-mandibularis (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.

49.3 RAKOTOMANGA, M; AZZOUZI, N; SENGGER, F; GUYON, R; HITTE, C; BARTOLLER, JF; D COTTA, H; OZOUF-COSTA, C; GALIBERT, F*; CNRS UMR6066, Universite de Rennes 1, Rennes, France; CNRS UMR6062, Universite de Rennes 1, Rennes, France; CRF-EMVT, UPR20 Centre de Recherche en Faunologie, 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. Spienocytes 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 the on the syntenic 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 planned.

56.12 RAUBENHEIMER, David; Massey University, Auckland; d.raubenheimer@massey.ac.nz

Nutritional Pharmacology
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 Pharmacology. 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.
unilateral activation of abdominal muscles during locomotion.

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 estrogenic activity. In this 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 effects of TCS exposure on vitellogenin induction and sperm production in mature male western mosquitofish, Gambusia affinis.

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 [125I]-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 [125I]-GH from both GHR1 and GHR2, the affinity of either receptor subtype for PRL was substantially less than that for GH; salmonid somatotropin, another member of the GH-PRL family, did not displace labeled GH except at pharmacological concentrations. [125I]-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 I0B 0444860 to M.A.S.)
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.

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 there 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.

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.
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*, possess 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.

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 (Curacao, 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 Curacao. 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 than 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.

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 pippens* 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. pippens*, 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. pippens*, 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. pippens* 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.
Evolutionary Insights About Hummingbirds’ Serrate Tomia
For many years it has been believed that the minute serrations on the tomtia (cutting edges of the beak) of hummingbirds serve in the capture of small arthropods. This belief most likely exists because the serrate tomtia resemble similar structures that function in prey capture as described in previous studies (e.g. scopate, denticulate and lacerate tomtia) of other species. To date, however, there has been no test of this hypothesis about the function of serrate tomtia 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 tomtia are used for arthropod capture. Additionally, recent data suggest that the tomtia 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 tomtial 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 tomtia 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.

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

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.

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.

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Cutaneous water loss and lipids of the skin of tropical and temperate 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.

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 059295 to TJR and AR054246 to EA.
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.

Ontogeny of feeding kinematics in the seahorse Hippocampus reidi from newly born to adult

One of the most important aspects 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 zebras. 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.
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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, there are still questions about the origin of these conserved regions.

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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, 2x10^7, 2x10^8 or 2x10^9 conidia/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 10^7 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.

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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 Biodynamics)
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.

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 immunocompetence 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.

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.
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. olseii. Captive A. mississippiensis occupy a novel region of morphospace orthogonal to the wild populations ontogenetic shape change. This suggests the phenotypic plasticity in A. mississippiensis 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-hatching size range of 22 wild specimens from the same geographic range.

The role 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 organs 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 arborize 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.

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.
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 phylogenetic 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.

Explaining patterns of diversity within ray-finned fish
Using a large molecular timescale we present the first systematic study of the pattens 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 ostariophysian 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.
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.

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 immunohistochecmical, 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.
11.11 SCHMIDT, Victor*; MCCARTNEY, Michael; UNC, Wilmington; vs7867@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 coincidently 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 vice 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.

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; schulteis.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 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.

91.11 SCHROEDER, J.L.; REED, J.; University of Minnesota; jschoeters@umn.edu
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January 3-7, 2009, Boston, MA
SICB 2009 Annual Meeting Abstracts

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.

56.1 SCHWARTZ, M.L*; NORENBURG, J.L.; Seattle University, WA; Smithsonian Institution, Washington, DC; norenburg@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.

4.3 SCHWANZ, Lisa E*; BRISON, Dustin; GOMES-SOLECKI, Maria; OSTFELD, Richard S; Cary Institute of Ecosystem Studies, University of Pennsylvania, New York Medical College; schwanz@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.

