S2-1.2 ABZHANOV, Arhat; Harvard University; *aabzhano@genetics.med.harvard.edu*

Pecking at the origin of avian morphological variation

The features of the vertebrate face are often readily recognizable as it displays a number of species-specific characteristics. The beaks of birds in addition to the ordinary masticatory function also serve as important tools and display stunning adaptive variation. We primarily focus on Darwin's finches in which dramatic variations in the size and shape of beaks evolved and are well documented. Importantly, the differences in beak morphology are inherited and developmentally regulated. We are interested in studying the molecular and genetic basis for the evolutionary changes in avian beak morphology. To that purpose we performed candidate gene and microarray screen approaches to understand roles for developmental genes in craniofacial evolution. For several genes now we were able to show both the morphology-specific expression and functional significance of this expression for beak skeletogenesis.

20.8 ADDIS, E. A.*; BUSCH, D. S.; CLARK, A. D.; WINGFIELD, J. C.; University of Washington; *addise@u.washington.edu*

Seasonal social modulation of testosterone in the Costa Rican rufous-collared sparrow (Zonotrichia capensis costaricensis)

Previous work has shown that birds breeding in northern temperate regions adjust production of testosterone in response to the stage of the breeding cycle and in some cases following social interactions. In contrast, studies on tropical breeding birds have suggested they regulate testosterone production in different ways. For example, the rufous-collared sparrow (*Z. capensis*) in Ecuador shows a pattern of testosterone level different from its northern congeners and does not increase testosterone, but does exhibit aggressive behavior, in response to simulated territorial intrusions (STI) (Moore et al. 2002). Building on that work, we investigated whether season has an effect on the social modulation of testosterone and behavior in two populations of rufous-collared sparrows in Costa Rica. Because pairs in both of these populations of birds in Costa Rica breed asynchronously, we chose to investigate social modulation of testosterone and behavior at three distinct times of year: the dry season, late March, the transition to the rainy season, early May, and the rainy season, early July. We conducted simulated territorial intrusions and collected baseline samples during these three periods. Season had a significant effect on testosterone levels and there was an interaction between season and the simulated territorial intrusion treatment, but no increase of testosterone following STI. Here we explore the physiological and behavioral results of this study, and their implications for control of breeding seasons in the tropics.

1.7 ADOLPH, S.C.; GARTNER, G.E.A.; OUFIERO, C.E.*; GARLAND, T.; Harvey Mudd College, Claremont CA, Univ. of California, Riverside; *ggart001@ucr.edu*

A phylogenetic analysis of scale variation in the lizard genus Sceloporus

Although the general function of reptilian scales is well understood, the functional significance of variation in scale size and morphology is less clear. Scale size and number vary both within and among species of squamates, and scale counts have been extensively used as taxonomic and phylogenetic characters in lizards and snakes. Studies have explored the potential adaptive significance of variation in scale size and number and have typically focused on possible climatic correlates of scale size variation (e.g., environmental temperature). Here we examine the hypothesis, from Soulé (1966) and Regal (1975), that smaller scales (manifested as more scale rows) should be advantageous in colder climates (e.g., at higher latitudes) to aid in heat retention whereas fewer scale rows (larger scales) will evolve in warmer environments to aid in heat dissipation. We gathered data on snout-vent length, number of dorsal scale rows, number of femoral pores, and latitude (as a surrogate for temperature) from the literature and museum specimens for 106 species/populations of *Sceloporus* lizards, and analyzed the data with phylogenetically based statistical methods. Mean number of dorsal scale rows ranged from 27 to 88, which is almost certainly far greater than could be caused by direct environmental effects alone (i.e., phenotypic plasticity). Some of the variation in scale rows was related to body size, with larger-bodied species having fewer scale rows, and thus by implication larger scales. After adjusting for the correlation with SVL, number of scale rows had highly significant phylogenetic signal ($P << 0.001$, $K = 0.726$). In a multiple regression with independent contrasts, the effect of SVL remained negative and statistically significant, and the effect of latitude was positive and also significant, which is consistent with the Soulé-Regal hypothesis.

39.1 ADOLPH, S.C.*; HARDIN, J.S.; Harvey Mudd College , Pomona College; *adolph@hmc.edu*

Estimating organismal performance: maximum performance, repeatability, and phenotypic correlations between traits

Whole-animal performance is often a key link between physiology/morphology and individual fitness. Laboratory measurements of performance almost always exhibit within-individual variation (i.e., repeatability less than 1.0). Within-individual variation causes biased estimates of several performance parameters, including maximum performance and correlations between performance under different conditions (e.g., sprint speeds at different temperatures). The bias becomes more severe as the amount of within-individual variation increases. Statisticians have been aware of correlation bias (= attenuation) since Spearman's work in 1904, but corrections for bias are rarely applied in integrative biology. We describe how knowledge of the within- and among-individual components of variance (or equivalently, repeatability) can be used to obtain an unbiased estimate of the correlation between two traits, such as performance under two conditions or between a performance trait and an underlying physiological trait. However, unbiased estimators have not yet been developed for maximum performance itself, or for correlations involving maximum performance. Estimates of maximum performance (as well as its repeatability) depend on the magnitude and pattern of intraindividual variability and the per-individual sample size. The empirical form of these relationships can be used for an approximate correction for bias. We illustrate these phenomena with data on burst sprint speeds of *Sceloporus* lizards. We also discuss how the allocation of sampling effort between the number of experimental subjects versus the number of measurements per individual influences the accuracy and precision of performance estimates.

50.1 ADRIAENS, D*; BEKAERT, K; Ghent University, Belgium; *Dominique.Adriaens@ugent.be*

Morphology and mechanism of the opercular spine locking apparatus in haematophagous candiru catfish

During early evolution of actinopterygian fishes, mouth opening enabled by the hyoid system became assisted by the opercular linkage system, coupling opercular rotation to lower jaw depression. This coupling remained quite stable during teleostean evolution, with some variation on what is linked to what. However, in some special cases, a decoupling of the opercular system from the lower jaw occurred, thereby creating the possibility for a novel function to arise. This evolved at least two times independently in the Neotropical loricarioid catfishes, *i.e.* within the Trichomycteridae and the Scoloplacidae-Astroblepidae-Loricariidae clade. This presentation focuses on the opercular apparatus in the trichomycterid clade, especially with the structural innovations that arose within the haematophagous candiru lineage of Vandelliinae. These so-called parasitic catfishes are known to use an erectile apparatus with spines to anchor themselves in gill cavities of large fishes (or other unfavourable cavities). These spines, born by the opercular and interopercular bone, however, are not to be considered an adaptation to their specialised feeding behaviour as they are present in all trichomycterids. However, structural innovations of a basal trichomycterids condition did occur of which it is hypothesised that they assist the opercular system for locking their spines in gill cavities during feeding. A detailed morphological study, relying on graphical 3D-reconstructions, allowed recognising several innovations in *Vandellia*, which are not present in *Trichomycterus* (basal trichomycterid). Modelling of the graphical reconstructions, and taking into account the observed structural couplings and articulations, was done to hypothesis the movements of the components involved during spine erection.

S5.9 AKAM, M*; BRENA, C; CHIPMAN, A.C; ERIKSSON, J; PEEL, A; University Museum of Zoology, Cambridge; *m.akam@zoo.cam.ac.uk*

The Origin(s) of Segmentation in Animals

Three major animal lineages are segmented - the annelids, the pan-arthropods and the vertebrates. Traditionally, annelids and arthropods have been assumed to share a common origin of segmentation, while vertebrates were thought to have acquired segmentation independently. New phylogenies of the animal kingdom challenge this assumption. Studies of the developmental and genetic mechanisms underlying segmentation can help us to test these hypotheses, but before we can do this, we must explore the diversity of mechanisms within each phylum, and consider the possibility that similar gene networks may have been recruited convergently in different lineages. I will discuss these questions, focusing on studies of segmentation in insects, myriapods and onychophorans

S1-4.1 ALEXANDER, D.E.; University of Kansas; *dalexander@ku.edu*

Under Vogel's wing, my work takes off: Bugs, birds, books and Boeing

One of my first courses as a graduate student at Duke University was Steven Vogel's biological fluid mechanics course, and about then he became my advisor. My background in oceanography, and enjoyment of building gadgets, made Vogel's lab very inviting. My first research project was on sand dollars, which taught me that marine field projects take much longer than terrestrial ones. My second project, on tunicate pumping, ended when a nearly identical study was published in the middle of my first field season. Sage advice from Steve turned me toward animal flight mechanics, which remains my major research interest. Several years ago, Steve suggested I consider writing for a general audience. This eventually led to me write a book, which I found very rewarding. I have continued writing, and am currently working on a comparison of the mechanics of airplane flight versus the mechanics of airplane flight. Although the physics of flying animals and flying machines are essentially the same, the mechanical and functional differences are numerous and obvious. The key difference that underlies most of the other differences is that of power sources: animals use muscles whereas airplanes use engines based on rotating machinery. Muscles dictate flapping for power, which in turn constrains animal wing structure. In contrast, engines for power simplify wing structure. Engines also follow completely different scaling relationships than muscles. Muscle specific power scales negatively with body mass and thus constrains size, but engine specific power is nearly independent of size and is not a significant constraint on increasing aircraft size. My appreciation of the fundamental nature of this power difference was partly inspired by Steve's discussions of the lack of wheels in biology and influenced by his description of humans' historical reliance on muscle power.

36.1 ALFARO, ME*; COLLAR, DC; WAINWRIGHT, PC; Washington State University, University of California, Davis; *alfaro@wsu.edu*

Ubiquity of many-to-one mapping in functional traits: examples and evolutionary implications

Many functional traits can be decomposed into the emergent functional property and its underlying parts. For example, maximum bite force is determined by the product of two morphological parameters: the area of the physiological cross section of the jaw closing muscles, and the mechanical advantage of the lower jaw. In this model, identical bite forces can be attained by two distinct combinations: one in which the jaw adductor is relatively large and the mechanical advantage small and another in which the adductor is small and the mechanical advantage large. We use the term many-to-one mapping to describe this intrinsic redundancy between trait form and function. To examine how pervasive this property is in complex systems, we considered a diversity of functional traits from recent comparative studies and measured the degree of morphological redundancy present in the empirical data sets. We also used computer simulation to generate theoretical distributions of the number of morphological solutions over a range of biologically relevant functional values. Our findings indicate that 1) morphological redundancy is empirically widespread and, 2) it is generally true that there are far fewer solutions to extreme values of functional properties than moderate values. We suggest that many-to-one mapping is of special significance to the study of organismal diversification because of its potential to partly decouple morphological and functional evolution and because intrinsic form-function relationships may influence the outcome of morphological convergence in the face of similar selective pressures. For these reasons, we suggest that many-to-one mapping is a major principle of organismal design.

BART.1 Altshuler, D.; University of California, Riverside
The Aerodynamic and Neurophysiological Mechanisms of Animal Flight through the Lens of Evolution
One of the most remarkable adaptations in animals is the ability to fly. Birds, bats and insects are among the most successful of terrestrial organisms, and their colonization of diverse habitats and ecological roles provides a rich context for studies of animal behavior and ecology. The study of how animals fly is an intrinsically multidisciplinary field that involves aspects of aerodynamics, physiology, and neuroscience. Although most flight research concerns either mechanisms or ecological interactions, flight behavior provides a powerful yet experimentally tractable system with which to merge reductionist and comparative approaches to understand how complex locomotion is accomplished, and how variation in locomotor performance influences higher-order behaviors. I aim to integrate approaches ranging from laboratory experiments to evolutionary comparisons because understanding the mechanisms of flight control also requires understanding the historical forces that have shaped it. Conversely, to evaluate the mechanisms by which ecological changes result in biological adaptations requires a well-described system that can be studied in different environments.

S1-2.5 ANDERSON, E.J.*; LAUDER, G.V.; Harvard University;
eanderson@oeb.harvard.edu
Thrust augmentation confirmed in self-propelled, tandem flapping foil robots by foil-wake interaction
The question of energy recapture from the wake of upstream structures or fins of swimming fish by downstream fins has been discussed from a theoretical perspective for many decades. The phenomenon is difficult to confirm experimentally due to the fact that fish are self-propelled, deforming bodies for which the sources of thrust and drag are not easily decoupled. We have confirmed thrust augmentation using a different metric for swimming performance self-propelled speed. We have constructed a flapping foil robot mounted in a flume on air-bearings that allows for the accurate determination of self-propelled speed. Two flapping foil robots separated by 0.5, 1, or 2 chord lengths in the streamwise direction were connected with a sensitive force transducer. The foils were then programmed to move with a particular pitch and heave. The starting phase of the downstream foil was varied for each trial. The flume speed was tuned until the flapping foil robots were self-propelled, i.e. held station in the flume at the position that they rest when the flume speed was 0. Self-propelled speed and force transducer measurements confirmed the existence of significant maxima in thrust augmentation (and reduction) for particular foil-to-foil spacing, phase differences, and flapping frequencies. Single foil and tandem foil control trials did not exhibit the same effect. Flow visualization shows the mechanism to be related to the effective angle of attack of the downstream foil due to the structure of the wake of the upstream foil. This confirms recent computational work on the phenomenon, the hypotheses by early investigators of fish fluid dynamics, and the suggestions of recent experimental work on bluegill sunfish focusing on the kinematics and flow fields of the in-line fins of swimming fish.

25.4 ANDERSON, Philip S. L.; Univ. of Chicago;
andersps@uchicago.edu
The Effect of Blade Design on Fracture Toughness in Biological Materials
Dental structures capture, retain and fragment food for ingestion. The morphology of gnathostome dentition should be viewed in light of the material properties of the prey. Animal muscle and skin are tough materials which inhibit fragmentation unless energy is continually applied directly to the tip of the fracture. Using a sharp blade greatly reduces the fracture toughness (the work required to bisect an item) of such materials. Despite the variation of bladed tooth morphology in gnathostomes, few studies have experimentally examined the effects of different blade designs on cutting efficiency. I test the effects of different blade morphologies on the fracture toughness of select biological materials. I cut pieces of raw, unprocessed biological tissues (fish and shrimp) with a double guillotine device. The testing machine accommodated straight blades, and blades angled and paired to create bladed notches and matching bladed triangles, and permitted measurement of the work required to cut the material. I hypothesized that the bladed notches and triangles would require less work to fragment the biological materials than straight blades. Blade design does have a large effect on the work required to fragment biological tissues. A notched blade reduced the work to fracture of biological tissues tested by up to 300 J/m^2 (25% reduction). Biological specimens that contained multiple materials with different properties (shrimp covered in cuticle) showed greater reduction (50%) in work to fracture when more acutely angled blades were used. A bladed triangle matched to a notch reduced work to fracture by another 200 J/m^2. Strain patterns seen using photoelastic gelatin show that the reduction in work to fracture when using triangular and notched blades arises from an overall reduction in the strain placed on the material when cut.

71.6 ANGIELCZYK, Kenneth; Univ. of Bristol;
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How to be a miniature turtle: comparisons of ontogeny in the Emydinae using geometric morphometrics
Miniaturization is a widespread phenomenon among animals, and often is accompanied by profound changes in morphology, physiology, and development. An obvious question to ask about miniaturized species is how their ontogenies compare to those of their larger relatives. For example, do miniaturized species resemble tiny adults of larger species, or do they retain the size and morphology of juveniles of larger species? The Emydinae include two of the smallest extant turtle species, *Glyptemys muhlenbergii* and *Clemmys guttata*, as well as more normally-sized species. To examine whether these two species attained their small sizes by modifying their ontogenies, I compared ontogenetic changes in plastron shape in *C. guttata*, *G. muhlenbergii*, and their larger relatives using geometric morphometrics. The results of these analyses indicate that the ontogenies of *C. guttata* and *G. muhlenbergii* are not simply truncated versions of those of larger emydines. Instead, both species display unique alterations in plastron shape as they grow. The plastron shapes of *C. guttata* and *G. muhlenbergii* also tend to become more similar to those of their larger relatives as ontogeny progresses. The turtles examined in this study range from hatchlings to large adults, but no pre-hatching embryos were used. When combined with the morphometric results, this fact suggests that the major differences in plastron shape between the miniaturized emydines and their relatives form early in development, with post-hatching ontogeny counterbalancing these differences to some degree. This convergence between adult shapes may reflect constraints on the morphology of the shell imposed by its protective function or the need to maintain a relatively hydrodynamic shape in species that are amphibious or aquatic.

31.1 APPLEBAUM, Scott*; WILSON, Alex; NUNEZ, Scott; The University of Texas at Austin; *scotta@utmsi.utexas.edu*

Ontogeny of the cortisol stress response and expression of CYP11B in larval red drum

In addition to their crucial role in stress and osmoregulatory function corticosteroids play an important role in teleost development. Corticosteroids may influence larval development directly, or through interactions with the thyroid system which is responsible for the larval to juvenile transformation. Nonetheless, the development of adrenocortical function in teleosts is poorly understood. Due to the potential impact on development, it is valuable to determine the ontogenetic onset of corticosteroid production and when an integrated corticosteroid stress response is first evident. In this study, we describe the ontogeny the corticosteroid stress response and the expression of a key corticosteroidogenic enzyme, CYP11B, in larval red drum (*Sciaenops occelatus*). Stress experiments were conducted between 1 and 33 days post-hatch (DPH). Groups of larvae were subjected to an acute handling stress and sampled at 0.5, 1, and 3h post-stress for cortisol analysis. Larvae sampled prior to stress were used to establish basal cortisol levels. Basal cortisol was first detected at 3 DPH, increased to a maximum of 4.9 ng/g at 13 DPH, and declined to 1-2 ng/g for the remainder of the study. Cortisol did not increase in response to stress prior to 6 DPH. After 6 DPH, stress caused significant increases (9 to 153 fold) in larval cortisol content. Stress-induced cortisol increases in 6 to 11 DPH larvae was highest after 3h. In larvae older than 11 DPH cortisol levels peaked at 0.5h and declined to near basal levels by 3h post-stress. Eggs and larvae collected between 0 and 33 DPH were analyzed for the expression of CYP11B mRNA and preliminary results indicate that CYP11B is expressed beginning 1 DPH.

68.2 ARELLANO, S.M..; University of Oregon, Charleston; *arellano@uoregon.edu*

Does larval biology limit the vertical distribution of the deep-sea mussel Bathymodiolus childressi?

Bathymodiolus childressi is a mixotrophic mussel harboring methanotrophic endosymbionts in its gills and is known from hydrocarbon seeps in the Gulf of Mexico, ranging in depth from 546 to 2222 m. Population genetics reveal no differentiation throughout the Gulf of Mexico (GoM), suggesting widespread larval dispersal in this region. However, the larval biology that makes such widespread dispersal possible has not been investigated. Here we begin to answer: 1) Which embryological and physiological factors limit the vertical distribution of *B. childressi* larvae? and 2) Do energetics limit vertical migration by *B. childressi* larvae to the productive surface waters? To do so, we induced spawning via serotonin injection to adult *B. childressi* maintained in the lab. Induction of spawning was successful as early as September and continued through March. Laboratory cultures maintained at 7-8 ºC developed at an average rate of one division per 4-9 hours through the 32-cell stage. Larvae hatched by 36 to 48 hours and developed a D-shell by day 8; however, development could be delayed so that the larval shell did not begin formation until day 12. Cultures were maintained for up to two weeks, but never metamorphosed in the lab. We used a MOCNESS plankton tow throughout the water column above the GoM seeps to collect plankton at various times of the year. *B. childressi* larvae are present as shallow as 200 m in winter months. Although survival of trocophore larvae decreases with increasing temperatures, thermal tolerances are within the range of temperatures found in the Gulf of Mexico during the spawning season, indicating that temperature does not limit vertical migration. Empirical estimates of metabolic rate and swimming speed of *B. childressi* larvae were also conducted to test an energetic model that estimates vertical migration potential in deep-sea larvae.

28.4 ARONOWSKY, A.*; ANDERSON, L.C.; HELLBERG, M.E.; Louisiana State University; *audrey@geol.lsu.edu*

Redescription of the freshwater bivalve Guianadesma sinuosum and implications for the historical biogeography of northern South America

The tropical bivalve *Guianadesma sinuosum* Morrison, 1943 is restricted to freshwater, an uncommon habitat for either of the two clades (Corbulidae or Lyonsiidae) to which it has been assigned. In our previous morphology-based phylogenetic analyses, including both corbulid and lyonsiid species, we found *G. sinuosum* to be nested within the Corbulidae. Specimens attributed to *G. sinuosum* have been collected throughout northern South America, including the central Amazon River in Brazil; the Courantyne, Suriname, and Marowijne Rivers in Suriname; and the Demarara, Cuyuni, and Essequibo Rivers in Guyana. The discontinuity of these localities, in separate drainages, presents an interesting biogeographic problem. Further complicating the issue, specimens attributed to a nearly identical species, *Anticorbula fluviatilis* (Adams, 1860), have been collected from the Trombetas River, an Amazon tributary in Brazil and the Maranon River in Peru. In order to begin untangling this problem, we recollected *G. sinuosum* from Morrison's type locality at Kartabo Point in the Cuyuni River of Guyana. Here, we present a redescription of *G. sinuosum* based on our new material and museum specimens. We will discuss new phylogenetic analyses and the potential of *G. sinuosum* and closely related fossils from northern South America for reconstructing the biogeographic history of this region.

57.6 ASHLEY-ROSS, M.A.*; LUNDIN, R.; JOHNSON, K.L.; Wake Forest University; *rossma@wfu.edu*

Kinematics of level terrestrial and underwater walking in the California newt, Taricha torosa

Although fossil evidence indicates that the tetrapod limb predated the move onto land, underwater locomotion involving the limbs, and how it might differ from locomotion on land, is poorly understood. We therefore quantified the movements of the body axis and limbs of the California newt, *Taricha torosa*, during steady-speed walking on a treadmill, and walking on a level surface while submerged in water. Angles describing the lateral flexion of the trunk, rotation of the limb girdles, and protraction/ retraction of the humerus and femur were measured in two dimensions, while angles between the humerus and forearm, between the femur and the crus, and between the various limb segments and the treadmill surface, were measured in three dimensions. Treadmill walking in *Taricha* demonstrated a kinematic pattern similar in its general aspects to level walking in other sprawling tetrapods; newts used a diagonal couplets lateral sequence walk with a duty factor of 77%. When submerged, the footfall pattern was altered to a diagonal couplets diagonal sequence trot, with a duty factor of 40%, and more variable timing of footfalls. Underwater walking included periods of suspension, made possible by the buoyancy of the water. In comparison to treadmill walking, submerged walking was characterized by reduced movements of the pectoral girdle, and greater extension of the limbs during all parts of the stride. Comparison of level locomotion (both environments) with walking on an incline (up and down) in and out of water demonstrated differences in the relative contribution of the axial systems (trunk bending and limb girdle rotation) versus limb movements in generating forward progression; the limbs contribute more in level walking, while the axial systems provide more of the propulsion on an incline.

57.5 ASTLEY, H. C.*; JAYNE, B. C.; Univ. of Cincinnati; *astleyhc@email.uc.edu*

Effects of perch diameter and incline on the arboreal locomotion of snakes

Moving in arboreal habitats poses several functional challenges including variable branch diameters, inclines, grasping, balancing and fitting onto the limited width of the perch. In contrast to lizards and primates, the arboreal locomotion of snakes is poorly understood despite the fact that many snake species are arboreal. Thus, to determine how perch diameter and incline affect the kinematics and locomotor performance of snakes, we videotaped one-meter long corn snakes (*Elaphe guttata*) moving on seven cylinders (diameters 1.6 - 20 cm) at five inclines (horizontal, +45º and +90º). Many of the effects of diameter depended on incline. For example, snakes could not move uphill or downhill on the two largest perch diameters. When moving downhill, snakes often slid continuously while grasping the perch to reduce speed. Unlike downhill locomotion, horizontal and uphill movement was a variant of concertina locomotion, in which the snake formed alternating bends of the body that periodically stopped and grasped the perch. For a given diameter, the average forward velocities were greatest, intermediate and slowest when moving downhill, horizontally and uphill, respectively. When moving horizontally, the forward displacement per cycle had large and significant increases with increased diameter, but differences in forward velocity were minimal as a result of increased cycle duration. Similar to the manner in which snakes fit into tunnels of varying width, as perch diameter increased the corn snakes had fewer lateral bends of the body and the angle of the snake's body between the left and right sides of the perch increased and approached ninety degrees. The detrimental effects of inclined large diameter perches on the locomotion of corn snakes resemble those of some primates, but they contrast with the beneficial effects for most arboreal *Anolis* lizards, which can adhere to perches without grasping them.

S1-3.4 AUTUMN, K*; GRAVISH, N; WILKINSON, M; SANTOS, D; SPENKO, M; CUTKOSKY, M; Lewis & Clark College, Stanford University; *autumn@lclark.edu*

Frictional Adhesion of Natural and Synthetic Gecko Setal Arrays

Gecko toes are adhesive only when dragged in shear away from their tips. This is due to the anisotropic function of the arrays of angled foot hairs (setae) that comprise the gecko adhesive. We measured 2D dynamics of bonding and de-bonding in isolated gecko setal arrays and the toes of live geckos. We found that adhesion depended directly on shear force (friction), consistent with previous results showing that single setae detach at a critical angle A* = 30°. We proposed a new model, frictional adhesion, for the function of gecko-like adhesives. In the non-adhesive direction, the Coulomb law governs friction: $F_{normal} >= -1/\mu$ Fshear. In the adhesive direction, the adhesive force is limited by the shear force and A*, $F_{shear} >= - F_{normal} \div \tan A^*$, which defines the minimum shear load to withstand a given adhesive load. This explains why geckos use opposing feet and toes to maintain shear forces that prevent detachment, and informs the design of synthetic gecko-like adhesives. We compared the new frictional adhesion model with the JKR and Kendall models of adhesive contact. The loading constraints predicted by the contact models lead to different force control strategies during attachment and detachment to prevent unwanted slippage and minimize foot detachment forces in a model gecko. We then fabricated arrays of synthetic anisotropic elastomeric microstructures. The 2D dynamics of the synthetic arrays were consistent with the frictional adhesion model, and enhanced the ability of a gecko-like climbing robot to scale a smooth vertical surface. We suggest frictional adhesion as a key benchmark for the performance of gecko-like synthetic adhesive structures. Support: DARPA N66001-03-C-8045, NSF-NIRT 0304730, DCI/NGIA HM1582-05-2022, Emhart, and J&J Dupuy-Mitek.

68.1 AVENI-DEFORGE, K.*; WETHEY, D. S.; Univ. of South Carolina, Columbia; *kyled@biol.sc.edu*

Modeling the Mottling, How Mussel Beds are Prone to Patchiness

Mussels are dominant space competitors in the rocky intertidal. Solitary mussels produce byssal threads, extra-celluluar, shock absorbing fibers, to the substrate in order to resist dislodgement by the forces of lift and drag. The mussels' ability to deal with intense hydrodynamic forces is facilitated by the formation of dense aggregations, in which mussels not only reduce the hydrodynamic forces impinging on their shells by changing orientation, but also reduce the individual investment in byssal thread production, by attaching threads to neighboring shells as well as to the substrate. The number of neighbors with which a mussel interacts, and the number of byssal threads involved in those interactions generate a network through which forces are distributed, and the mussel bed is tied together. The clearing of patches is thought to be initiated by the loss of an individual, or clump of mussels, destabilizing the immediate neighborhood of the loss, and resulting in a chain reaction of dislodgement, creating a gap in the bed. Here we present an interacting particle model that incorporates empirically determined parameters for thread production, shell orientation, and interaction between aggregation members. The model demonstrates that mussel beds are intrinsically prone to patchiness, affirming that the loss of an individual can substantially destabilize a small neighborhood of mussels. However, the model also shows that there are check-points within aggregations that may help to prevent the spread of gaps.

43.1 AZIZI, E.*; ROBERTS, T.J.; Brown University; *manny_azizi@brown.edu*

Variable Gearing in Pinnate Muscles

Pinnate muscles are characterized by short fibers that attach at an angle relative to the muscle's line of action. Recent studies have shown that as obliquely oriented muscle fibers shorten they also rotate. Fiber rotation during a muscle contraction changes the relationship between the shortening velocity of a fiber and the output velocity of the muscle tendon unit. When fiber shortening is combined with rotation the gear ratio of the muscle (muscle velocity/ fiber velocity) increases. Although fiber rotation results in a velocity advantage, the proportion of fiber force directed along the muscle's line action declines. This direct trade-off suggests that the relative force and velocity output of a muscle depend in part on the magnitude of fiber rotation. Our computer simulations suggest that dynamic muscle shape changes during shortening influence the magnitude of fiber rotation and therefore modulate the nature of this force-velocity trade-off. In this study we used an in situ muscle preparation of the lateral gastrocnemius of wild turkeys (n=5) to determine whether gearing can vary across mechanically diverse contractions. We used a servomotor to measure whole muscle force and velocity and sonomicrometry to measure fascicle velocity and muscle bulging during a series of isotonic contractions at varying force levels. We find that gear ratio varies dynamically with muscle load such that at high muscle forces, fiber rotation was minimized. These results suggest that architectural gear ratio is determined not only by static muscle anatomy, but also by the mechanics of force production during contraction. Variable gearing may be one way that the mechanical behavior of pinnate muscles can be modulated to meet a range of mechanical demands.

37.4 BABBITT, G.A.; Arizona State University; *babbitts@gmail.com*
Stress, stability and size: capturing process variation in the development of multicellular organisms
Definitions of developmental instability (DI) and its most common estimator, fluctuating asymmetry (FA), have often assumed that the variation in FA is caused by the organism's ability to buffer additive effects of independent perturbations during the process of development, leading to a subsequent normal distribution in FA. Recent opinion and empirical research has questioned this view of the basis of FA. Because FA is generated during growth, it is best viewed as a specific type of process variation or error that includes both the propogation of multiplicative errors (geometric Brownian motion) during growth in geometrically expanding cell populations, as well normal error in the timing of the termination of growth. In addition this generative process is probably also under simple regulatory control (e.g. via a Rashevsky-Turing process). In this paper, I present a tissue level model of FA with these generative and regulatory aspects. The model is used to simulate variation of FA in large populations exposed to various levels of environmental stress and genetic relatedness. Results are compared to large samples of wild trapped, inbred and isogenic lines of Drosophila. The simulation demonstrates that mean FA decreases with growth rate (i.e. increasing with environmental stress) and that FA decreases with relatedness among the population. Inbreeding also increases leptokurtosis in the distribution of FA in both the simulation and in Drosophila lines. The simulation also reveals Pertoldi's theorem; that phenotypic variance and FA are correlated under environmental stress in clonal populations. The potential application of the statistical model in studies of environmental and genetic stress and the behavior of cancer tissue are discussed.

56.2 BABBITT, Courtney C.*; WRAY, Gregory A.; Center for Evolutionary Genomics, Institute for Genome Science and Policy, Duke University; *courtney.babbitt@duke.edu*
Functional analysis of cis-regulatory evolution in humans and other primates
Due to the extensive similarities in coding regions between humans and chimpanzees, it has been proposed that the genomic basis underlying uniquely human traits is due, in large part, to changes in gene expression. However, to date, few specific changes in primate *cis*-regulatory evolution have been well characterized. Our framework for investigating these changes is to identify and functionally explore instances of positive selection on *cis*-regulatory regions in the primate lineage, and specifically on the branch leading to humans. The aim of this study is to identify and characterize functional changes in *cis*-regulatory sequences, specifically those that may have played a role in the evolution of cognitive traits. We are approaching this in two ways: 1) examining candidate genes with known promoter polymorphisms that are statistically associated with affective and developmental disorders in humans; and 2) testing genes showing a high signature of positive selection in the human lineage, as determined by a bioinformatics screen also done in our lab. The 5' flanking regions from multiple humans and representatives of three non-human primate species have been cloned into luciferase reporter constructs. We are transiently transfecting these constructs into appropriate human cell lines, then measuring changes in expression levels using a dual luciferase assay. After identifying the genes with significant functional differences within the human lineage, we plan to test a subset of genes with additional constructs or by association analyses with specific cognitive traits. Combined, these data may identify changes within specific *cis*-regulatory regions in which the evolution of gene regulation has led to uniquely human traits.

6.1 BABONIS, L.S.**; HYNDMAN, K.H.; LILLYWHITE, H.B.; Univ. of Florida, Gainesville; *babonis@ufl.edu*
Comparative immunolocalization of Na+/K+-ATPase and Na+/K+/2Cl- cotransporter in osmoregulatory tissues from marine and semi-marine snakes
The sublingual salt gland is the primary site of salt excretion in sea snakes. Using histology and immunohistochemistry, we located two ion transporters, Na^+/K^+-ATPase (NKA) and $Na^+/K^+/2Cl^-$ cotransporter (NKCC), in salt glands from three species of sea snake collected from Taiwan: *Laticauda colubrina*, *L. laticaudata*, and *L. semifasciata*. Both transporters were found in great abundance in the basolateral membranes of the tubular epithelia in all three species. These results are consistent with the localization of these transporters in other secretory tissues such as the gills of teleost fishes and the rectal salt glands of elasmobranchs. Unlike sea snakes, North American watersnakes in the genus *Nerodia* are not known to possess salt glands; however, at least two species in this genus inhabit marine and brackish water environments. Although reptiles are incapable of producing hyperosmotic urine, it is likely that some degree of osmotic stress can be counteracted by the kidneys. In addition, the ability to detect ephemeral sources of fresh water in marine environments could reduce the need for physiological osmoregulation. Therefore, we expect to find NKA and NKCC in the secretory tubules of watersnake kidneys and the chemosensory tissues of the oral epithelia. Understanding the relationships between the physiology and behavior of semi-marine snakes will lead to useful insights concerning the evolution of the fully marine species.

41.1 BADE, L.M.; Univ. of Missouri, St Louis; *lmbpb2@umsl.edu*
Future Ecologists As Researchers: A F.E.A.R. Factor Summer in St Louis
Students in urban settings have limited exposure to conservation biology and ecology topics. In actuality, studying ecology in urban environments is accessible, rewarding, and can provide students with authentic research opportunities. Towards these goals, the Biology Department at the University of Missouri-St Louis and Missouri Science Teaching and Education Partnerships (MO-STEP, a National Science Foundation GK-12 Program) implemented the Future Ecologists As Researchers (F.E.A.R. Factor) program. F.E.A.R. Factor was a 6-week summer internship program for high school students funded by NSF. Through field work and on-site research, students studied aquatic, prairie, and forest ecosystems, investigated native and exotic species, and discovered the wildlife in managed urban habitats. Students measured biodiversity in urban ecosystems, compared biotic and abiotic factors, investigated habitat fragmentation, and studied the impact of introduced species in Missouri habitats. The National Science Education Standards were addressed through the inquiry-based structure of the program. Reinforcement of life science content standards such as biological evolution and interdependence of organisms were supported through field research and direct observation. Students improved their higher-order skills by developing hypotheses, designing experiments, critiquing scientific literature, routinely interacting with scientific professionals, and explaining and defending their research and hypotheses in oral presentations. The F.E.A.R. Factor program concluded with a Student Symposium, with each student presenting their research through a poster session attended by faculty, graduate students, teachers, parents, and peers.

S8-1.5 BADYAEV, Alexander; University of Arizona; *abadyaev@email.arizona.edu*

Origin and evolution of novel phenotypes: From environmental induction to genetic inheritance in color displays

The origin of novel phenotypes is one of the most controversial and unresolved questions in biology. Phenotypic accommodation of environmentally-induced developmental plasticity is thought to be an initial step in the evolution of some adaptations, but empirical examples are rare. Diet-dependent carotenoid coloration of many animals provides a unique opportunity to trace the developmental incorporation of novel environmental inputs into the evolution of complex adaptations. I will present a conceptual framework for the evolution of genetic inheritance of environmentally-induced plasticity in coloration and apply this framework to the study of the recent evolution of two color morphs in a newly established bird population. I show that epigenetically regulated feather growth enables incorporation of novel diet-derived pigments, whereas recurrent selection on resulting color phenotypes facilitates genetic assimilation of novel environmental inputs. These results are consistent with the view that phenotypic accommodation can bridge the environmental origin of adaptation and its genetic determination.

70.2 BAHLMAN, Joseph Wm*; WAINWRIGHT, Peter C.; Brown University, University of California at Davis; *Joseph_Bahlman@brown.edu*

Evidence for passive suction feeding in Pacific Bluefin tuna, Thunnus orientalis

Suction feeding is the most widespread and commonly used mechanism of prey capture in teleost fishes. In all described examples, this behavior involves the rapid expansion of the mouth and buccal cavity, generating suction, and causing water and prey to flow in through the mouth aperture. We used video to record Pacific Bluefin tuna at the Monterey Bay Aquarium, in Pacific Grove, California. We obtained 19 lateral view video sequences of tuna feeding. In each sequences, we tracked the movement and calculated velocity for the tuna, the prey, and tuna's mouth aperture. Suction was shown by the acceleration of prey towards and into the tuna's mouth. Buccal expansion was shown by changed in mouth aperture size, and the dorsal-ventral depth of the head. 5 sequences displayed suction associated with a clear buccal expansion. The remaining 14 sequences show the tuna swimming with their mouths held continuously open, and still generating significant suction without any visible buccal expansion. More detailed kinematic analysis shows the magnitude of the suction generated is positively correlated with mouth aperture size and swimming speed. In some feedings the magnitude of suction generated by swimming with their mouth held open is greater than suction generated in sequences that involve buccal expansion. We propose a mechanism for passively generating suction (without rapid buccal expansion) via a pressure gradient between the opercular opening and the mouth aperture caused by accelerating flow around the tuna's body. We suggest that higher flow velocity at the opercular opening relative to the mouth aperture may induce a flow of water through the buccal cavity that the tuna uses to suck the prey into its mouth during ram feeding.

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

What do pitvipers see? Computer visualizations based on anatomy, optics, heat transfer, and neurophysiology

The facial pit of pitvipers (Viperidae: Crotalinae) appears to function as a pinhole eye, using thermal infrared radiation to form temperature-contrast images on a sensory membrane suspended in the pit. The facial pit has a complex 3-dimensional shape, both internally and externally, that determines the nature of the image falling on the membrane. Image strength and sharpness interact; reducing the pinhole aperture increases sharpness but decreases irradiance. However, neural image sharpening may partly break this interaction. We present an improved model of facial pit function based on combined optical and heat transfer analysis, extending previous work by including a proper estimate of atmospheric transmittance for thermal infrared radiation and adding the effect of convection-conduction heat loss from the membrane. Pit aperture characteristics, membrane sensitivity, image sharpening and tonic (constant) vs. phasic (rate of change) neural response interact to produce the final image. We combined our model and published neurophysiological data to explore these interactions by creating video representations of the thermal infrared view of prey items active outdoors. Convective heat loss from the membrane significantly reduces estimated temperature contrast, and has a larger effect on smaller pit organs, e.g. immature snakes. Consequently, membrane receptors must be sensitive to temperature differences on the order of 0.001°C if snakes can detect a mouse at ca. 1m as suggested by Ebert and Westhoff, J. Comp Physiol A, 2006. The results suggest behavioral studies to better characterize the limits of the facial pit sense and laboratory studies to better define the physical and neurological aspects of the facial pits.