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.
both controllers and whole systems. Including animals, robots, and other devices, as well as enabling design of methodology of "templates and anchors," for modeling complex systems lead to effective strategies that simplify control. This effort contributes to the tripod-stance dynamics can be represented by a single virtual leg and offers have similar dynamic responses to perturbations. This result shows how apparent structural differences in the equations of motion, the two systems steady-gaits by calculating respective Jacobians. We found that despite single-leg systems local responses to perturbations along identical equations are found for the single leg CT-SLIP. We analyzed the tripod and is formalized as a set of Euler-Lagrange equations of motion. Similarly, cockroach's tripod support are effectively reduced to a single virtual leg reduction and supporting experimental data, we show how the dynamics of a locomotion and compliant-legged robots. Spring-Loaded Inverted Pendulum (CT-SLIP) appear sufficient to explain perturbed center-of-mass behavior in 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.
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 -50°C; 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 -30°C, and gnats showed 70% survival. The head/thorax froze at -50°C, 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

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 distinctive 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.

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 nototheniid 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.
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 monophagy. 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.
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 receptor produced by the co-expression of the LW opsin and a non-opsin red filter pigment allows N. stephensi to use conjugation over functionalization. Conjugation enzymes have broader substrate acceptability and produce less reactive conjugate like glucose or an amino acid.

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 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 

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. Catechol-O-methyl transferase may play an important role in allowing Neotoma stephensi to specialize on juniper.

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 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. 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 conjuge 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.

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.

75.4 SMITH, B.; MCKECHNIE, A.E.%; Univ. of Pretoria; amckechnie@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 atrorococineus; 29%), Fork-tailed Drongo (Dicrurus adsimilis; 35%) and White-browed Sparrow-weaver (Plocepasser mahali; 17%), and in a crepuscular species, the Pearl-spotted Owllet (Glaucidium gnomus, 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.

75.5 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.
Neoblasts in Nemertodermatida

Our current understanding of the stem-cell (neoblast) system in Platynematina 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 acoele 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 apelii, Sterreria 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 triclad, 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 Platynematida, whereas Acoela and Rhabditophora both generate new epidermis instead through inwandering of neoblasts from the parenchyma.

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 North Carolina at Charlotte; smithj@winthrop.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).

91.11 SOKOLOVA, I.M.; University of North Carolina at Charlotte; isokolov@unc.edu

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63.3 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 serotonicergic 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@unc.edu

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strike forces are influenced by evolutionary as well as developmental factors. Smaller sizes, workers should strike with about twice as much force. *O. cephalotes* workers contrasted with interspecific scalings, which were isometric. From these results, *O. cephalotes* workers compare to species of large monomorphic species (~100mm), but at smaller sizes, *O. cephalotes* workers should strike with about twice as much force as similarly-sized species (60 mm vs. 30 mm). The lower variation found in the polymorphic species suggests that interspecific differences in strike forces are influenced by evolutionary as well as developmental factors.

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**67.3 SPAGNA, J.C.*; PATEK, S.N.; SUAREZ, A.V.; William Paterson University, Univ. of California, Berkeley, Univ. of Illinois, Urbana-Champaign; Spagna@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 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 0.79-4.90). 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 (~100mm), but at smaller sizes, *O. cephalotes* workers should strike with about twice as much force as similarly-sized species (60 mm vs. 30 mm). The lower variation found in the polymorphic species suggests that interspecific differences in strike forces are influenced by evolutionary as well as developmental factors.

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**69.2 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 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.

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**89.2 SPEISER, D.I.*; JOHNSEN, S.; Duke Univ.; dis4@duke.edu**

**The optics and evolution of scallop eyes**

Scallop eyes 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. 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 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.

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**25.10 SOTKA, Erik E.; College of Charleston; sotkaee@cocf.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.

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**SI6.3 DIS4, S.**

**The role of eye size in the feeding ecology of marine herbivores**

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**S6.3 SOTKA, Erik E.; College of Charleston; sotkaee@cocf.edu**

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**SICB 2009 Annual Meeting Abstracts**

January 3-7, 2009, Boston, MA
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 cockroach’s 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-stribe lateral plane dynamics. This approach reveals sufficient encoding for stable wall-following and suggests that significant processing occurs at the primary mechanoreceptive afferents.

Kinethmoid-Mediated Premaxillary Protrusion: Development of a Complex Trait Provides Clues to Its Evolution

Kinethmoid-mediated premaxillary protrusion is a complex protrusible upper jaw in the zebrafish (Phoxinus phoxinus) that generates hypotheses regarding the evolution of this character. Early in development the adductor mandibulae muscle arises as a single unit. The 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.
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 (X2=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 (X2=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.