47.5 BANCROFT, B.A.**; BLAUSTEIN, A.R.; Oregon State University; *bancroft@science.oregonstate.edu*

Effect of UV-B radiation and skin color on survival and growth in larval amphibians

Ultraviolet-B radiation (UV-B) negatively affects many living organisms, especially amphibians. However, UV-B has been present throughout evolutionary history and amphibians have a number of strategies to avoid or mediate damage caused by UV-B. One defense strategy is the use of photoprotective compounds and pigments. Melanin is a photoprotective pigment that can be induced upon exposure to UV-B. In addition, tadpoles use melanin to adjust body color in response to substrate color. We raised tadpoles of two species (*Pseudacris regilla* and *Rana cascadae*) on dark or light backgrounds and exposed them to UV-B in the laboratory for three weeks. We hypothesized that darker tadpoles would have higher survival and growth rates than light tadpoles when exposed to UV-B. *P. regilla* tadpoles exhibited more color change than *R. cascadae* tadpoles in all treatments. Tadpoles exposed to UV-B experienced higher mortality and reduced growth regardless of skin color or species. Our results suggest that melanin does not prevent negative effects of UV-B radiation in larval anurans.

25.8 BANTILAN, K*; COMBIE, K; SCHAEFER, J; PRINGLE, D; LONG, J; KOOB, J; Vassar College, University of California, Irvine, Shriners Hospital, Mount Desert Island Biological Laboratory; *kubantilan@vassar.edu*

Building Biomimetic Backbones: Modeling Axial Skeleton Morphospace

In order to understand the mechanical design of backbones, we seek to build artificial axial skeletons that mimic the structure and function of biological systems. Recognizing that the chordate axial skeleton ranges in structure, we use hagfish, which bear an adult notochord, and sharks, which have a jointed vertebral column, as our two biological targets. To characterize mechanical properties, we conducted dynamic bending tests, measuring the complex modulus and its constituent loss and storage moduli. To build notochords, we mold gelatin rods and cross-link the denatured collagen to select different values of moduli. The creation of vertebral columns presents special challenges, since the composite of low- and high-modulus elements, namely joints and bones, concentrates stress during bending. To address this, we created two different kinds of vertebral columns, one that bends by differential compression and one that bends by differential tension. These two different patterns of bending strain delimit a mechanically-feasible range of designs for backbones. Supported by the National Science Foundation grant DBI-0442269.

29.1 BARBOZA, P.S.*; PARKER, K.L.; Univ. of Alaska, Fairbanks, Univ. of Northern British Columbia; *ffpsb@uaf.edu*

Timing of birth affects body protein dynamics of mothers in an arctic mammal

Rapid changes in climate are altering the timing and abundance of food for seasonal reproduction in arctic animals. Reindeer and caribou typically form large herds throughout the circumpolar north. Timing of birth is separated by one month for these two subspecies of *Rangifer tarandus* under similar conditions. Reindeer (*R. t. tarandus*) lose more body mass during pregnancy than caribou (*R. t. granti*) because they complete pregnancy in late winter when food intakes are still low. We used isotopically labeled diets to demonstrate that maternal protein stored from early winter is used for 96% of fetal protein in reindeer and only 84% of fetal growth in caribou. Both subspecies rely on maternal body protein for 87-94% of the protein deposited in the growing calf. Successful calving by caribou is most vulnerable to delays in spring plant growth at the end of pregnancy, whereas reproduction by reindeer is more vulnerable to short summers and reduced food supplies in early pregnancy. The response of Rangifer herds to environmental change therefore will depend on reproductive strategies for timing of birth and the use of body stores to support pregnancy and milk production.

49.9 BARKER, JENNIFER S.**; HUXMAN, T.; BRONSTEIN, J.; DAVIDOWITZ, G.; University of Arizona; *jbhepcat@email.arizona.edu*

Ecological stoichiometry of Manduca sexta herbivory on Datura wrightii.

Host plants can differ in quality among different habitats, among plants in the same microhabitats, as well as among leaves within an individual plant. The herbivorous insect *Manduca sexta* (tobacco hornworm: Sphingidae) obtains all its nutrients from its host plant *Datura wrightii* (jimson weed). It has been proposed that phosphorus (P) content in diet determines organismal growth rate (Growth Rate Hypothesis). We examined how C:N:P in the host plant *D. wrightii* translated into C:N:P in the herbivorous caterpillar *M. sexta* in a semi-natural environment that emphasized differences in the nutritional quality of the host plant. *D. wrightii* were subjected to one of the four combinations of high/low water and high/low nutrient treatments in either soil or sand substrate. The sand substrate stressed the plants, reduced their photosynthetic rates, and amplified treatment differences more than soil substrate. *M. sexta* hatchlings fed within a single treatment until pupation. Pupae were tested for C:N:P by mass spectrometry and colorimetric assay. Results show that the C:P and N:P ratios in the leaves varied widely among treatments but were confined to a narrow range in the insects. No association could be found between pupal mass or development time with P levels. A strong correlation between insect growth rate and P levels of plants grown in sand existed, but the correlation was not apparent for caterpillars that fed on soil-grown plants. This indicates that the growth rate hypothesis is most evident for animals under stressful conditions. C:N:P levels in the caterpillars' diets did not translate directly into caterpillar C:N:P. This lack of correspondence between leaf and caterpillar C:N:P is partly due to selective foraging behavior by the caterpillar.

S7-1.4.2 BARRY, BK*; ENOKA, RM; Univ. of Colorado, Boulder; *Benjamin.Barry@colorado.edu*

An Inhibitory Spinal Reflex Between Elbow Flexor Synergists

Decades of work on spinal reflexes in humans based on measuring Hoffmann (H) reflexes in muscles of the forearm and lower leg has provided a relatively limited understanding of the modulation of afferent pathways during functional tasks (Pierrot-Deseilligny & Burke, 2005). An alternative approach is to use the spike-triggered stimulation technique (Stephens et al. 1976), which allows investigation of reflex pathways in muscles from which the H-reflex may not readily be recorded, and it avoids some of the interpretation issues associated with the H-reflex. Such an approach is being used in our laboratory to investigate an inhibitory reflex between the brachioradialis and biceps brachii muscles. An electrical stimulus is applied at a submotor threshold to the brachioradialis branch of the radial nerve and its effect on the discharge of a tonically active motor unit in biceps brachii is determined. Post-stimulus time histograms constructed from the interspike intervals of the isolated motor unit indicate that the stimulus consistently delays the occurrence of the subsequent discharge of a biceps brachii motor neuron. Presumably, the inhibitory reflex connection between these two synergist muscles for an elbow flexion torque, aids in the control of the substantial supination torque exerted by biceps brachii. In support of this, the magnitude of the inhibition recorded from the same biceps brachii single motor unit (n = 18) varies systematically when the forearm posture is shifted between pronated and supinated positions. The reflex pathway likely involves either type I non-reciprocal inhibition or presynaptic inhibition mediated by primary afferent depolarization interneurons. This posture-dependent spinal reflex may contribute to the durations that various submaximal contractions can be sustained with the elbow flexor muscles. Supported by NINDS NS043275.

S1-1.12 BARTOL, I.K.*; STEWART, W.J.; Old Dominion University, Norfolk, VA; *ibartol@odu.edu*

Ontogenetic differences in squid jet structure

Squids rely heavily on a pulsed jet for locomotion throughout ontogeny, but the jet is used in very different flow regimes depending on life history stage. Squid hatchlings (paralarvae) may operate at a Reynolds number (Re) = 1, whereas some large squid adults operate at a Re = 10^8. Over this wide Re range, the physics of fluids play an important role in development of jet features integral to propulsive swimming performance, and consequently swimming strategy may correlate closely with Re. We investigated whether jet structure and swimming behavior change as a function of life history stage. Using a customized holding chamber and a zoom lens with a 0.8 x 0.8 cm field of view, we performed digital particle image velocimetry (DPIV) experiments with free-swimming long-finned squid *Loligo pealei* paralarvae (dorsal mantle lengths (DML) ~ 0.2 cm). Older life history stage experiments were conducted using brief squid *Lolliguncula brevis* (2.0 9.0 cm DML) swimming in a water tunnel equipped with a multi-camera motorized traverse system and laser guide arm for kinematic and DPIV data recording. Vortex rings were a conspicuous jet feature in all life history stages and jet plug length (L) to funnel diameter (D) ratios were useful indices for predicting vortex ring structure. Paralarvae generally exhibited higher pulsing rates, higher relative jet velocities, and more rapid vortex dissipation rates than the adult squid. Vortex rings with and without trailing jets were observed in all life history stages, but large adults swimming at high speeds had the largest L/D ratios and vortex rings with the longest trailing jets. The implications of these findings for swimming efficiency will be discussed.

43.5 BATTIPROLU, Pavan K*; FARRAR, Richard S; HARMON, Kelli J; PIERSON, Nicholas S; RODNICK, Kenneth J; Idaho State University; *battpava@isu.edu*

SEX DIFFERENCES IN TELEOST CARDIAC BIOCHEMISTRY AND PHYSIOLOGY: WHAT HAVE WE BEEN MISSING?

Unlike numerous mammalian studies, studies of cardiac physiology and metabolism in fishes have paid little attention to sex or the possibility of sex differences. We determined effects of glucose, sex steroids, and Ca^{2+} on cardiac contractility and metabolism in sexually immature, male and female trout. We also measured stored energy (glycogen, protein and triglycerides) in cardiac tissue. Fish were euthanized by blunt trauma. Ventricles were either 1) frozen rapidly and assayed for stored energy substrates or 2) dissected into uniform strips, attached to isometric force transducers, stretched to 90% of L_{max}, and electrically-stimulated at 0.5 Hz under aerobic conditions in either glucose or substrate-free media for 60 min at 14°C. Strips were treated with either testosterone or estradiol and controls received glucose or substrate-free conditions for the duration of experiments during which twitch force (F) and media metabolites were measured. Our results demonstrate that 1) cardiac glycogen was higher in males compared with females; 2) exogenous glucose (independently) and testosterone (males) or estradiol (females) all promoted F; however, increments in contractility were greater in males; 3) lactate release was 2-fold greater in females; and 4) female ventricle strips were more sensitive to Ca^{2+} than males. Similar to mammalian studies, our findings suggest that sex differences exist in cardiac energy metabolism, hormone responsiveness and Ca^{2+} sensitivity. Future studies should document and consider sex as an important variable for cardiac metabolism and performance in fishes. Funded by NIH P20RR16454, NSF-Idaho EPSCoR EPS-0447689, and NSF IOB-517669

2.2 BAUER, B.C.**; WOMASTEK, I.; DITTAMI, J.; HUBER, S.; University of Veterinary Medicine Vienna, Austria, University of Vienna, Vienna; *barbara.bauer@vu-wien.ac.at*

Early photoperiod and temperature affect growth and sexual maturation in male guinea pigs

Seasonally breeding mammals use environmental cues like photoperiod, temperature and food abundance to accurately time growth and reproductive onset. Evidence from laboratory rodents and humans indicates that components of a photoperiodic and temperature sensitive system might still be preserved even in non-seasonally breeding species. We used the domestic guinea pig (*Cavia aperea f. porcellus*) to investigate whether early photoperiod and temperature might affect juvenile growth patterns and sexual maturation in this non-seasonally breeding species. We found that in males, growth and testosterone titers during puberty were significantly affected by pre- and early postnatal photoperiodic and temperature conditions. Males gestated and lactated in LD 16:8 / 25°C grew significantly faster and had higher testosterone levels at an earlier age than males gestated and lactated in LD 8:16 / 15°C. Whereas in females, no significant treatment effect on growth patterns or the onset of puberty was found. We therefore conclude that in juvenile guinea pigs, reproductive development and growth might be more sensitive to environmental conditions in males than in females. This work was supported by the Austrian Science Fund (P18089-B03) and the Austrian Academy of Sciences (APART).

47.11 BECK, ML*; SCHWABL, H; WEBSTER, MS; Washington State University; *beck@mail.wsu.edu*

The effects of timber harvesting on growth and stress hormone levels in nestling Prothonotary warblers (Protonotaria citrea)

Anthropogenic habitat fragmentation and modification are becoming increasingly pervasive problems for many natural populations. Habitat fragmentation or reduction may have drastic effects on a population by greatly reducing the number of individuals or their reproductive success. However, less drastic habitat modification may have more subtle effects that are only detected by examining a population in detail. More subtle effects of habitat modification could include differences in the stress response or changes in the development of young. We examined the effects of habitat modification on nestling growth and condition in the Prothonotary warbler (*Protonotaria citrea*). In our case, habitat modification was defined as areas in which timber had been harvested in the last 10 years in a manner that thinned the forest by 40-60%. We predicted that nestlings raised in areas where timber was harvested would be in worse condition, less mature at fledging, and grow at a slower rate than those raised in unharvested areas. We further predicted that nestlings in harvested areas would have higher levels of corticosterone than those raised in unharvested areas. We found no significant differences in growth rates, condition, or maturity of nestlings in the harvested and unharvested areas. Furthermore, stress hormone concentrations did not differ significantly between nestlings raised in the harvested and unharvested habitats. Our results show that prothonotary warblers are not negatively affected by thinning the forest surrounding their breeding sites. However, forest thinning that encompasses the aquatic areas in which they nest may negatively affect the birds as they strongly prefer to breed in shaded areas.

2.1 BECKMAN, B.R.*; SHIMIZU, M.; NOAA Fisheries, University of Hokkaido; *Brian.Beckman@NOAA.gov*

Post-prandial response of insulin, IGF-I, and IGFBPs in fasted coho salmon.

Insulin and insulin-like growth factor-I are peptide hormones that apparently arose from a common ancestral gene. Both IGF-I and insulin are important components of the endocrine growth regulation system. To better understand how these structurally similar hormones interact with nutritional signals to regulate fish growth we undertook an experiment featuring fasting and re-feeding. Coho salmon juveniles were fasted either over-night, for one week, or for three weeks. Subsequently, half of the fish from each fasting group were fed. The post-prandial response of fish from all treatments was followed at four hour time intervals through a 24 hour cycle by collecting terminal blood samples from a sub-set of fish. Plasma levels of insulin, IGF-I, IGFBP1, and 41 k IGFBP (putative IGFBP3) were assessed from these fish. Basal levels of insulin were similar for fish from all three fasting treatments, post-prandial increases in insulin were graded according to fasting status (greatest response in fish fasted the least amount of time). In contrast, basal levels of IGF-I varied among fasting treatments with highest levels in fish fasted only overnight. Post-prandial changes in IGF-I were slight. The differential response of IGF-I and insulin to feeding following a fast is likely due to differences in how these hormones are produced, stored, and cleared. IGF-I is secreted constitutively after production and is retained in the blood by IGFBPs. In contrast, insulin is stored after production and secreted in response to a cascade of signals following feeding. However, insulin is rapidly cleared from the blood after secretion while clearance of IGF-I is retarded by the IGFBPs. These data help reveal the diversity of mechanisms regulating endocrine actions.

16.2 BENTLAGE, Bastian*; WöRHEIDE, Gert; Geoscience Centre of the University of Göttingen, Germany; *b_bentlage@gmx.net*

Phylogeography of Pericharax heteroraphis (Porifera) from the Great Barrier Reef

Resolving the biogeographic histories of tropical marine invertebrates remains a challenge. Sponges (Phylum Porifera) are well-suited models for such studies due to the restricted dispersal capabilities of their short-lived larvae and thus the high probability of preservation of past population genetic structures. We employed two unlinked nuclear markers to uncover the phylogeographic patterns of the common coral reef sponge *Pericharax heteroraphis* from the SW Pacific, focussing on the Great Barrier Reef (GBR). A new marker system for sponges was developed, the second intron of the ATP synthethase beta subunit-gene, and analysed together with nuclear rDNA internal transcribed spacer sequences (ITS1-5.8S-ITS2 region plus flanking gene sequences). We used Single-Stranded Conformation Polymorphism (SSCP) analysis to phase alleles and investigated its applicability to aid poriferan phylogeographic and population genetic studies. We discovered very low variation among rDNA sequences (0.3% to 1%) and the phylogeographic patterns derived from these sequences appear to be the result of persistent ancient polymorphisms rather than population history. The intron, in contrast, provided better resolution of population genetic structures. SSCP analysis proved to be an effective tool for phasing alleles of about 400bp length. Our analyses suggest a past population subdivision between the northern and central GBR followed by a subsequent range expansion of subpopulations. The patterns uncovered differ from those of previous studies on *Leucetta chagosensis*, a close relative of *P. heteroraphis*. These discrepancies might be attributed to different responses of both taxa to environmental changes, like small sea-level oscillations. Our hypothesis awaits corroboration using an extended geographic sampling scheme.

36.2 BERGMANN, PJ*; MEYERS, JJ; IRSCKICK, DJ; University of Massachusetts at Amherst; *pjbergma@nsm.umass.edu*

Evolving to be short and stubby orthogenesis and grades of evolution in body plan in lizards.

Evolutionary changes in body proportions are of central interest in evolutionary biology, as such changes can affect organismic function. Relative changes in limb and body lengths are particularly important in influencing locomotor performance and kinematics. Although the evolution of body elongation and limb reduction has received considerable attention, the evolution of a short and stocky body plan have not. The evolution of a short and stocky body plan may be affected through directional evolution, or orthogenesis; or alternately, through the evolution of a series of grades from a more typically proportioned body. The Phrynosomatidae is a lizard clade containing a diversity of body proportions, including the short, broad-bodied horned lizards (*Phrynosoma* spp). We document patterns of body proportion evolution among 23 species of phrynosomatids by examining head, limb and body dimensions. Our findings show positive associations between body length and front and hind limb lengths, but negative associations between those variables and body width. A phylogenetically uncorrected analysis indicates these associations scale differently with body size in each of the three main subclades (horned, sand and fence lizards) of phrynosomatids. In all of these subclades, stockier lizards are also larger. However, the degree of stockiness increases most dramatically with body size in sand lizards, and least dramatically in horned lizards. A phylogenetically corrected analysis supports the general association between body size and stockiness, but does not detect differences between subclades. The results indicate both a directional correlated evolution of body dimensions, and that the three major phrynosomatid subclades represent separate grades of evolution.

19.3 BERGSTROM, MA*; MENSINGER, AF; Univ. of Minnesota Duluth; *berg1102@d.umn.edu*

A comparative study of sensory physiology and competitive interactions of the invasive round goby with three native species: slimy sculpin, spoonhead sculpin, and logperch

Population declines in native benthic fish populations across the Great Lakes have been attributed to the round goby (*Neogobius melanostomus*) invasion. Few studies have performed both behavioral and physiological experiments to characterize the ability of round gobies to displace native species. Round gobies appear to be more aggressive, mature more quickly, have higher fecundity than most native species, and have been documented to negatively impact the mottled sculpin (*Cottus bairdii*) (Janssen and Jude 2001). Other benthic species potentially affected by round gobies due to diet overlap or interspecific competition include the slimy sculpin (*Cottus cognatus*), spoonhead sculpin (*Cottus ricei*), and logperch (*Percina caprodes*). Experiments were conducted over three weeks with one round goby and one or two natives in a simulated stream. Native fish were able to maintain or slightly increase weight in the absence of the goby. Although slimy sculpins were able to maintain this trend after the additional of the goby, spoonhead sculpins and logperch experienced significant weight loss when combined with a round goby. Concurrent predator-prey studies indicated that round gobies detected prey at greater distances in the dark than native fish, suggesting greater range of its mechanosensory lateral line. However both sculpin species exhibited longer reactive distances than the round goby and logperch during daytime conditions. The goby's ability to outcompete native fish for limited food combined with its nocturnal sensory advantage provide distinct advantages that have contributed to its successful invasion.

61.4 BERKE, Sarah K*; WOODIN, Sarah A; Univ. of South Carolina; *berke@biol.sc.edu*

Decorating behavior and predation: new insights from polychaetes and crustaceans

Decorating behavior, in which animals actively attach foreign material to their bodies or their structures, occurs in 25% of the major metazoan phyla. Decorating is commonly assumed to provide camouflage, and strong experimental evidence supports this hypothesis in some systems. We present evidence that camouflage may not be important in other decorating systems: a tube-decorating polychaete (*Diopatra cuprea*) and a decorator crab (*Oregonia gracilis*). We manipulated the tube decoration of *Diopatra* in the field, quantifying rates of damage to the tubes as measures of predation attempts. Removing tube decoration had no effect on predator attack rates, suggesting that *Diopatra's* decoration does not interfere with predator recognition of its prey. Similarly, we manipulated the decoration or *Oregonia* in the field and the laboratory. Field tethering experiments and laboratory predation assays produced little evidence that decoration decreases predation risk for these crabs, although there were exceptions. These results are discussed in the context of other systems, with an eye towards identifying system properties which make camouflage likely or unlikely.

7.8 BERNATIS, J.L.*; BAKER, S.M.; BAKER, P.; WARREN, G.L.; University of Florida, Florida Fish and Wildlife Conservation Commission; *bernatis@ufl.edu*

Ecophysiology of the Channeled Apple Snail, Pomacea canaliculata complex, in Florida

The South American channeled apple snail *Pomacea canaliculata*, and related species (*P. canaliculata* complex), are introduced species with populations rapidly expanding across Florida. Possession of both lungs and gills, coupled with the ability to aestivate for several months, gives the snail an advantage in tolerating environmental perturbations. Prior research has focused on controlling the species; therefore, the purpose of this project is threefold and examines the general ecology, physiology, and environmental impacts of the snail. Field studies in Florida have determined that virtually any body of freshwater may serve as a potential habitat. Preliminary physiological results suggest wide ranges in desiccation tolerance (> 90 days), temperature (> 35° C), oxygen (< 50% DO), pH, and salinity. Feeding experiments have demonstrated the potential impact of the snails on ecosystems. Preliminary data indicates that small snail populations (n=10/m^2) are capable of regularly consuming 220g of plant material per 24 hours, regardless of prior feeding status. However, consumption fluctuates based on the plant species, demonstrating feeding preferences of the snails. The limited knowledge of the species in their native range and introduction into a different ecological demographic habitat limits the ability to predict the full impact of the species. However, the preliminary data related to physiology and feeding suggests that, while the species may tolerate wide environmental conditions, a major limiting factor is the presence of adequate food.

S1-5.9 BIEWENER, A.A.; Harvard University; *biewener@fas.harvard.edu*

Unraveling the Link between Muscle Activation Timing and Force

The temporal relationship between muscle activation and tension development is critical for studies of muscle recruitment using electromyography (EMG), as well as for how EMGs may be used to interpret muscle function more generally. However, several factors influence the timing of neuromotor activation relative to force production. These include (1) the intrinsic rate of force development, which depends on the rates of excitation-contraction coupling and acto-myosin cross-bridge cycling, (2) the amount of series-elastic compliance (SEC) in the muscle or muscle-tendon unit, and (3) the nature of external loading transmitted to the muscle via the skeletal system it attaches to and moves. Higher operating frequencies require faster intrinsic rates of force development and reduced SEC, and are facilitated by active stretch of a muscle before it shortens or by isometric contraction. These differences in contractile function and the timing between EMG and force development are influenced by animal size and locomotor mode, or biomechanical context. Relative timing is compared and evaluated for various muscle systems in which in vivo force and EMG data are available based on the author's and others' work. Whereas the phase advance and EMG duration *relative to force output* is 6% and 63% for the cockatiel pectoralis during flight and 5% and 43% for the plantaris longus of *Xenopus* during swimming, it is 8% and 68% for the lateral gastocnemius (LG) of goats during trotting. This means that force development continues beyond EMG activation for 20% of the locomotor cycle in the cockatiel pectoralis, 38% in *Xenopus* plantaris longus but only 9% in the goat LG. It is likely that phase delay and relative duration of EMG versus force are less for faster muscles and smaller animals than for slower muscles and larger animals. Consequently, interpretations of muscle function based on EMG timing can be unraveled by neuromotor linkages.

9.6 BINDER, W/J; Loyola Marymount University; *wbinder@lmu.edu*

Changes in the mandible with age in carnivorans

As individuals age, skull morphology has been shown to change and reflect new force distributions. This type of change is especially interesting in carnivoran (members of the Order Carnivora) teeth and jaws, as feeding is so important and can have a direct effect upon the bony structures involved. Carnivorans have a single set of adult teeth which are subject to wear over time, and tooth wear results in a decreased force per unit area, which can lower resultant forces at the occlusal bite points. To offset this, the mandibles, under greater strain to eat the same foods with reduced forces at the teeth, may show increased bone thickness to offset these greater loads. Thus both increased age and greater tooth wear in the individuals should correlate with greater bone deposition in the jaw. In addition, this would be expected to be much more prevalent in species which have harder diets (including hyenids, and some mustelids such as the sea otter) than in those with generally mixed or softer diets (ursids and felids). I tested this hypothesis by measuring mandibular cortical bone thickness in individuals from ten species within six families of the Order Carnivora to get a reasonably broad sample. The results seem to confirm the correspondence of increased mandibular cortical thickness with age to a strong degree with measured hyenids and procyonids, and to a lesser degree with felids. No such positive correlation is seen with the measured canids, mustelids and ursids. This may demonstrate the effects of both hardness of diet, which also effects tooth wear, and how limited dietary choices are for older individuals (degree of ominivory).

S10.5 BIRENHEIDE, R.*; MERZ, R.A.; SICB Webmaster, Swarthmore College; *webmaster@sicb.org*

Rolling out the SICB Library - What are the procedures for submission and review?

The SICB digital library offers an online submittal system to authors (available through the SICB website or at http://www.sicb.org/dl/). Our online form gathers information about the submitted entry depending on the topic and the type of material. This information is used to generate the metadata necessary for initially cataloging and later for effectively searching materials. Guidelines for authors are provided on the website and a variety of files can be uploaded, from text or picture files to movies and interactive online software. This variety of file types enables demonstrations or interactive activities that are not possible with print media. When editors are notified of new submissions via an automated email system, they view the entries and then email links to reviewers. As with paper journals, entries are reviewed by at least two peer reviewers (chosen by the editors when a manuscript is submitted) and evaluated for both scientific accuracy and pedagogical value. Comments are returned electronically to the author. The manuscript is published when the editors switch the entry to live on the webpage. The submittal and review systems are easily updated and refined using feedback from users.

69.6 BISHOP, K.L.*; SWARTZ, S.M.; BREUER, K.; TIAN, X.; Duke University, Brown University; *klb23@duke.edu*

Compliant wings and the evolution of gliding in vertebrates

Gliding flight is often regarded as a simple, primitive form of locomotion and has consequently attracted little scientific attention as a form of locomotion in its own right. However, gliding has evolved independently at least twelve times in vertebrates, including representatives in each vertebrate class. Studies of the performance of gliding vertebrates indicate that many of them achieve shallow glides and can travel substantial distances. Kinematic studies have shown that gliding mammals use extremely high angles of attack, beyond the angles at which airplane wings would typically stall, yet generate much higher lift coefficients than expected for stalled wings. Part of the explanation for this lies in lift-enhancing properties of low aspect ratio wings, but another part lies in the properties of flexible, extensible membrane wings. To investigate the relative performance of flexible and rigid wings, we measured aerodynamic forces produced by physical models of wings in a wind tunnel. In addition, we used high-resolution video of membrane wings to measure deflections across the wing surface under aerodynamic loading. Membrane wings generated higher lift coefficients than rigid wings at all angles of attack. Moreover, flexible wings had a "softer" stall, with lift decreasing with increasing angle of attack beyond the stall angle at a lower rate than in rigid wings. Imaging results show that the amplitude of wing deformations increases and that wing camber decreases around the stall angle, both of which may contribute to the soft stall. We suggest that compliant skin is exceptionally well suited to a role as a lift generating surface and may render more likely the repeated evolution of gliding in vertebrates.

S5.5 BLACKSTONE, N.W.; Northern Illinois University; *neilb@niu.edu*

Redox signaling and the transition from basal metazoans to bilaterians

Living things invariably consist of some kind of compartmentalized redox chemistry. Signaling pathways mediated by oxidation and reduction thus derive from the nature of life itself. The role of such redox signaling broadened with major transitions in the history of life. Prokaryotes often use redox signals to deploy one or more variant electron carriers and associated enzymes to better utilize environmental energy sources. Eukaryotes transcend the strong surface-to-volume constraints inherent in prokaryotic cells by moving chemiosmotic membranes internally. As a consequence, eukaryotic redox signaling is frequently between these organelle membranes and the nucleus, thus potentially involving levels-of-selection synergies and antagonisms. Multicellular eukaryotes typically exhibit redox gradients between layers of cells, due for instance to differences in the availability of substrate and oxygen. The origin of the animal mouth allowed sequestering large amounts of substrate, exaggerating these redox gradients. Multicellular redox regulators collections of metabolically active cells emitting a disproportionate share of redox signals correspond to these steep redox gradients. In early-branching metazoans such as cnidarians and sponges, environmentally based redox signals actually or potentially mediate many aspects of growth, form, and life history. The origin of the bilaterians contradicts this trend of an increasing role for redox signaling in the history of life. Many bilaterians lost their ability to respond to redox signals because of the restricted potency of their somatic cells. Growth, development, and even senescence became more subject to internal signals. Redox signaling was largely confined to the timing of life history. These changes may reflect the advantages of diminished levels-of-selection conflicts between the cell and the organism. In parallel, organism-level selection is more potent in bilaterians.

53.6 BLAESSE, Anne-Kathrin*; BROEHAN, Gunnar; WEIHRAUCH, Dirk; University of Osnabrueck, Germany; *weihrauchblues@gmx.net*

A study on cation/H^+ exchangers in the midgut of Manduca sexta larvae: Flux experiments, tissue mRNA expression analysis and cellular localization.

The midgut epithelium of *M. sexta* consists mainly of two cell types: the goblet cells, responsible for K^+ secretion, and the columnar cells, where nutrition and ammonia uptake takes place. Ussing experiments showed that outwardly directed K^+ flux and inwardly directed NH_4^+ transport are inhibited to different degrees by apically applied amiloride, however, both in a dose dependent manner. Thus it is suggested that at least two different members of the NHE family play here a role in K^+ secretion and NH_4^+ uptake, respectively. Up to date we obtained full length cDNA sequences of two insect NHE isoforms, which showed 61% and 53% identity in deduced amino acid sequence to the mammalian NHE8 and NHE6, respectively. Employing semi-quantitative triplex RT-PCR mRNA expression levels of the insect NHE8 or NHE6 were compared to the expression levels of the V-ATPase subunit D and the ribosomal protein S3 (internal standard) in a particular tissue. While the insect NHE8 showed similar relative expression levels in all tissues (ant., med., post. midgut, hindgut, Mal. tubules, tracheae, ganglia, fatbody), insect NHE6 revealed differences in the expression pattern with ant. and post. midgut exhibiting significant lower relative expression levels compared to hindgut, Mal. tubules, tracheae, ganglia and fatbody. The V-ATPase, putatively energizing cation/H^+ exchangers in *M. sexta*, is strongly expressed in all gut sections and Mal. tubules (transport epithelia) but showed significant lower expression levels in tracheae, ganglia and fatbody. Immunohistochemistry revealed apical/subapical and cytoplasmatic localization of NHE8 in the goblet cells suggesting a role in K^+ excretion but not NH_4^+ uptake.

67.3 BLATCH, S.A.*; HARRISON, J.F.; Arizona State Univ.;
sydella.blatch@asu.edu

Physiological Consequences of Folic Acid in the Fruit Fly

Folic acid is essential for DNA synthesis and methylation, a form of epigenetic regulation. Irregularities in folate metabolism have been linked with a host of diseases, but the mechanisms remain unclear. The fruit fly is well-suited to explore these relationships since it has a short lifespan and well-characterized development. This study asks how dietary folate affects the fitness of the fruit fly *Drosophila melanogaster*. We measured aspects of growth and development on 20 in four treatment groups, 0, 30, 100, or 300% required dietary folate. We examined flies born into the dietary treatments (F1) as well flies whose parents were also born into the dietary groups (F2). Based on mammalian studies, we predicted that increasing folate supply would increase growth and fitness in both generations. In F1, there were very few differences observed due to folate, suggesting maternal transfer of folate. In F2, the 0 and 300% folate flies laid fewer eggs, but the eggs developed sooner, were more likely to become pupae from the larval stage, and grew faster than the 30 and 100% groups. The tradeoff between egg-laying rate and offspring growth/development rates suggest that folate influences egg quality. This could be due to low and high rates of DNA synthesis or methylation caused by low and high levels of folate respectively, which has been observed to affect development and fitness in mammals. However, the faster development seen in the 0% folate flies is unexpected. This occurrence could be due to alternate pathways or adaptations not observed in mammals. Supported by NSF IOB-0419704 to JH and NSF HRD-0602425 to ASU.

8.2 BLOB, R.W.**; ESPINOZA, N.R.; PRUETTE, M.E.; WRIGHT, K.M.; CIRILO, S.R.; GOSNELL, J.S.; Clemson Univ., Erskine College;
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Single Limb Forces in Jumping Frogs: Implications for Limb Bone Loading

The explosive jumps of frogs represent a dramatic locomotor behavior that might be expected to place substantial loads on the limb skeleton. Our measurements of *in vivo* strains from the femur of jumping frogs have indicated only moderate load magnitudes, though these recordings have shown a complicated loading regime that combines axial and bending loads with variable degrees of torsion. To help understand the mechanics underlying the loading regimes identified during strain recordings, we synchronized measurements of three-dimensional ground reaction force components acting on a single limb with measurements of three-dimensional limb kinematics in jumping bullfrogs (*Rana catesbeiana*) and cane toads (*Bufo marinus*). The vertical component of the ground reaction force frequently exceeded one body weight in magnitude during jumps, but the mediolateral component was usually much smaller. Bending and torsional loads, therefore, are likely related primarily to the inclination of the limb relative to a primarily vertical ground reaction force, rather than inclination of the ground reaction force itself. Small mediolateral forces also have been found previously in other species using non-parasagittal locomotion (e.g., lizards, alligators), and thus appear to be common among diverse modes of locomotion in vertebrates.

29.2 BLOMQUIST, C.H.*; ATKINSON, S.; BURKANOV, V.N.; GRACHEV, A.I.; University of Minnesota, Alaska SeaLife Center/University of Alaska Fairbanks, Alaska SeaLife Center;
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Activity of steroidogenic enzymes in ovary, corpus luteum and placenta of the ringed seal Phoca hispida

The sites and relative activity levels of steroid-synthesizing enzymes involved in estrogen, androgen and progesterone formation within the maternal-fetal-placental unit during pregnancy in pinnipeds are not well-understood. In this study, 17beta-hydroxysteroid deyhdrogenase (17beta-HSD) activity with estradiol (E_2) and testosterone (T), 3beta-hydroxysteroid dehydrogenase/5-ene-isomerase (3beta-HSD) activity with DHEA, and 3-ketosteroid reductase (3-KSR) activity with 5alpha-DHT were assayed in samples of ovary, CL, placenta and fetal ovary from four reproductive tracts recovered from pregnant ringed seals. The highest levels of each activity (pmol/mg protein) were detected in CL tissue. 3-KSR was the predominant activity in all of the samples, followed by 3beta-HSD. The product of the 3-KSR reaction was 5alpha-androstane-3alpha,17beta-diol. 17beta-HSD activity with E_2 exceeded that with T in CL and ovary in all cases. Activities in fetal ovaries were comparable to those in the maternal ipsilateral ovary lacking the CL. In placenta, 3beta-HSD was near or below the detection limit of our assay, 17beta-HSD activity was detected, as was 3-KSR. Our findings suggest the CL is the major site of 17beta-HSD, 3beta-HSD and 3-KSR activity during the latter stages of pregnancy in *P. hispida*. Our finding of a predominant 3-KSR activity leading to the formation of 5alpha-androstane-3alpha□17beta-diol raises interesting questions as to the possible role of this estrogenic steroid during pregnancy.

58.3 BOBACK, S.M.*; SECOR, S.M.; University of Alabama;
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Causal association between organ masses and aerobic metabolism in the diamondback water snake

Organ mass variation has been interpreted to be an underlying source of inter-individual variation in metabolic rate. We addressed this hypothesis by exploring the relationship between organ mass and aerobic metabolism in the diamondback water snake (*Nerodia rhombifer*). We measured from over 300 water snakes (7 1930 g) standard metabolic rate (SMR), maximum metabolic rate (VO_{2max}), and the wet and dry masses of all organs including skin, muscle, and bone. Dried organ masses (Log10) scaled to body mass (Log10) with exponents ranging between 0.80 and 1.30. Mass residuals from logarithmic regressions were positively correlated between most organ pairs. Scaling exponents of SMR and VO_{2max} were statistically equivalent and their mass residuals were significantly correlated. SMR residuals were correlated with dry mass residuals of the heart, lung, liver, stomach, small intestine, large intestine, kidneys, bone, and skin, whereas VO_{2max} residuals were correlated with mass residuals of the heart, liver, stomach, bone, and skin. Incorporated into a multiple regression, heart, liver, stomach, and kidney masses explained 40% of the variation in SMR and 12% of the variation in VO_{2max}. Apparently, in the diamondback water snake variation in organ mass and consequently organ metabolism underlies inter-individual variation in aerobic performance.

3.4 BOCK, Natika L*; PAUL, Dorothy H; University of Victoria, British Columbia; *nlbock@uvic.ca*

Telson Mechanosensory Systems Differ among Squat Lobsters, Mole Crabs (both anomalans), and Crayfish (a macruran).

Munida quadrispina (squat lobsters) resemble macrurans (e.g., crayfish) in behavior and morphology, but are more closely related to *Emerita analoga* (mole crabs). Nevertheless, the distribution of projection mechanosensory neurons in their 6th abdominal ganglion (A6) differs from that of homologous neurons in crayfish and mole crabs (Bock and Paul. Neurosci Abstr, 2005. Online). We hypothesize that this reflects species-specific differences in tailfan peripheral sensory structures. Here we examine the organization of sensory setae and their afferent neurons in tailfans of *M. quadrispina* and *E. analoga* for comparison with that of the well-studied homologous system in crayfish. We use SEM to survey setae and identify putative sensory structures, various staining methods to describe the sensory innervation, and electrophysiology to characterize setal afferent responses. Most sensory setae in *M. quadrispina* appear to be singly innervated, rather than dually, as in crayfish, where the two neurons have opposite directional preference. Numerous setae of different types fringe the margins of the telson in *M. quadrispina*, while setae on the dorsal surface are mostly grouped in circlets. Preliminary extracellular recordings suggest that setae of a circlet may have different preferred directionality, which, if true, could be an evolutionary adaptation to compensate for loss of dual innervation. The dorsal telson surface of *E. analoga* is nearly devoid of setae, but innervated setae occur along the margin and as tufts adjacent to the uropod base. Substantial species-specific differences among telson mechanosensory systems appear to correlate with the differences in posture and locomotion, but have not yet provided insight into the differences in A6 projection interneurons. Funded by NSERC.

S5.1 BOERO, Ferdinando*; SCHIERWATER, Bernd; PIRAINO, Stefano; DiSTeBA , University Lecce, Italy, ITZ, Ecology & Evolution, Hannover, Germany; *boero@unile.it*

Cnidarian milestones in metazoan evolution

Cnidaria (characterized by the presence of cnidocysts) contain most of the characters considered as milestones of Metazoan evolution. It is suggested that nervous cells, bilateral symmetry, eyes, statocysts, chitinous skeleton, calcium-based skeleton, metamery, and apoptotic pathways first emerged in the Cnidaria and that this group led to the array of diversity, known as the Cambrian explosion, that represents the main animal phyla of the present. Some authors even suggest that the origin of the coelom and mesoderm date back to the Cnidaria. The hypothesis of homology of the above traits throughout the animal kingdom is testable by the identification of their genetic determinants. Morphological homology is to be supported by genetic homology. Such tests are being made, and in most cases they support homology of morphological traits. The milestone of metazoan evolution might have been the loss of cnidocysts in some (or even one) cnidarian species, leading to further development of some of the traits that are all present in what is possibly the founding phylum of Metazoan diversity.