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)
96.3 STEWART, J.R.; ECAY, T.W.; HEULIN, B.; East TN State Univ, Station Biologique de Pampont; stewart@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. Ovipsited 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, although 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).

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 T3 or 200nM T4 for 3-12-days, or 0.05% KClO4 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.

34.2 STEWART, T.A.; ALBERTSON, R.C.; Syracuse University; tlastew01@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.

78.4 STOCK, D.W.; University of Colorado, Boulder; David.Stock@Colorado.edu
Zebrasfh 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 ontogenegyte 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 cyprinid 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.
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.

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.
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 offensives 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 offensives, 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.

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 to act to maintain developmental stability in the larval appendages. Supported by NIH R01 GM0122.

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 noctuid 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 colony 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. Furthermore, 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/percussion. 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
Hemichordates 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 Hirrinniidae, 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.

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\(^{3/5}\). 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.

57.1 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.

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 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.

January 3-7, 2009, Boston, MA
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 affinis. 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.

40.5 SZYMIK, Brett G*; SATTERLIE, Richard A; Eastern Connecticut State University, University of North Carolina Wilmington; szymkb@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 Cliones 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.

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, sith, 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.

40.3 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 hemicrithia, are crescent-shaped, as has been described previously for ray-finned fishes. However, proximally all hemicrithia 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.
**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.

**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 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 constructed 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 maneuvering 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 continuous thrust generation during both outstroke and instroke. Movement of the dorsal half of the fin only produced thrust during the outstroke but generated very little thrust during the instroke.
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.

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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.

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.
Differences in mass-specific BMR between 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. We used quantitative genetics to confirm that both mitochondrial and nuclear genes determining metabolic rate at the whole-organism level. Involving both mitochondrial and nuclear genes determining metabolic rate at the whole-organism level, and community structure on coral reefs. 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.), 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.
105.2 TOBALSIKE, B.W.*; WARRICK, D.R.; University of Montana, Missoula; bret.tobalske@msou.mt.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 (< 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 < 2.5 and maximum L:D ratios were < 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.

97.6 TOMANEK, L.*; VALENZUELA, J. J.; HITT, L. R.; California Polytechnic State University, San Luis Obispo; itomanek@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 their different 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 is much more distinct in M. galloprovincialis.

component analysis shows that the protein response to hyposaline conditions is much more distinct in M. galloprovincialis than in M. trossulus. We are currently using matrix-assisted laser desorption ionization (MALDI) -tandem time-of-flight mass spectrometry to identify proteins of interest.

97.4 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 Sulf of 17E 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 17E 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 17E estradiol. These results highlight the potential effects of environmental estrogens on reproductive behavior in Betta splendens.

SICB 2009 Annual Meeting Abstracts

January 3-7, 2009, Boston, MA
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.

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 lactating females had reproduced 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.
cycles after the stimulus, which may invalidate one of the assumptions that inputs are independent, that their effects sum linearly, and that 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.

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, they are a key model system for gaining insight into the ontogeny of basal vertebrates and the evolutionary innovations of gnathostomes. We use Dil 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 Dil 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 myoblasts. 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.

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 - are consistent with the theoretical model. In contrast, top walking speeds (around 0.7) in guinea fowl - as for humans - are consistent with the theoretical model.
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.

2.2 VAN SANT, MU*; 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 evolutionary relatedness datasets containing values for related species 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.
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.

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.

Beyond the beak: wing shape variation in Darwin's finches.

Wing design in birds is subject to a suite of interacting selective pressures. As different performance traits (e.g. manoeuvrability, 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 Galapagos. 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.

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.
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 than 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 threat levels.
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 electric 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.

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 morpha
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.