S1-1.6 BOLLER, M.L.; Hopkins Marine Station of Stanford University; *boller@stanford.edu*

Waves drag down macroalgae

Vogel coined the term reconfiguration to describe the hydrodynamic process by which a flexible organism changes shape in response to the hydrodynamic forces imposed upon it. Reconfiguration is important to marine macroalgae in that it reduces the magnitude of hydrodynamic forces and decreases the risk of dislodgement and/or fragmentation; reconfiguration has been said to be a prerequisite for survival for some macroalgae. However, our understanding of the mechanisms of reconfiguration in the intertidal zone is limited because this complex solid mechanical/hydrodynamic process is almost impossible to directly observe in the field and difficult to replicate in the lab. In this study, reconfiguration in intertidal macroalgae was examined in two laboratory setups: a medium-speed recirculating flow tank and a high-speed gravity flume, which together encompass a range from 0.1 to >10 m s^{-1}. A recently proposed reconfiguration drag model was fit to the medium-velocity data and used to predict drag at high velocities. This model separates the changes in frontal area and drag coefficient, potentially allowing for more accurate extrapolation than previously possible. High-speed measurements obtained from the gravity flume served as a test of the model. Results indicate that the reconfiguration model effectively characterizes drag when a sufficient velocity range (e.g. 1 to 6 m s^{-1}) is examined and that velocity dependent effects of reconfiguration must be accounted for when extrapolating from low velocities. Combined with measurement of macroalgal tenacity, this model should make better predictions of survival on wave exposed shores.

65.10 BOWLIN, M.S.*; WIKELSKI, M.C.; Princeton University; *mbowlin@princeton.edu*

Calibration of heart rate and energy expenditure during flight and at rest in a passerine

Previous calibrations between heart rate and energy expenditure measured using either doubly labeled water or respirometry have shown that in large birds, for a given species and activity there is generally a linear relationship between the two variables i.e. the oxygen pulse remains steady. Nothing is known about how closely heart rate tracks energy expenditure in small birds (e.g. passerines), however, so we performed two calibrations for Swainson's Thrushes (*Catharus ustulatus*), a small (~35g) passerine migrant: one on resting birds and one on birds migrating' in a wind tunnel. Resting birds (three male, three female) were tagged with heart rate transmitters and placed in a respirometry chamber overnight, where both heart rate and VO_2 were monitored. Energy expenditure was varied intraspecifically by varying temperature. For the flying calibration, heart rate was measured during five six-hour flights in a wind tunnel; the doubly-labeled water method was used to calculate average energy expenditure during each of the flights as well. Here we present the results of the two calibrations between heart rate and energy expenditure for Swainson's Thrushes at rest and in flight.

47.6 BOYD, EB*; BUSCH, DS; WINGFIELD, JC; Univ. of Washington; *ellen@boydvet.com*

Reproductive and Immune Consequences of Intermittent Increases in Corticosterone in the White-Crowned Sparrow Zonotrichia leucophrys gambelii: An Experimental Paradigm for Repeated Acute Stressors.

Animals secrete glucocorticoids in response to stressful events. These elevated levels of glucocorticoids suppress reproduction and regulate the immune system to promote survival in the face of acute stress but can be deleterious in the long term. We investigated the link between the acute stress response and the development of long term chronic stress. Though little is known about glucocorticoid's direct role in these events in a natural setting, measurement of glucocorticoids as an indicator of individual and population well being is becoming more prevalent in research and as a management tool. We tested whether intermittent increases in the glucocorticoid corticosterone (CORT), at different frequencies, can cause similar effects to chronic stress. White-crowned sparrows were treated one or three times daily with a topical solution of ten ug CORT in 20 ul DMSO or 20 ul DMSO as a control for two or five weeks. All birds were exposed to ten hours of light and 14 hours of dark (10L:14L) per day for one week then changed to 20L:4D for the remainder of the treatments so the experiment encompassed the transition from short to long days. There was a significant affect on gonadal development (testis mass) in birds treated with CORT three times per day for five weeks compared to controls. This group also experienced a decline in health, and changes in white blood cell count consistent with chronic immune suppression. There were no differences between the once a day group or the group treated for two weeks and the controls. These results show that intermittent increases of corticosterone simulating acute stress responses, if frequent, can cause the deleterious effects associated with chronic stress.

1.11 BOYKO, C.B.; American Museum of Natural History; *cboyko@amnh.org*

A fabulous new species of parasitic isopod (Crustacea) found on deep-sea shrimp associated with glass sponges off Japan, with notes on phylogenetic relationships.

Two specimens of the shrimp *Spongicoloides iheyaensis* Saito, Tsuchida & Yamamoto, 2006 (Crustacea: Caridea: Spongicolidae) found in commensal association with hexactinellid glass sponges in deep waters off Japan were found to bear parasitic isopods (Crustacea: Epicaridea). Although initially identified by the authors of the host shrimp species as bopyrid isopods, these parasites occur attached to both the ventral surface of the abdomen and the anterior part of the carapace near the eyes and are referable to the genus *Faba* Nierstrasz & Brender à Brandis, 1930, which is a group of cryptoniscid isopods related to, but quite distinct from the Bopyridae. The genus *Faba* currently contains 3 species that are parasites of shallow water shrimp, including 1 originally described as a rhizocephalan barnacle; each species is known only from a single female type specimen (males are unknown). New information on morphological structures is offered, especially on the mode of attachment to the host cuticle, as well as developmental data gleaned from the contained embryos. A discussion on the phylogenetic affinities of *Faba* is given, with emphasis on its possible relationship to *Danalia* Giard, 1887, and on the validity of the Fabiidae sensu Danforth, 1963.

27.1 BRANDT, Y*; ANDRADE, MCB; University of Toronto at Scarborough; *ybrandt@utsc.utoronto.ca*

Do Tetragnatha spider jaws scale like genitalia or like armaments?

In many animal taxa, copulatory appendages show negative allometry (relative appendage size decreases as body size increases) whereas appendages used in fighting and threat display are positively allometric (relative appendage size increases as body size increases). The chelicerae (jaws) of adult spiders in the genus *Tetragnatha* are conspicuously elongated, often exceeding the carapace (cephalothorax) in length. Spider chelicerae are used to subdue prey and to combat conspecifics, but in male and female *Tetragnatha* chelicerae also function to clasp and secure the partner in copulation. Male and female *Tetragnatha* copulate frequently throughout their adult lifespan, with last male sperm priority. Herein we describe scaling patterns of *Tetragnatha* chelicerae, as a step toward elucidating the selective pressures and constraints that shape chelicerae length. Carapace lengths of males do not differ from females, yet in all species, the chelicerae of males are longer than female chelicerae. Among species, carapace and chelicerae length is correlated, and male carapace length is correlated to female carapace length. After removing the effects of carapace length, male and female chelicerae length remain significantly correlated. Among species, both male and female chelicerae are positively allometric, and the allometric values do not differ between the sexes. Yet within species, females exhibit greater allometric values than do males. These scaling patterns are inconsistent with the scaling patterns of either genitalia or armaments. We discuss the potential of size-assortative mating and patterns of intra-specific body size variation to account for patterns of Tetragnathid jaw elongation.

16.3 BRANNOCK, P M*; WETHEY, D S; HILBISH , T J; University of South Carolina; *brannockp@biol.sc.edu*

THE GEOGRAPHIC DISTRIBUTION OF MYTILUS GALLOPROVINCIALIS AND M. TROSSULUS IN NORTHERN JAPAN: THE POTENTIAL ROLE OF TEMPERATURE

The *Mytilus edulis* (common blue mussel) complex consists of three sister species (*M. edulis*, *M. galloprovincialis*, and *M. trossulus*) that are morphologically similar and capable of interbreeding when they co-occur. *M. galloprovincialis* has invaded a majority of the geographic locations where it is found today, while the other two species in this complex do not appear to invade or be as successful in their invasions as *M. galloprovincialis*. In 2004 a preliminary study utilized three nuclear loci (Glu-5', MAL-I, and ITS) to observe the geographic distribution of *M. galloprovincialis* and *M. trossulus* around the island of Hokkaido. Results illustrated *M. galloprovincialis* dominates the Sea of Japan side of the island while *M. trossulus* is found on the eastern portion of Hokkaido. In addition, the level of hybridization in Hokkaido far exceeds that observed in other locations where *M. galloprovincialis* and *M. trossulus* hybridize. To determine if body temperature was correlated with distribution, average maximum and minimum body temperature for each month in 2004 were estimated with a mechanistic simulation model. *M. trossulus* genotypes were found only where yearly body temperature minimum was below 18°C, which restricts them to the eastern portion of Hokkaido. A more extensive study in the summer of 2006 examined individuals collected from 26 sites around the island of Hokkaido and 24 sites around the northern portion of the island of Honshu. Preliminary results from Glu-5' assay has shown the distribution pattern to remain the same. There is some hybridization on the east coast northern Honshu, but this level is very small compared to that found in Hokkaido. Future work includes assaying samples at the ITS and MAL-I loci and assessing the roles aerial and water temperature play in determining mussel body temperature and distribution.

49.4 BRANTE, Antonio*; FREDERIQUE , Viard; FERNANDEZ, Miriam; Pont. Univ. Catolica de Chile, Station Biologique de Roscoff; *abrante@bio.puc.cl*

Siblicide in Crepidula coquimbensis (Gastropoda): the role of multipaternity

Sibling cannibalism during intracapsular development is a common strategy observed across different marine invertebrate taxa. It is still an open question what factors are determining intracapsular cannibalism intensity and driving the evolution of this behavior in marine invertebrate species. Hamilton predicted that the average cost of consuming a mate on inclusive fitness decreases as the average relatedness among mates declines. Thus, intracapsular cannibalism may be favored by polyandry and sibling cannibalism should be commonly observed among distantly related victims. We tested this hypothesis using as a biological model *Crepidula coquimbensis* (Gastropoda), a marine gastropod exhibiting intracapsular cannibalism. Adults are sedentary and inhabit empty shells of marine snails. Females encapsulate their embryos and brood them in their shelters. These characteristics allowed us to collect the brooding females as well as all potential fathers from a single shelter, and therefore to study the paternity of the embryos. In order to test the proposed hypothesis we first conducted paternity analysis for this species, to assess if polyandry occurs in nature. We developed five polymorphic microsatellite markers to then quantify intracapsular paternity. We analyzed approximately 20 embryos per capsule, in five capsules of a clump, for a total of 10 females. The genetic variance of these clumps was estimated throughout embryonic development. We then tested the effect of embryos relatedness on cannibalism rate, constructing artificial groups of approximately 100 embryos with different level of relatedness. Our results show that cannibalism rate is directly related with level of relatedness between embryos and polyandry may play a critical role on the evolution of siblicide in marine gastropod.

39.8 BRECKO, J*; HERREL, A; VAN DAMME, R; University of Antwerp; *jonathan.brecko@ua.ac.be*

Does among-population variation in head shape reflect diet diversity in Natrixsnakes?

Species of the (semi-) aquatic snake genus *Natrix* vary considerably in the degree of trophic specialisation. For instance, some populations of the viperine snake (*N. maura*) feed almost exclusively on fish, while others prey primarily on frogs. In contrast, the dice snake (*N. tesselata*) is known as an extreme fish specialist. Biomechanical considerations predict a functional trade-off in the ability to prey on fish or frogs: catching fish under water requires a small, streamlined head, whereas swallowing frogs necessitates a large, mobile head. We therefore expected that differences in dietary choice would be reflected in the variation in relative head size and shape. More specifically, we predicted a larger interpopulational variation in (relative) head dimensions in *N. maura* than in *N. tesselata*. We measured 14 morphometric characteristics in museum specimens from a large number of populations of both species. We corrected these variables for body size and introduced them into principal component analyses. The scores on the first three principal axes were then examined for inter- and intrapopulational variation. In contrast to our expectation, overall variation in head shape in the fish specialist *N. tesselata* was comparable to that in the catholic *N. maura*. Differences in head shape among populations contributed significantly to the overall variation in both species. Surprisingly, the amount of variation explained by interpopulational differences was more important in *N. tesselata* (40%) than in *N. maura* (25%). When comparing specimens of *N. maura* with fish and frogs in their stomachs, the former tend to have longer and narrower heads, with smaller distances between the eyes and the nostrils, and reduced dorsal, ventral, frontal and lateral head surfaces.

67.2 BRENNAN, April M.*; VAN TETS, Ian G. ; University of Alaska Fairbanks, University of Alaska Anchorage; *ftamb@uaf.edu*

Seasonal changes in the diet of a non-hibernating high-latitude rodent: the northern red-backed vole, Clethrionomys rutilus.

Rodents, such as lemmings and voles, which do not use hibernation and torpor, must choose foods that will enable them to meet their high energetic needs. These needs, and the food available to meet them, are likely to change seasonally. The aim of this study was to test whether free-living northern red-backed voles, *Clethrionomys rutilus*, preferentially ate items that were high in digestible energy and whether seasonal dietary changes correlated with changes in plant abundance and plant energy. We used stomach, cecum, and colon contents to assess diet and measured the gross energy and abundance of common plants found in our field sites. The voles' diet included a large proportion of hypogeous fungi from late spring through late fall with an increasing proportion of woody dicotyledonous plants (i.e. lowbush cranberry and paper birch) in October and November. Dicotyledonous roots contain vesicular-arbuscular mycorrhizae and are only common in the winter diet when epigeous fungi were rare in the field site. During spring thaw (April and May), the proportion of moss and young grass shoots increased to 35% of the diet. The changes in stomach contents were positively correlated with the gross energy content of plants. Our data support the hypothesis that voles preferentially eat energy rich and digestible foods but does not necessarily support the hypothesis that their diet changes due to plant abundance, as we could not measure the abundance of hypogeous fungi in our study sites. This study does, however, highlight the importance of hypogeous fungi to this species.

69.2 BREWER, M.L.*; ROBERTS, S.P.; University of Nevada, Las Vegas; *brewerm5@unlv.nevada.edu*

High speed video analysis of flight maneuvers in Dipterans

The kinematics, biomechanics, and energetic costs of insect hovering flight are relatively well-understood, yet detailed observations of maneuvering flight, much less descriptions of its associated aerodynamic and metabolic correlates, lag far behind. In this study we address these issues by using three orthogonally placed high-speed (5500 frames per second) digital video cameras to record flight behavior in *Drosophila melanogaster* and several species of hoverflies (Syrphidae), which are among the most acrobatic and maneuverable of all biological flyers. Following take-off, *Drosophila* perform stereotypical maneuvers (generally planar arcs and hairpins) when they encounter overhead obstacles. The induction of such flight behavior will allow us to test the effect of evolutionary and developmental variation in wing size and shape on take-off flight performance and maneuverability, specifically the duration and turn radii of these maneuvers. The recordings of syrphids show that some species hover with a near horizontal longitudinal body axis and as well as a near horizontal stroke plane, and are capable of an array of maneuvers including rolling descent, yaw rotation, rapid ascension and backwards flight. During certain maneuvers, some syrphids articulate the head in a manner to keep it (and presumably their plane of vision) horizontally aligned. Such recordings will be necessary to elucidate the aerodynamic mechanisms of complex flight behavior occurring on small temporal and spatial scales.

67.1 BRITT, E.J.*; HICKS, J.W.; BENNETT, A.F.; Univ. of California, Irvine; *ebritt@uci.edu*

The energetic consequences for prey specialist and generalist populations in the garter snakes Thamnophis elegans, T. couchii and T. ordinoides.

The Western Terrestrial garter snake, *T. elegans*, exists in two geographically isolated populations in northern California: a coastal population with a specialized diet of slugs and an inland population with a generalized diet of fish, anurans, mice and leeches. To test whether or not the coastal slug eaters have an energetic advantage over the inland generalists when digesting slugs, we have shown that the snakes from the specialized coastal populations assimilate more net energy from a slug diet than do the generalist snakes. Recently, we have expanded our comparison to include closely related garter snake species considered to be dietary specialists on slugs (*T. ordinoides*) and fish (*T. couchii*). We tested the hypothesis that dietary specialization of garter snakes is accompanied by increased digestive efficiency compared to generalist garter snakes, when feeding on specialized prey types. From our results, there is evidence to suggest that this group of garter snakes exhibit larger differences in digestive efficiency on the lower quality prey item (slugs) than the more common prey item (fish). Slug specialist *T. ordinoides* and *T. elegans* both digested slugs better than generalist *T. elegans* and *T. couchii*. However, digestive efficiency was more similar between the different groups of snakes when feeding on fish. This study was supported by NSF grant IBN 9727762 awarded to A.F.B and J.W.H. and by NSF grant IOB 0445680 awarded to J.W.H.

49.1 BRODIE, R. *; GODLEY, J.; Mount Holyoke College; *rbrodie@mtholyoke.edu*

the effect of summer storms on the recruitment success of fiddler crabs

The estuarine fiddler crabs, *Uca minax*, *U. pugnax* and *U. pugilator*, have complex life cycles spanning vastly different salinity regimes. Larvae are spawned in estuaries and travel to the coastal ocean where development takes place; after metamorphosing to the megalopal stage, fiddler crabs reinvade estuaries where they settle and metamorphose. In the coastal ocean, larvae experience relatively stable physical conditions, however, upon reinvading estuaries they are exposed to great fluxes in salinity and temperature. In this study, we measured shifts in the salinity regime caused by storm events, and determined the impact of these changes on species frequencies of megalopae from three *Uca* species in the water column and of their recently settled juvenile crabs on the benthos along a salt marsh creek in South Carolina. For megalopal stages in the water column, we found that the relative proportions of the three species changed significantly along salinity gradients and in response to storm events. When the salinity regime normalized, species frequencies for megalopae returned to pre-storm proportions. Only *U. minax* megalopae were present in the water column during a storm event, while *U. pugnax* had been the most abundant species in the water column prior to the storm. Settled juvenile crabs of all three species were more resilient than megalopae to flash salinity changes associated with summer freshets. Our results show that the duration and severity of salinity change are important variables impacting the presence of these *Uca* species in the water column and suggest that the physiology and behavior of the megalopal stage strongly influence where populations occur within estuaries.

S3-1.3 BROWNE, W.E.; Kewalo Marine Lab, University of Hawaii; *wbrowne@hawaii.edu*

Pelagic Amphipods: Hyperiids, Hypertrophies, and Homoplasies on the High Seas

Homoplasies, the reappearance of similarities between related lineages, are one of the most fascinating and perplexing phenomena in evolution. The amphipods rank as one of the most ecologically successful and speciose extant orders of the Crustacea. Surprisingly, the phylogenetic relationships among amphipods have remained a mystery despite their abundance. Lineage analyses based on morphology have been plagued by homoplasy combined with a lack of stable synapomorphies. Amphipods as a group have very successfully invaded a multitude of ecosystems, including the open ocean environment that collectively constitutes 99.9% of the habitable space on our planet. In comparison to more familiar nearshore intertidal benthic amphipods, the hyperiids have highly divergent morphologies due to their pelagic life history. Some of the more readily apparent adaptations include hypertrophied olfactory and visual systems, eye duplications, and appendage modifications. Employing a three-pronged approach that combines molecular phylogenetics, morphological analyses, and developmental analyses offer an opportunity to identify and assess character homoplasy in detail. I will present the first molecular phylogeny sampling a wide range of taxa in the group, revealing some of the critical homoplasies between lineages. I will also highlight recent studies on the organization and formation of the head and anterior nervous system in the experimentally tractable amphipod model system, *Parhyale hawaiensis*, which impinge on the evolution and development of these important traits. I will show that detailed comparative studies of aspects of these results in a phylogenetic context allow for exploration of developmental mechanisms associated with some of the character traits that appear to be important for successful existence in Earth's dominant environment.

34.1 BRYAN, M.B.*; SCOTT, A.P.; LI, W.; Michigan State University, The Centre for Environment, Fisheries and Aquaculture Science; *bryanmar@msu.edu*

An androgen-receptor signaling system found in the sea lamprey, Petromyzon marinus

The nuclear receptor superfamily is ancient lineage of transcription factors, which are predominately activated by small ligands. As part of this superfamily, the gonadal steroid receptors have received much attention due to both their importance as a key evolutionary innovation within the vertebrate lineage, and in regulation of development and reproduction. Current theories regarding the evolution of steroid receptors have relied heavily on information garnered from the sea lamprey, *Petromyzon marinus*. As one of only two extant Agnathan lines and as a vertebrate taxon that evolved over 500 million years ago, lampreys are a key group in which questions regarding the timing of vertebrate innovations, such as the steroid-receptor systems, can be examined. Here we present new findings showing the existence of an androgen receptor (AR) in the sea lamprey and thereby demonstrating that receptors for this class of steroid evolved before the agnathan-gnathostome divergence, which is much earlier than previous assumptions. The lamprey AR has binding characteristics that are typical of other vertebrate steroid receptors (e.g. it can be extracted from the nucleus as well as the cytoplasm and also binds to DNA). Although some ligand is found in plasma, it is mainly present in the testis (in association with the AR), and levels in the testis increase after stimulation with lamprey GnRH. We also demonstrate a putative hormonal role for androgens in lampreys. This research was supported by the Great Lake Fishery Commission and National Science Foundation #IOB 0450916.

22.4 BRZEK, P.*; KSIAZEK, A.; KONARZEWSKI, M.; Univ Bialystok PL; *brzek@uwb.edu.pl*

Effect of food restriction on ageing in laboratory mice (Mus musculus) selected for high and low basal metabolic rate (BMR)

The rate of aging is functionally related to the rate of metabolism. On the other hand, ageing can be delayed by caloric restriction, which implies a direct link between metabolism and reduced caloric intake. In our experiment, we examined the effect of 30% food restriction (FR) on mortality rate and physiological changes occurring between 6 and 12 months of age in laboratory mice divergently selected for high (H-BMR) or low (L-BMR) level of BMR. Mortality rate did not differ between control individuals of both lines. However, FR regimen decreased mortality rate in L-BMR, and increased in H-BMR line, as compared with control groups. Food restriction decreased swim-elicited peak metabolic rate in both lines, and BMR and post-swimming hypothermia in H-BMR line. However, BMR remained significantly higher in H-BMR than L-BMR line. The capacity to control oxidative stress (quantified as the total anti-oxidant enzymatic activity in blood serum) was similar in both lines and not affected by feeding regimen. Nevertheless, since H-BMR mice maintained higher metabolic rates throughout the whole experiment, we speculate that they were subject to more intense oxidative stress, which possibly contributed to their higher mortality. We conclude that our experiment demonstrated stronger effect of FR regimen on physiological traits of high BMR mice.

37.1 BUCHHOLZ, D.R.; Dep\'t of Biological Sciences, University of Cincinnati; *buchhodr@ucmail.uc.edu*

Diverse responses with identical genes: Identification of a core set of thyroid hormone-induced genes across tissues during frog metamorphosis

Thyroid hormone plays a central role in vertebrate post-embryonic development. Amphibian metamorphosis provides a unique opportunity to examine thyroid hormone-dependent developmental changes, which include major physiological and morphological changes in tadpoles, such as tail resoprtion, generation of limbs, remodeling of brain and intestine. To establish a global molecular framework for understanding morphological changes induced by thyroid hormone, we identified a set of gene expression profiles via microarray analysis during the intestinal remodeling process controlled thyroid hormone. Samples were obtained from Xenopus laevis tadpole intestines at a premetamorphic stage (stage 53) after 0, 1, 3, and 6 days of 10 nM triiodothyronine (T3) treatment, which induces successive cell death and proliferation essential for this intestinal remodeling process. Using a set of 21,807 60-mer oligonucleotide probes representing > 98% of the Unigene clusters, we found that 1,997 genes were differentially regulated by at least 1.5 fold during this remodeling process and were clustered into four temporal expression profiles; transiently up- or downregulated and late up- or downregulated. Gene Ontology categories significantly associated with these clusters were proteolysis, cell cycle, development and transcription, and electron transport and metabolism, respectively. Furthermore, meta-analysis with T3-regulated genes during the metamorphic changes in brain, hind limb, and tail indicated that more than 70% of T3-regulated genes are tissue-specific. On the other hand, a core set of upregulated genes, most previously unknown to be T3-regulated, were identified, and are composed mainly of genes involved in transcription and cell signaling.

48.7 BUCK, C.L.*; KARPOVICH, S.A.; TØIEN, O; KOHL, F; BARNES, BM; Univ. of Alaska Anchorage, Alaska Department of Fish and Game, Univ. of Alaska Fairbanks, Univ. of Alaska Fairbanks; *loren@uaa.alaska.edu*

Overwinter patterns of body temperature of free-living arctic ground squirrels.

We previously determined that arctic ground squirrels *Spermophilus parryii* are naturally exposed to extreme thermal conditions while overwintering in underground hibernacula in Northern Alaska. Animals in captivity also show relatively long torpor bout lengths (TBL) and adopt the lowest core body temperature (Tb) measured in any hibernator. Since, we have investigated patterns of hibernation and Tb in free-living arctic ground squirrels on the North Slope of Alaska using small, abdominally-implanted temperature sensitive data loggers. Between 1996 and 2001, we collected Tb data from a total of 50 individual animals of known sex and age continuously over winter. Age, sex, and reproductive status of animals significantly influenced timing and patterns of daily torpor and hibernation. Adult females initiated hibernation in late summer prior to juveniles and males and resumed euthermia in spring after reproductive males. Non-reproductive males, yearlings that do not reproductively mature in their first year, ended torpor after reproductive males. Mean TBL (14.62±1.81 d) did not differ by age, sex or status; however, the euthermic phase of arousal intervals in females (0.87±.04 d) was significantly shorter on average than in males (1.03±0.09 d). The penultimate arousal was significantly shorter in duration for reproductive males (1.35±1.11 d) than either females (1.85±.21 d) or non-reproductive males (3.17±2.17 d). In total, females were hypothermic (TB

52.5 BUCKLEY, C.R.*; IRSCHICK, D.J.; ADOLPH, S.C. ; University of Massachusetts; *crcbuck@gmail.com*

The persistence of environmentally-induced phenotypic variation in western fence lizards

Developmental plasticity is known to have profound effects on the phenotypes of young organisms, especially ectotherms. Evolutionary biologists have demonstrated changes in phenotype that include neonates' morphology, behavior, physiology and performance in response to proximate environmental influences (e.g. temperature, humidity) during incubation. However, to date, few studies have examined the persistence of these traits' environmentally induced variation through ontogeny. We studied the importance of developmental plasticity to the quality of lizard hatchlings over time. We hypothesized that whereas incubation would noticeably affect hatchling traits, these effects will become weaker as animals are raised in a common post-hatching environment, and that as a result traits will converge on an intermediate phenotype. We collected pregnant female *Sceloporus occidentalis* from two high-elevation (approximately 2200m) and two low-elevation (approx. 1350m) populations in California and subjected their eggs to two incubation environments representative of the extreme conditions experienced by these eggs in the wild (warm and cool). We raised the hatchlings for at least 11 weeks in the laboratory and measured their morphology (limb and head dimensions), growth rate, thermal preference, and sprinting performance at biweekly intervals. Our data reveal that although source population and incubation environment have significant effects on these animals' phenotypes, in some cases, these differences do not persist over time. We discuss the ecological relevance of developmental plasticity in comparison to the rearing environment in these lizards, and caution that studies of developmental plasticity should include a post-hatching component.

40.2 BURKE, A.C.*; DURLAND, J.L.; SFERLAZZO, M; Wesleyan University, Middletown, CT; *acburke@wesleyan.edu*

Patterning domains in the vertebrate mesoderm and the generation of morphological variation.

The body plan of vertebrates comprises an axial system of a cranium and segmental vertebrae and ribs. In jawed vertebrates the axial system is integrated with an appendicular system, the paired fins or limbs and their girdles. In a developmental sense, this body plan is conserved throughout the lineage. The appendicular skeletal elements arise from the lateral plate mesoderm (LP) and the axial skeleton arises from the paraxial somites. All of the striated muscles for both systems arise from the somitic myotomes. Despite the conservation of this embryological pattern, the final morphological outcome is extremely diverse, as exemplified by the different adult morphology of frogs, snakes, turtles, humans, etc. Morphological evolution occurs primarily through changes in the actions of regulatory genes that affect patterning. We have explored the integration of the somitic and lateral plate mesoderm in a variety of tetrapods and define distinct primaxial and abaxial domains in the developing body wall. The dynamic interface between these domains we call the Lateral Somitic Frontier. Experimental evidence from chick and mouse suggests that patterning information changes when somitic cells cross the frontier. I will present a hypothesis whereby primaxial and abaxial domains behave as independently patterned modules, thus facilitating morphological evolution within the vertebrate body plan.

48.9 BURNS, J.M.*; RICHMOND, J.P.; CLARK, C.A.; LESTYK, K.C.; Univ. Alaska, Anchorage, Univ. Connecticut, Alaska Dept Fish Game; *afjmb4@uaa.alaska.edu*

Hematology of pinniped pups: implications for developing divers

Blood is the major oxygen storage site for most marine mammals, holding 50-70% of oxygen reserves in adults, with muscle storing most of the remaining reserves. However, due to very low myoglobin content in juvenile muscles, blood is a much more important oxygen reserve in younger animals. Despite this importance, mass specific blood oxygen stores do not increase linearly as pups grow, but instead decline during the lactation period, reaching adult values only near, or after, the onset of independent foraging. We investigated the changes in HCT, Hb, blood volume and blood oxygen reserves in developing phocids (harbor, harp, and hooded seals) and otariids (Steller sea lions), and correlated observed changes with measured iron stores, binding capacity, and erythropoietin (EPO) levels. In phocids, serum ferritin was lower and saturation rates and EPO levels higher in pups than in adults, suggesting that iron kinetics may influence red cell production and the development of oxygen reserves during the nursing period, perhaps due to limited iron intake in milk. In contrast, age related differences in blood oxygen stores persisted in otariids well past the time when iron stores and EPO levels were similar to those of adults, suggesting that other factors may be important in regulating hematological development when growth proceeds at a slower pace. Remarkably, both phocid and otariid pups begin independent foraging only once mass-specific oxygen reserves reach ~2/3 those of adults.

61.3 BUSH, S.L.; University of California, Berkeley & MBARI; *stephalopod@berkeley.edu*

Autotomy as a deep-sea squid defense

In oceanic midwaters animals are vulnerable to predation from all directions, therefore it is likely that a diversity of defensive tactics are employed by deep-sea organisms. One maneuver is to startle a predator upon attack such that the predator flees in confusion or hesitates long enough to allow the potential prey's escape. This may be the mechanism utilized by the mesopelagic squid, *Octopoteuthis deletron*. Handled specimens lost distal arm portions that continued to move for several seconds while the single, large photophore of each arm-tip bioluminesced. *In situ* observations confirmed that arm loss occurs naturally. Some individuals were missing up to one half of an arm and tissue regeneration was clearly in progress in several specimens. Histology revealed the presence of fracture planes in the arm musculature, making this the first known deep-sea squid with the ability to autotomize arms. Dropping one or more arms that continue to move and bioluminesce might hinder predatory attempts. The potential continuous loss and regeneration of tissue is surprising given the energetic limitations of deep-sea organisms.

11.6 BUSHOLD, G.J.*; FREAMAT, M.; TRANT, J.M.; KAWAUCHI, H.; TAKAHASHI, A.; MORIYAMA, S.; NOZAKI, M.; SOWER, S.A.; Univ. of NH, Durham, UMBI, Baltimore MD, Kitasato Univ, Japan, Niigata Univ, Japan; *gbushold@unh.edu*

Production and Purification of Recombinant Lamprey Gonadotropin Hormone Beta Chain in Drosophila S2 Cell Line

Lamprey gonadotropin (GTH) has most recently been identified in lampreys (Sower et al. 2006). Low production of glycoprotein hormones in fish species has been problematic in purification of large quantities of active GTH from lamprey tissue. To understand the role of gonadotropin in lampreys, homologous lamprey GTH is being produced by recombinant techniques to be used in future studies. Therefore, our goal is to express lamprey GTH through the use of the Drosophila Expression System (Invitrogen), which has been shown to be capable of producing active recombinant catfish GTH's. The coding sequence for the lamprey GTHβ chain was cloned into the pGCAP1 plasmid. Primers specific to the 5'and 3'ends were used to amplify the DNA fragment, which was then ligated into the pMT/V5His expression vector. The expression construct was transfected into the S2 cell line using the Calcium Phosphate transfection reagent. In addition, co-transfection of lamprey GTHβ with channel catfish GTHα or human chorionic gonadotropin (hCG) α was also performed. A tethered construct, which linked the lamprey GTHβ to hCGα, tested the importance of interactions between subunits of heterodimers. Preliminary results from lamprey gonadal in-vitro culture showed that concentrated medium containing each of these three transfected complexes elicited a positive increase in estradiol. Due to the success of these initial steps, further purification methods are underway to produce greater yields of lamprey GTH. (Supported by NSF Grant 0421923 to SAS) sasower@unh.edu

54.5 BUTCHER, M.T.*; HERMANSON, J.W.; DUCHARME, N.G.; BERTRAM, J.E.A.; Univ. of Calgary, Cornell Univ., Univ. Calgary; *mbutche@clemson.edu*

Equine digital flexor muscle contractile function studied in vivo

The forelimb digital flexor muscle complex of the horse displays a remarkable range of architectural diversity despite each muscle having basically the same mechanical advantage across the same functionally important joint. Previous research has focused on muscle-tendon unit architecture, contractile properties of the muscle fibers, and fiber MHC composition and motility as a basis for understanding muscle function. Current research focuses on *in vivo* whole muscle function of the short compartment deep digital flexor (DDFsc) and the superficial digital flexor (SDF). Direct recordings of muscle force (via tendon strain gages) and muscle fascicle length (via sonomicrometry crystals) were made over a range of gaits and speeds. The DDFsc fascicles shorten during the contact period in walking (1.8 ms^{-1}), trotting (4.1 ms^{-1}) and cantering (7.0 ms^{-1}) while producing low force, resulting in a modest amount of positive *net* work generation. The SDF fascicles initially shorten following hoof contact, but eccentric contraction predominates during the contact period while force is high, leading to substantial negative *net* work generation. Findings suggest that the long fiber, unipennate DDFsc muscle supplements power during running whereas the short fiber, multipennate SDF muscle is specialized for economical force production and enhanced elastic energy storage. Apparent *in vivo* functions are largely consistent with the contractile physiology of the fibers from each muscle and likely indicates a specialized limb-spring design for locomotion economy using a bouncing trot as the primary running gait.

S8-2.2 BUTLER, MA; University of Hawaii at Manoa; *mbutler@hawaii.edu*

Adaptation, sexual dimorphism, and ecolomorphological diversity in Caribbean Anolis lizards

Sexual dimorphism is widespread and substantial throughout the animal world. It is surprising, then, that such a pervasive source of biological diversity has not been integrated into studies of adaptive radiation, despite extensive and growing attention to both phenomena. Rather, most studies of adaptive radiation either group individuals without regard to sex or focus solely on one sex when studying the relationship between morphology and resource use. However, sexual dimorphism may be constrained by the breadth of ecological variation, or "species packing" may be increased by sexes occupying different regions of available ecological and morphological space. In this study, I show that sexual differences contribute substantially to the ecomorphological diversity produced by the adaptive radiation of Caribbean *Anolis* lizards: within anole species, males and females occupy mostly non-overlapping parts of morphological space; the overall extent of sexual variation is large relative to interspecific variation; and the degree of variation depends on ecological type. These results have implications for both studies of sexual dimorphism and adaptive radiation: (1) these results cannot be explained exclusively by sexual selection; no matter the proximate mechanism, ecological factors strongly influence the evolution of *Anolis* sexual dimorphism. (2) when sexual dimorphism in ecologically-relevant traits is substantial, ignoring its contribution may significantly underestimate the adaptive component of evolutionary radiation.

47.1 BUTLER, L K*; HAYDEN, T J; BISSON, I; WIKELSKI, M; ROMERO, L M; Tufts University, Medford, MA, US Army Engineer Research and Development Center, Champaign, IL, Princeton University, Princeton, NJ, Princeton University, Princeton, NJ; *luke.butler@tufts.edu*

Chronic stress and corticosterone: CORT response to seven days of rotating stressors in two free-living songbirds

Vertebrates require time and energy to cope with and survive prolonged disruptions of the life cycle, or chronic stress (after Wingfield 2005, J. Mamm.). Therefore, distinguishing chronically-stressed from non-chronically-stressed populations is important for species conservation. Recently, chronically-stressed captive European Starlings were shown to have lower basal and acute stress-response levels of corticosterone (CORT), the major avian glucocorticoid, than non-chronically-stressed starlings (Rich and Romero 2005). We studied the effect of chronic stress on CORT levels in free-living populations of an endangered songbird, the Black-capped Vireo, and a non-endangered, sympatric congener, the White-eyed Vireo. For each species, we attempted to create a group of chronically-stressed adults by presenting rotating, unpredictable stressors at nests during the incubation and nestling stages. After at least 7 days of stress treatment, we captured adults and sampled basal and acute stress-response CORT concentrations, which we compared to non-chronically stressed adults at the same stage of the breeding cycle. Our results 1) illustrate any effect of chronic stress on CORT levels in two free-living songbirds, 2) compare the CORT response to acute and chronic stress between an endangered species and a common, sympatric congener, and 3) demonstrate the utility of CORT comparisons for identifying chronically-stressed vertebrate populations.

S1-4.10 BYRNES, G. T.*; SPENCE, A. J.; Univ. of California, Berkeley; *byrnes@berkeley.edu*

Locomotor biomechanics of a free-ranging gliding mammal (Cynocephalus variegatus)

One of the biggest challenges in comparative biomechanics is to describe the locomotor performance of animals in their natural environment. This is important because measures of performance in the lab might not directly reflect the behavior of free-ranging animals. Furthermore, the subset of behaviors represented in the lab may not be an accurate representation of the full repertoire of behavioral variation. In gliding mammals, the locomotor forces during take off and landing might have significant outcomes for survival, in avoiding predation or injury. However, these forces have not been measured in any free-ranging animal. This study examined the locomotor behavior of free-ranging colugos (*Cynocephalus variegatus*) using custom-designed data-loggers, allowing the collection of both behavioral and biomechanical data in the field. The logger consists of a three-axis accelerometer sampled at 100Hz and a bank of flash memory allowing up to 75 hours of data to be stored at this rate. We examined the timing and duration of glides as well the peak forces associated with take-off and landing events. Glide duration, a proxy for glide length, predicted peak landing force but not peak take-off forces. Longer glides allowed animals to reduce the impact forces associated with landing. This is further evidence that these gliding mammals actively modulate aerodynamic forces during glides. By examining locomotor kinetics in the natural environment, this allows insights into the link between biomechanics and the ecology of the organism.