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.
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 demography, 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 cyclonic 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 cycles 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, Fresno; inley@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 (20°C) and fasting. Groups of animals were acclimated to either 20°C or 30°C. 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 30°C. At 30°C, fasted tilapia given glucose had significantly lowered plasma ghrelin levels, whereas there was a significant increase in plasma ghrelin at 20°C. 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 (NA04AR4170038 R/A-122PD) and the NSF (IOS-0639771) to LGR.
performed using a 4,980 gene microarray developed for could be compared. Microarray analyses of transcriptome profiles were clade prior to microarray experiments so that corals hosting clades C and D RFLP analysis of the 18S ribosomal subunit was used to confirm symbiont and frozen at -80 C for genotyping and microarray analysis. Genotyping by two hours of exposure to the maximum temperatures, nubbins were sampled heated at a constant rate for 4 hours to 32 C and 34 C, respectively. After were held at 28.5 C for one hour, after which the two treatment tanks were to a control (constant 28.5 C), and two heat-ramp treatments. All aquaria effects of symbiont type and microhabitat on the heat stress response of this symbiont clade on host physiology are poorly known. To study the relative moderate pool host both clade C and D. While clade D is Symbiodinium, while conspecifics in a found that colonies of the scleractinian coral Acropora hyacinthus from (28-36 C), and moderately fluctuating pools (28-32 C). Previous studies coinciding with rising sea surface temperatures, it is important to understand heat stress responses in the coral Acropora hyacinthus Microarray analysis of the effects of symbiont type and microhabitat on the 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 Otu, 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.
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.

**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 (3D-LIF) 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 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.

**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 hummingbird (*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.
56.4 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 urchin 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 organism’s 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.

53.5 WIERMSA, 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.
We now need to understand how loss of the tegulae affects the flight motor performance of the moths without tegulae were similar to that of the controls. When challenged to track a plume of attractive wind-borne odor the signal maximum down stroke position, from the fore and hind wings, one. We removed the tegulae, a sensory structure known from locusts to whose front and hind wings are physically linked and appear to function as a single pair, whereas in the Lepidoptera, the hindwings beat with independent and out of phase beating of the fore and hind wings. However, little is known about the role of local feedback in the Lepidoptera, locust, whose front and hind wings beat out of phase with each other. Information from local feedback sensors is known to have profound effects on the performance of the flight motor. Behavioral context modulates the loss of local feedback sensors on flight in the moth Manduca sexta.

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 ephibanchial 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.

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.

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 upward. 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; prwillis@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.

18.6 WILMOT, Michae*l; KOSUGI, Takayoshi; FREAMAT, Mihael; SCHULTZ, Bernadine; SOWER, Stacia A.; University of New Hampshire, Durham, University of New Hampshire Durham; sasower@csunix.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 (PreEnsemble, 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.

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 wings. 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-flapping motions in slow flight and reduced forward-flap excursions in fast flight.

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.
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.

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.

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.
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 poeciliid 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 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 (*neuroligin* & *neuroserpin*) 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.

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 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.

33.1 WYETH, R.C.*; CROLL, R.P.; St. Francis Xavier Univ., Dalhousie Univ.; nyeth@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 nitricergic sensory cells, at least one of which appears to not be ciliated. The histaminergic cells project centrally while the nitric cells without cilia have no projections. Mapping the projections of the remaining nitricergic 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.

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.

24.5 WYNEKEN, Jeanette; Florida Atlantic University; jwyneken@fau.edu
Structure and Function of the Turtle 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 saurapsids the muscular ridge is important in separating high O2 vs. low O2 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.
Calculated spring/actuator work data from our model to be consistent with work using experimental joint moment and joint angle data. We expect and spring and calculate the spring constant that minimizes total actuator moments and work were calculated for elbow, wrist, and Capra hircus (and ground reaction force data in three adult male African Pygmy goats 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. 

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.

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.

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.

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.
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 sequence 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.

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.
against direct epigenetic interactions being constraints. 

similarity in structure of conditional independence relationships for FA argues connected unit, a result consistent with its functional integration. The weak FA. The structure of integration suggests that the mandible is a single components, slightly less so in conditional independence relationships for both species are moderately similar in both symmetric and FA components, even in conditional independence graphs. Fewer, in deer mice than squirrels. Size is more highly integrated for both jaw, with the molar alveolus linked to more parts, and the incisor alveolus to 

In both species, we find shapes of adjacent parts to be correlated along the In predation experiments using P. decipiens N. coriiceps to did not change, but D. preferred fresh thallus of P. gracilis was not available, the only preference displayed was for fresh P. antarctica P. decipiens over all other alternatives. If P. decipiens to all other preferences of P. gracilis did not change, but G. antarctica preferred fresh thallus of D. menziesii to P. gracilis. In predation experiments using N. coriiceps, more P. gracilis survived on the highly structured D. menziesii and its analogue than on the simply structured habits. 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.

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 examined 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. 

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.
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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-drug 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 anecysis, 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.

January 3-7, 2009, Boston, MA