34.3 CAMPBELL, Terry/G*; GAREY, James/R; University of South Florida; *tcampbe2@chuma.cas.usf.edu*

Analysis of Glycerol 3-Phosphate Dehydrogenase and Sarco/Endoplasmic Reticulum Calcium Ion Channel ATPase for Potential Use in Deep Metazoan Phylogeny

Genetic sequence data have been used to analyze phylogenetic relationships for over a decade and numerous data sets have been generated for testing metazoan relationships at many taxonomic levels. Because of the rapid divergence of major animal forms during the Cambrian radiation, deep phylogenetic relationships among metazoans have been particularly difficult to determine. Most molecular level studies of broad metazoan phylogeny have utilized ribosomal RNA gene sequences or have contained only a few phyla. Only a few studies have used nuclear protein coding genes and broad representation across Metazoa. Highly conserved and thus easily amplified nuclear protein coding genes such as the elongation factor 1 alpha gene (EF1&alpha) have been proven unsatisfactory for deep metazoan phylogeny because they do not contain enough phylogenetic information. We are exploring the use of the glycerol 3-phosphate dehydrogenase gene (G3PDH) and sarco/endoplasmic reticulum calcium ion channel ATPase (SERCA) because they are more variable than EF1&alpha but is conserved enough to be amplified relatively easily. Here we present an analysis of a metazoan datasets of G3PDH and SERCA and assess the potential of these genes for resolving deep phylogenetic relationships within Metazoa.

7.3 CARLETON, Scott A*; AAMICK, Lori; University of Wyoming; *scarlet@uwyo.edu*

Efficiency of protein incorporation and diet quality determine trophic isotope spacing in fish

Ecologists use the enrichment in ^{15}N of an animal's tissues relative to its diet to determine trophic position. They assume that isotopic spacing between trophic levels is constant and approximately equal to 3.4 . We will present a model that questions the constancy of this value with data supporting the predictions of this model. Briefly, the model predicts that ^{15}N isotopic spacing should depend on the efficiency of protein incorporation and on diet quality. We tested this model with Nile tilapia (*Oreochromis niloticus*). Tilalpia were placed on three diets differing in protein content. Tilapia within these three treatments were fed 4%, 8%, or 16% of their body mass. We weighed Tilapia weekly to adjust feed rations for a total of 58 days until fish in all treatments had tripled in mass. Fish were individually dried to a constant mass, homogenized, defatted, and analyzed for ^{13}C and ^{15}N. We found that 1) ^{15}N declined in fish's tissues with increased efficiency of protein incorporation 2) fish on lower protein diets had higher ^{15}N isotopic spacing than fish on higher protein diets, 3) fish on higher protein diets had larger ^{13}C isotopic spacing than fish on lower protein diets, and 4) that ^{15}N spacing is not dependent on fractional growth rate. Our results suggest that the ^{15}N trophic spacing between tissue and diet is not constant, nor equal to 3.4 . Studies that rely on stable isotopes to diagnose trophic position must take into account the effect of both the efficiency of N incorporation and diet quality on the isotopic enrichment between trophic levels.

8.6 CARLSON, KJ*; JUDEX, S; Universitaet Zuerich, Stony Brook University; *carlson@aim.unizh.ch*

Zig-zag locomotion alters shape of the murine limb bone diaphysis

Many terrestrial animals incorporate rapid turns as a part of predator avoidance behavior, while arboreal animals encounter irregularly spaced substrates necessitating frequent turns during daily travel. Yet consequences of turning behavior on long bone morphology are not resolved. We investigated this relationship in 30 growing BALB/cByJ female mice randomly asssigned to one of three behavioral groups (n = 10). Mice were single-housed for eight weeks in custom-designed cages from day 30 post birth. Enclosures accentuated zig-zag or linear locomotion in the two experimental groups, while a control group lived in standard laboratory mouse conditions. Locomotor behavior was recorded using an instantaneous focal sampling strategy approximately twice per day for the duration of the experiment. Bones were harvested for microCT scanning at day 87 post birth. Femoral cross-sectional properties at midshaft were evaluated relative to body weight and compared. Groups do not differ significantly in mean cortical area, mean body weight, or activity level. Zig-zag mice have significantly more elliptical diaphyses than controls ($p = 0.025$), and also more elliptical diaphyses than linear mice, though the latter difference is not significant ($p = 0.083$). Linear and control mice do not differ ($p = 0.725$). Shape differences at the femoral midshaft primarily reflect reduced anteroposterior rigidity in the zig-zag group relative to the other groups, though none of these differences are significant. Given a virtual absence of genetic variability and equivalent bone mass and activity levels, femoral shape differences reflect a behavioral difference that can be attributed to turning locomotor behavior. Funded by NASA and NSF.

42.3 CARR, J.A.*; MARSH, R.L.; Northeastern University; *carr.je@neu.edu*

Muscle Function in a Complex Muscle During Legged 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*) were used to test this hypothesis. Common Moorhens were used because this species has an ILPO and employs both swimming and running 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. Preliminary results show that in the Common Moorhen, 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.

30.2 CARRENO, C.A.*; NISHIKAWA, K.C.; Northern Arizona University; *cac36@nau.edu*

Behavior and Morphology of Aquatic Feeding in Pipid Frogs

Feeding behavior and morphology was examined in the pipid frogs, *Pipa pipa*, *Xenopus laevis*, *Hymenochirus curtipes*, and *Pseudhymenochirus merlini*. Direct measurements of buccal cavity pressure during prey capture recorded localized pressure changes. For each species, the internal buccal pressure was found to drop significantly below ambient, and high-speed digital imaging revealed that pressure changes corresponded to gape cycles. *Pipa pipa* and *X. laevis* employed forelimb scooping in addition to suction feeding, but *H. curtipes* and *P. merlini* used suction feeding exclusively. The kinematics of suction feeding in the pipid frogs was compared to other suction feeding vertebrates as well as lingual feeding anurans. Species of pipids were not kinematically distinct, but each species consistently exhibited a wave of buccal expansion, similar to other aquatic vertebrates. The feeding behavior of pipid frogs is functionally convergent with other suction feeding vertebrates, and not phylogenetically constrained. The morphology and mechanics of the feeding apparatus was examined using buccal molds, clearing and staining, and gross dissection. The buccal cavity was found to be greatly enlarged, and extended posteriorly. Cleared and stained specimens showed that the hyoids are expanded and shifted posteriorly to support the buccal cavity. The feeding musculature is modified to produce expansion of the buccal cavity by retraction and depression of the hyoid. The morphology of the feeding apparatus in pipid frogs was found to be modified from typical anurans and has characteristics of suction feeding vertebrates.

S1-1.4 CARRINGTON, E.; University of Washington; *ecarring@u.washington.edu*

If at first you don't set seed, dry, dry, again

Rocky intertidal shores are often dominated by macroalgae which are alternately subjected to submersion in seawater and emersion in air. While many terrestrial angiosperm populations endure prolonged arid conditions by producing seeds, intertidal macroalgae such as *Mastocarpus papillatus*, instead have physiological adaptations to tolerate repeated desiccation. However, photosynthesis requires tissue hydration and thus desiccation potentially comes at the expense of reduced primary productivity. As with the broad leaves of Vogel (1970), morphology can influence the rate of mass (water vapor) and heat convection between a thallus and its surrounding environment, thereby influencing thallus desiccation and temperature during emersion. This study evaluates the influence of thallus morphology on the growth and persistence of an intertidal macroalga. A synthetic model was developed from previous analyses of the environmental physiology and heat budget of the red alga *M. papillatus*, using local meteorological conditions to provide a continuous estimate of thallus temperature, desiccation, and productivity. Run over an entire year, the simulations suggest that emersed carbon fixation is not an important component of the total carbon budget of a thallus, and that productivity is largely determined by the duration of daytime high tides. Changes in thallus morphology (e.g., thickness, branching) have only subtle effects on productivity, but dramatic effects on whether lethal temperatures are encountered during emersion. This synthetic approach not only provides a useful tool to evaluate potential trade-offs in performance with morphology, but also allows for prediction of the consequences of climate change on the productivity and persistence of a common intertidal species.

42.1 CARROLL, A. M.*; BIEWENER, A. A.; Concord Field Station, Harvard University; *acarroll@oeb.harvard.edu*

Function of uniarticular and biarticular heads of the triceps during jumping and landing in goats.

Muscle systems in the limbs of tetrapods are often organized into synergistic uni- and bi-articular regions. To understand how these regions might differ in their function, we investigated the function of the long (biarticular) and lateral (uniarticular) heads of the triceps muscle of four goats (25-43 Kg) during jumping and landing. EMG electrodes were used to measure muscle depolarization, sonomicrometry crystals were used to measure muscle strain, and inverse dynamics (based on simultaneous video, force plate recordings, and limb data) were used to estimate elbow moments and (by assuming equal stress) muscle force. Forelimb use during landing was symmetrical, but during jumping it was either be symmetrical (two bounding legs) or asymmetrical with separate leading and lagging legs. In all jumping and landing conditions the elbow was compressed in the onset of stance and extended later in stance. During the compression phase the lateral head was always stretched, while the long head was stretched only in landing. Both heads shortened during re-extension. During landing both heads functioned to absorb work and power, and more net work and power was absorbed in the lateral head. In all jumping conditions, the long head produced more total work and power than the lateral head which only produced net positive work and power in the leading jumps. Elbow moment and muscle stress were greatest in the leading leg of asymmetrical jumps, and were lowest in the lagging leg and during landing conditions. In general, biarticularity allows the long head to shorten throughout stance while strain in the lateral head is tightly tied to elbow kinematics. This research was supported by NIH grant AR-047679 to Andrew A. Biewener.

63.6 CARSTEN-CONNER, L.D.*; O\'BRIEN, D.M.; University of Arizona, University of Alaska, Fairbanks; *carsten@email.arizona.edu*

Resource allocation to testes in the walnut fly, Rhagoletis juglandis

Testes size often predicts whether a male will win during episodes of sperm competition. However, little is known about the source of nutrients allocated to testes development. Among holometabolous insects, metabolic resources can be derived from the larval or the adult diet, which often differ substantially in nutritional quality. Distinguishing the source of nutrients allocated to testes can shed light on life history factors that shape the evolution of male reproductive strategies. For instance, if allocated resources are derived mostly from larval reserves, then maternal influences such as oviposition decisions may ultimately determine male reproductive success. Conversely, if allocated resources are mostly derived from adult stores, then male reproductive success may rely more on the foraging ability of that individual. Here we used an experimental approach to assess resource allocation to testes development in walnut flies (*Rhagoletis juglandis*) from differing nutritional backgrounds. We fed adult male walnut flies on yeast diets that contrasted with the larval diet in carbon and nitrogen stable isotope ratios. This design allowed us to assess the dietary source of testes carbon and nitrogen and its change over time under differing adult nutritional regimes. We discuss our findings and the evolutionary implications.

11.3 CARUSO*, M.A.*; SHERIDAN, M.A.; North Dakota State Univ., Fargo; *Michael.Caruso@ndsu.edu*

Rainbow Trout Possess Two Proinsulin-Encoding mRNAs that are Differentially Expressed

Insulin plays an important role in the growth, development, and metabolism of vertebrates. Growing evidence suggests that some species of vertebrates possess two insulin genes; however, the phylogenetic distribution and the physiological significance of this phenomenon are not known. In this study, rainbow trout were used to examine further the polygenic origins of insulin. Two unique cDNAs that encode proinsulin were isolated, cloned, and sequenced from the endocrine pancreas (Brockman body). One 558-bp cDNA encodes a 105-amino acid protein (INS 1) and the other 571-bp cDNA encodes a 107 amino acid protein (INS 2). The sequences share 87.6% nucleotide identity and 89.7% deduced amino acid identity. Quantitative real-time PCR revealed that the two INS mRNAs were differentially expressed, both in terms of distribution among tissues as well as in terms of abundance within selected tissues. INS 1 was more abundant than INS 2 in the pancreas, pyloric cecum, and adipose. Both INS 1 and INS 2 mRNA were found at low levels within the brain. The regulation of INS mRNA expression was examined in Brockman bodies of trout placed on differing nutritional regimens. Fasting for 4 weeks or for 6 weeks reduced mRNA levels of both INS 1 and INS 2 compared to fish that were continuously fed. Refeeding fish for 2 weeks after previously fasting for 4 weeks resulted in a rebound of INS mRNAs to levels near those in continuously fed fish. These findings contribute to the understanding of the evolution of the insulin gene in teleost fish. In addition, these findings indicate that the expression of the INS genes in trout is differentially regulated. (Supported by NSF IOB 0444860)

12.1 CASKEY, J. L.*; HASENSTEIN, K. H.; BAUER, R. T.; Univ. of Louisiana, Lafayette; *shrimpgirl@louisiana.edu*

The role of cuticular hydrocarbons associated with mate recognition in Palaemonetes pugio

In the grass shrimp *Palaemonetes pugio*, behavioral evidence suggests that males respond to an insoluble substance (i.e. contact sex pheromone) on the exoskeleton of the postmolt parturial female. Cuticular hydrocarbons, glycoproteins or other compounds present on the surface of the newly-molted, parturial female might serve as the sex attractant. The purpose of this experiment was to determine whether the exoskeleton of postmolt parturial females contains cuticular hydrocarbons that function as contact sex pheromones. Extractions of postmolt parturial females showed the greatest number of peaks, 29, 13 of which were unique. Of these 13 unique peaks, we were able to identify one as anisole 2,3,4,5,6 pentachloro and one as 1-octadecene. Various hydrocarbons (tricosane, tetracosane, pentacosane, hexacosane, nonacosane) were found among the treatment groups. We also found the cuticular extracts of the treatments to contain the fatty acids hexadecanoic acid and octadecanoic acid. Postmolt parturial females differed significantly from all treatments supporting our hypothesis that postmolt parturial females employ a chemical to communicate their sexually receptive condition to males. We did not conclusively identify a single contact sex pheromone of *P. pugio*; however, it is likely a blend of hydrocarbons or their derivatives and not a single component.

42.4 CEDIEL, R*; SCHOENFUSS, H; BLOB, R; SHRANK, G; St.Cloud State, Clemson; *cero0201@stcloudstate.edu*

Ontogeny of Muscle Fiber Type Distribution in Climbing Hawaiian Gobioid Fishes: Muscle and locomotor correlation

Three species of Hawaiian amphidromous gobies are remarkable in their ability to climb waterfalls several hundred meters tall. Juveniles of *Lentipes concolor* and *Awaous guamensis* climb by rapid bursts of axial undulation with long rest periods during which the animal is attached to the waterfall with its pelvic sucking disk. Juveniles of *Sicyopterus stimpsoni* alternately attach the pelvic sucking disk and their sucking mouth to the waterfall and climb in prolonged bouts. Based on these differing climbing styles, we hypothesized that propulsive musculature in juvenile *L. concolor* and *A. guamensis* would be dominated by fast, white muscle fibers whereas *S. stimpsoni* would exhibit more slow, red muscle fibers. We further predicted that, because adults of these species shift to burst swimming, rather than climbing, as their main locomotor behavior, muscle from adult fish of all three species would be dominated by white muscle. Specimens for this study were collected in Hakalau Stream, Hawai'i, sectioned, and frozen at 80º C in isopentane. Serial sections were made and ATPase activity in transverse sections of muscle were evaluated. Juvenile *L. concolor* tail musculature was dominated by white muscle fibers while in juvenile *S. stimpsoni* red muscle fibers dominated propulsive musculature. Adults of all species exhibited peripheral bands of red musculature and a core of white fibers in the tail. Thus, the proportions in which different muscle fiber types are found in these species through ontogeny appear to help accommodate differences in their locomotor demands. These results indicate that these species overcome the common challenge of waterfall climbing through both diverse behaviors and physiological features.

69.9 CHADWELL, B.A.*; STANDEN, E.M.; LAUDER, G.V.; Wake Forest Univ., Harvard Univ.; *chadba1@wfu.edu*

Fin Shape and Fast Starts: A 3-D Kinematic Analysis.

Fish fins act as control surfaces to enhance locomotion and/or provide stability. Studies of median fins during C-starts have shown that, like axial kinematics, timing and direction of fin movements during Stages 1 & 2 (S1 & S2) are stereotypical and coordinated. To determine whether fin movement and shape during escape responses are due to passive deformation or active control, we compared fin kinematics to local axial kinematics. Three high-speed cameras were used to film fast starts in bluegill sunfish. Videos were taken at 500 fps and digitized to determine 3D kinematics of soft dorsal (sfD) and anal (An) fins. At five points along the length of each ray, lateral displacement (LD) and total curvature were calculated and compared to local axial kinematics, i.e. where the ray joins the midline. Throughout the entire fast start, the proximal regions of the rays matched, or even preceded, the timing, direction and speed of local axial movement, which was not expected if fin movements were completely passive. For more distal regions, ray kinematics differed from axial movement with these differences peaking at periods of high lateral acceleration: the onset of S1 when axial LD was first initiated, and then during the S1/S2 transition when axial LD changed directions. During these periods, the rays underwent the greatest amount of deformation; forming a brief S-curve with a proximal bend contralateral to the direction of axial LD and a distal ipsilateral bend. After the S1/S2 transition, differences between axial and distal fin kinematics decreased and fin deformation was reduced. We suggest that 1) sfD and An fins actively resist/reduce deformation throughout C-starts and 2) resistance to deformation of the distal fin regions is most effective when lateral acceleration is minimal.

20.7 CHAKRABORTY, M**; BURMEISTER, S. S; University of North Carolina, Chapel Hill; *mukta@email.unc.edu*

Estradiol induces female receptivity to conspecific calls in the túngara frog

Sex steroid hormones play crucial roles in mediating reproductive behaviors. In most vertebrates sex hormones such as estradiol and progesterone induce female receptivity. Female túngara frogs use acoustic cues for making mate-choice decisions and have high estradiol (E) and progesterone (P) concentrations when they are sexually receptive. To experimentally assess the effect of steroid hormones on receptivity to conspecific calls, females with naturally low steroid levels were hormone manipulated and their receptivity measured by phonotaxis choice tests. We found that E-injected females were more likely to be receptive compared to saline-injected females ($p < 0.001$). HCG (human chorionic gonadotropin) injections alone induced receptivity but females treated with a combination of hCG and fadrozole (an estrogen synthesis inhibitor) were less likely to be receptive than E-injected females ($p= 0.002$), suggesting that estradiol is necessary for phonotaxis. There was no significant difference in receptivity between E-injected females and E+P-injected females ($p= 0.27$), or between E-injected females and those injected with hCG alone ($p= 0.07$). Among receptive females, mean latency to respond to conspecific calls also did not differ among these three treatment groups ($p= 0.71$). Our results suggest that estradiol is necessary and sufficient to induce receptivity towards conspecific calls in this species and that progesterone does not contribute significantly to receptivity. These data offers exciting avenues for further research on the effects of estradiol in mediating receptivity via the sensory and motor pathways underlying phonotaxis.

2.3 CHANG, J.L.*; DOUGHTY, S.; WADE, J.; LOVERN, M.B.; University of Miami, Oklahoma State Univ., Michigan State Univ.; *stynoski@bio.miami.edu*

Sex and laboratory effects in second-to-fourth digit length ratios (2D4D) in green anole lizards

Digit length ratios can show sexual dimorphism related to embryonic steroid exposure. The second-to-fourth digit-length ratio has received the most attention, and previous studies suggest there is species-dependent variation in whether males or females exhibit the larger ratio. In the present study, we measured the 2D4D of all four feet for adult male and female green anoles (*Anolis carolinensis*) to determine whether this ratio is sexually dimorphic. One investigator at Michigan State University (MSU) and one at Oklahoma State University (OSU) measured the 2D4D of each foot using digital calipers. In addition, to assess to what extent such measurements are repeatable across laboratories, we compared the measurements from MSU to those from OSU. At both laboratories, we found that males had a significantly larger 2D4D ratio on the back right foot than did females, and that no sex difference existed on either the back left or front right foot. However, although no sex difference in the front left foot was found at MSU, the 2D4D on this foot was larger in females at OSU. Our results demonstrate both sexual dimorphism in 2D4D and repeatability between laboratories, but they also suggest the importance of verifying such repeatability if 2D4D or any other digit-length ratio is used as a potential indicator of the early steroid environment. Supported in part by funds from NSF (IBN-0234740) to JW.

65.8 CHAPPELL, MA; Univ. of California, Riverside; *mark.chappell@ucr.edu*

Voluntary exercise and aerobic performance in several small mammals

The upper limit of sustainable metabolic power output is set by maximum oxygen consumption (VO_2max). Physiologists have considerable data on VO_2max from a variety of species, but little is known about how frequently animals approach VO_2max during voluntary activity, and hence how important this limit is for routine behavior. That information is difficult to attain for free-living animals, but many small mammals readily use running wheels in captivity. I used that propensity to determine voluntary running performance (speed and oxygen consumption) over 24-48 h periods in 4 species of wild-caught small mammals: Belding's ground squirrel *(Spermophilus beldingii)*, golden-mantled ground squirrel *(S. lateralis)*, least chipmunk *(Tamias minimus)*, Panamint kangaroo rat *(Dipodomys panamintinus)*. The measurements also yielded data on preferred running speeds, energy costs of running, minimal resting metabolism (RMR), and daily energy expenditures. To determine aerobic limits, I also measured VO_2max in forced exercise. Tests were done at a field station at 2150 m (ambient pO_2 ~ 121 torr). Most animals ran extensively, covering species mean distances of 5.2 14.7 km/day, with a maximum of 25 km/day in an *S. lateralis*. In all species, the relationship between voluntary speed and oxygen consumption (VO_2) was linear. For most, maximal VO_2 during voluntary exercise was substantially less than VO_2max, but golden-mantled ground squirrels regularly ran at speeds that elicited VO_2 within 5% of VO_2max. Aerobic scope (VO_2max /minimal RMR) ranged from 7.2 - 9.6. All species ran at a variety of speeds, contrary to predictions that voluntary running should be at high speeds to minimize incremental costs of transport or predation risk.

3.10 CHEROSKE, A.G.*; CRONIN, T.W.; CALDWELL, R.L.; Mesa Community College, Univ. of Maryland, Baltimore County, Univ. of California, Berkeley; *cheroske@mail.mc.maricopa.edu*

Variation in mantis shrimp visual and chemical signaling under different light conditions

Many organisms perform behavioral displays that involve visual communication (often with color) during courting. While visual cues often are used at longer distances, chemical signals are very effective at closer ranges. Stomatopods (mantis shrimp) are some of the most aggressive predators found mainly in coral reef habitats. They use a variety of visual displays during mating and aggressive interactions and have a complex color vision system capable off discriminating color signals. Mantis shrimp also are known to use chemical odors that can affect behaviors. As with many marine organisms, stomatopods occur over a range of depths where light spectrum and intensity changes may obscure color signals. Under restricted light conditions, visual signals without color such as posture and movement, or chemical signals may be a more efficient mode of communication. In these lab experiments, we investigated if stomatopods vary their use of different signal types in response to changes in light conditions and different chemical cues. Animals in aquaria were presented with an isolated intruder under full-spectrum and narrow-spectrum blue light. Test animals also were presented with odors from food items, another individual or seawater under both lighting conditions. Reactions recorded were total number of responses, type of response and time to first response. Findings suggest that stomatopods use a variety of signals during interactions and can adaptively vary their use dependent on photic conditions. These inducible, plastic behavioral responses can potentially maximize signal transfer in different light environments.

66.4 CHRISTEL, Carolyn M.*; DENARDO, Dale F.; SECOR, Stephen M.; Arizona State University, University of Alabama; *carolyn.christel@asu.edu*

Gila monster digestion and exendin-4: absence of exendin-4 effect on metabolism, intestinal performance, or plasma nutrient concentrations

Gila monsters, one of two venomous lizard species, actively forage in their desert environment for eggs and litters of small mammals. Known to feed relatively infrequently on large meals (up to 35% of body mass), Gila monsters may require extraordinary regulation of digestive performance. One potential regulatory hormone is the peptide exendin-4, which was isolated from the saliva of Gila monsters and has demonstrated prolonged plasma glucose-lowering properties in mammals. Although exendin-4 has often been labeled a venom protein, circulating plasma levels of exendin-4 have been shown to increase in response to feeding. Thus, we examined the Gila monster's metabolic responses to feeding and the possible regulation of these responses by exendin-4. Specifically, we explored the effect of feeding and exendin-4 on Gila monster metabolic rate, intestinal mass, intestinal performance, and circulating nutrient concentrations. In response to rodent meals, Gila monsters experienced approximately a 5-fold increase in metabolic rate and maintained significantly elevated metabolic rates for up to 7 days post-prandially. Small intestine mass and nutrient transport rates increased by 50% irrespective of circulating exendin-4 concentration. Similarly, glucose and triglyceride levels increased significantly over time, but did not correspond to either a post-prandial or a delayed increase in circulating exendin-4 concentration. Our results demonstrate that while Gila monsters experience a significant increase in intestinal performance and circulating glucose and triglycerides after feeding, exendin-4 does not affect these physiological events. Therefore, the question remains whether exendin-4 is involved in regulating digestive events or is a venom protein.

8.1 CIRILO, S.R.*; ESPINOZA, N.R.; PRUETTE, M. E.; WRIGHT, K. M.; GOSNELL, J. S.; BUTCHER, M. T.; BLOB, R.W.; Erskine College, Clemson Univ., Clemson Univ.; *scirilo@erskine.edu*

Limb Bone Strain Rates Across Diverse Locomotor Modes: Hopping, Jumping and Walking.

Previous studies have found that when bones are exposed to higher rates of strain during loading, they can endure greater strain magnitudes before yield failure. Previously, we evaluated how differences in strain rate might affect load bearing in emydid turtles and ranid frogs, species that use different modes of locomotion. In a continuation of this study, we examined a bufonid frog, the marine toad *Bufo marinus*, which moves using short hops rather than the long jumps of ranid frogs. Given this difference in locomotor style, we expected strain rates for any given strain magnitude in bufonids to be smaller than those in ranids, but greater than those in turtles. Strain rates were collected *in vivo* from strain gages implanted on the right femur of multiple animals. Raw strain values and high-speed video were collected simultaneously as the animals traveled across a treadmill. Extracted strain rates positively correlated with strain magnitudes in each species. Contrary to expectations, we found that, for any given magnitude measured in bufonids, bufonids had strain rates greater than or equal to ranids but greater than emydids. This may be related to bufonids having shorter limbs than ranids, and thus developing the same magnitude of strain over a truncated time period. These differences in strain rate could contribute to differences in load bearing capacities of limb bones both across and within these lineages.

39.10 CHRISTY, J. H.*; DENNENMOSER, S.; Smithsonian Tropical Research Institute; *christyj@si.edu*

Fiddler crab claws are both beautiful and powerful weapons: a paradox resolved

Male fiddler crabs have one greatly enlarged claw that they wave to attract females for mating and that they use as a weapon to fight other males. Longer claws probably are more effective visual signals and attractive to females. Male fiddlers increase the length of their large claw by lengthening their dactyl (movable finger) and polex (fixed finger) disproportionately relative to the size of their manus, which contains the closing muscle. Consequently, as males grow, the closing force they deliver at the tip of their claw decreases relative to their size. J. Levinton and colleagues have called this the paradox of the weakening combatant: beauty begets weakness. We studied claw morphology and fighting in two tropical fiddler crabs *Uca beebei* and *Uca terpsichores* and found a resolution to this paradox. When fighting males contracted their intertwined claws the forces were delivered not at the tips of the claws but at tubercles on the inner margins of the dactyl and polex. These tubercles contacted the inner and outer surfaces of the manus and often left small puncture wounds providing a record of where the forces were delivered. As claws grow these tubercles remain relatively close to the apex of the gape so that the mechanical advantage governing the delivery of forces at these points stays constant or decreases only slightly relative to claw length. Consequently the closing force at these tubercles, the product of the mechanical advantage and the cross-sectional area of the closer muscle, increased much more rapidly with male size than did the forces at the tip of the claw. Through differential growth of the dactyl and polex distal to the tubercles where the forces of contraction are applied, male fiddler crabs make large claws that are both beautiful and powerful weapons.

S6-1.6 CIVETTA, Alberto; University of Winnipeg; *a.civetta@uwinnipeg.ca*

Genetics and molecular evolution of male reproductive genes

It has been shown that genes with a role in reproduction evolve relatively faster than others. Most comparative genomics analyses however, have pooled a wide variety of genes into a single sex-related category and differences in rates across sex-specific functional classes and within gene families have been overlooked. There is also a need to identify candidate genes responsible for interspecies divergence in reproductive phenotypes. Taking advantage of genome sequencing project data it is now possible to analyze rates of evolution across species for specific reproductive gene classes. However, interspecies comparisons of sequence divergence are somehow limited for formal tests of selection. I have been using population genetics analysis to test whether positive selection has driven rapid evolution of male reproductive genes. I am also using Drosophila simulans introgressed lines to measure phenotypic variation in male reproductive traits. I have identified chromosomal introgressions responsible for phenotypic divergence in traits such as male mating behavior, sperm competition and male inflicted reproductive cost. My lab is staring to use microarray technology to associate how these chromosomal introgressions affect genes expression and to single out candidate genes.

S1-4.7 CLARK, C.J.; Univ. of Calif., Berkeley; *cclark@berkeley.edu*
Is the Anna's Hummingbirds' dive-noise vocal or non-vocal?
Male Anna's Hummingbirds (*Calypte anna*) perform display dives in which they fly 30-50m up in the air, then dive head-first towards a perched female. At the bottom of the dive, they emit a loud noise called the dive-noise. Rodgers (1940) provides evidence that the dive-noise is produced by the tail, but Baptista and Matsui (1979) present acoustic evidence that the dive-noise is produced vocally. As neither hypothesis has strong support, the source of the dive-noise is an open question. I test the hypothesis that the tail produces the dive-noise using three methods: 1) high-speed kinematics of diving males, 2) sound-recordings of display dives before and after experimental manipulation of the tail, and 3) noises produced when tail-feathers of males and females are placed in a stream of air in the lab. I discuss the implications my results have on the evolution of wing and tail morphology in birds.

36.4 COLLAR, DAVID C; University of California, Davis; *dccollar@ucdavis.edu*
Discordance between mechanical and morphological diversity in the suction feeding mechanism of centrarchid fishes
Morphological diversity is widely used to infer ecological variation among species because differences in form underlie variation in functional performance of ecological tasks. However, complexity in the relationship between form and function can weaken associations between these levels of variation. I investigate the link between morphological and functional diversification in a mechanically explicit model of fish suction feeding performance, where the map of head morphology to feeding mechanics is many-to-one: multiple, alternative forms can produce the same mechanical property. In the freshwater fish radiation, the Centrarchidae, many-to-one mapping leads to discordance between variation in a suction index, which is proportional to the buccal pressure drop a fish is capable of producing, and variation in the underlying morphology. The major centrarchid clades exhibit an order of magnitude range of diversity in suction mechanics despite similar levels of diversity in the morphological variables. This cryptic pattern of mechanical diversity suggests an evolutionary history for suction performance that is unlike the one inferred from comparisons of morphology. Inasmuch as many-to-one mapping is common in functional systems, this property of design may lead to widespread discordance between functional and morphological variation.

S5.6 COLLINS, Allen/G*; CARTWRIGHT, Paulyn; NOAA, University of Kansas; *collinsa@si.edu*
Rocks and Clocks: Integrating Fossils and Molecules to Date Transitions in Early Animal Evolution
Among the key transitions in early animal evolution are those that occurred near the origins of multicellularity: the sponge body plan, epithelial tissues, guts, colloblasts, cnidae, bilaterality and mesoderm. Determining the relative order of these events is reasonably straight-forward as relationships of early diverging animal lineages become better understood. Despite progress on early metazoan phylogenetics, the absolute dates of various transitions in early animal evolution remain obscure. Some estimates from molecular sequence data substantially pre-date animal origins of Metazoa in the fossil record. More recent molecule-based estimates have narrowed the disparity, but the assumptions upon which these estimates are derived are controversial. We use recently uncovered evidence for deeply-nested cnidarian clades that existed during the Cambrian to carry out a new set of molecular estimates for the origins of key animal groups. Our estimates also substantially pre-date all known paleontological evidence for the presence of animals. We evaluate the current available molecular dating methods using these data and explore the possible implications of these early dates for the origin and diversification of early animal life.

25.6 COMBIE, K*; ENGEL, G; KOOB, T; LONG, J; Vassar College, Mount Desert Island Biological Laboratory; *kecombie@vassar.edu*
The Cellular-Hydrostat Network Model of the Notochord of the Atlantic hagfish, Myxine glutinosa
We hypothesized that the adult hagfish notochord's network of interconnected, vacuolated cells compartmentalizes and pressurizes fluid intracellularly, creating elastic-solid mechanical behavior in the absence of an extracellular matrix. Notochords were dissected, ligated, and quartered axially, producing sealed segments for dynamic bending tests. Half of the specimens were incubated in hagfish ringers on ice; the other half were frozen and thawed three times in hagfish ringers before bending tests. This treatment lysed the cells, which resulted in a significant decrease in the complex modulus, E*, and the storage modulus, E'. There was no difference in the loss modulus, E", or tan delta. We propose a biological design principle, the cellular-hydrostat network, that links the notochord's bending function during swimming and the intermediate filament bounded, polyelectrolyte-filled vacuoles in the cells of the notochord lumen. Supported by the National Science Foundation grant DBI-0442269.

59.5 CONRAD, J.L.*; NORELL, M.A.; American Museum of Natural History, New York; *jconrad@amnh.org*

Early evolution of Monstersauria (Reptilia, Squamata)

Monstersauria (beaded lizards, Gila monsters, and their fossil relatives) has a fossil record that extends back 100 million years (Ma) and includes taxa from North America, Europe, and eastern Asia. Most Cretaceous monstersaurs are known from isolated skull elements. However, new specimens of *Estesia mongoliensis* and *Gobiderma pulchrum*, both from the Late Cretaceous of Mongolia, offer new details about the evolution of this clade. Some basal platynotans and varanid relatives show similar osteoderms to those of basal monstersaurs such as *G. pulchrum*, suggesting that this and some other morphological features usually associated with monstersaurs are plesiomorphic for Varanoidea. *Estesia mongoliensis*, a proximal outgroup to *Heloderma*, is essentially identical to *Heloderma* in the palate morphology despite plesiomorphic features of the skull roof (e.g., complete supratemporal arch). One new specimen of *E. mongoliensis* shows that the snout was short and rounded as in *Heloderma*. Importantly, a skeleton of *E. mongoliensis* reveals no evidence of osteoderms. *Gobiderma pulchrum* is one of the basal-most known monstersaurs. The new specimen helps demonstrate the plesiomorphic skull shape, short crista cranii, and braincase morphology. Co-occurrence of *E. mongoliensis* and *G. pulchrum* in some strata indicate that the two were likely partitioning resources; the former was a savannah monitor-sized predator with venom grooves in its teeth, the latter was a beaded lizard-sized predator without venom. Both lived in dinosaur- and mammal-rich areas. The presence of several late Late Cretaceous fossils suggests that monstersaurs were once a more common faunal component in North America and Asia. It remains unclear whether monstersaurs originated in North America and invaded Eurasia multiple times, or vice versa.

65.5 CONTRERAS, H.L.*; BRADLEY, T.J.; Univ. of California, Irvine; *hcontrer@uci.edu*

Discontinuous respiration as a response to oxidative damage: Tale of a sedentary insect

Insects have a relatively high mass-specific metabolic rate due their small size. It is surprising, therefore, that numerous taxa exhibit the discontinuous gas exchange cycle (DGC), a respiratory pattern in which the spiracles undergo a distinct closed phase. Recently it has been suggested that the DGC evolved to reduce O2 concentrations in the body, since oxygen (even at low levels) causes oxidative damage to tissues. Hetz and Bradley (2005) proposed that the efficient respiratory system of insects may have evolved to sustain large energy requirements needed for periods of high metabolic demand (e.g. during flight). DGC would be expected, therefore only during periods of low metabolic demand. We investigated the respiratory pattern of the Madagascar Hissing Cockroach (*Gromphadorhina portentosa*), a sedentary, non-flying insect. To examine the effects of changing metabolic rate, we subjected ten roaches to varying temperatures (10, 20, 30C) and recorded their respiratory pattern. Since *G. portentosa*, is relatively inactive, we expected to obtain maximal metabolic rates and a continuous respiratory pattern at higher temperatures. As temperatures decreased, the incidence of the DGC was expected to increase with decreases in metabolic rate. We found that closed phases became very rare at 30C. At lower temperatures the proportion closed phases increased. We conclude that metabolic rate dictates the insect's respiratory pattern (where an increase in demand induces continuous respiration and a decrease elicits DGC) and the length of respiratory cycle (as temperature decreases the time spent in each bout increases).

61.1 COSTA, D.P.*; BLOCK, B.; BOGRAD, S.; KOCHEVAR, R; TOPP-SCIENCE-TEAM, ; Univ of California, Santa Cruz, Stanford University, ERD-SWFCS-NMFS, Monterey Bay Aquarium; *costa@biology.ucsc.edu*

Utilization of the North Pacific By Marine Mammals and Others Top Predators: Tagging of Pacific Pelagics: Using Electronic tags to discover Hotspots in the Pelagic Realm

In an effort to understand and locate biological hotspots in the North Pacific Ocean, the Tagging of Pacific Pelagics program is using biologging technology to simultaneously map the location of marine vertebrates including sharks, tuna, albatrosses, seals and whales. Hot spots are regions of high biological activity where linkages occur between physical forcing, primary production, secondary consumers and top pelagic predators. Although it is generally accepted that these hotspots occur and are important, surprisingly little is known about these congregating spots for marine organisms in the open ocean. Our lack of understanding of the aggregating forces in the pelagic ocean ecosystem stems largely from limitations of available technology. Prior studies have focused on single species tracking and few have attempted to examine interactions among top pelagic species. TOPP is coupling electronic tagging data with satellite remote sensing technologies to simultaneously map the movements of diverse pelagic species and link their movements to oceanographic processes. To date we have tagged and tracked mako, salmon and white sharks, elephant seals, bluefin and yellowfin tuna, black-footed and Laysan albatross, California sea lions and leatherback sea turtles. To date our analysis indicates that frontal features associated with the North Pacific Transition zone and the California Current are the major regions of common habitat utilization for these species.

14.6 COTTER, P/A; EVERSON, J/J; RODNICK, K/J*; Univ. of Alaska Anchorage, Diagnostic Imaging of Idaho, Idaho State University; *afpac1@uaa.alaska.edu*

A Novel Assessment of Hemodynamics in the Intact Trout Heart

For the first time, we used simultaneous electrocardiography and echocardiography to characterize hemodynamics of the salmonid heart *in vivo*. We determined timing patterns of the cardiac cycle; characterized systolic function; and measured flow dynamics through all cardiac valves in tricaine-anesthetized, sexually immature and mature, male and female rainbow trout in freshwater. At 14&degC and 32-91 bpm, atrial filling, ventricle filling, and ventricular ejection time (ET) accounted for 43-87%, 14-27%, and 23-44% of the cardiac cycle, respectively. Ventricular ejection occurred entirely during atrial filling and ended prior to the T-wave. At similar heart rates, trout QT intervals were 57% longer than normal human QT intervals, and longer than electromechanical systole (QS_2), a finding not observed in mammals. QS_2, ET, S_1S_2(mechanical systole), and PEP (pre-ejection period) were positively related to MV and cardiac cycle length. PEP/ET was independent of MV and cardiac cycle length, suggesting that enlarged ventricles of sexually mature male trout maintain functional capabilities. Sinoatrial flow was of longer duration (0.54 ± 0.03 s) and lower velocity (30.7 ± 2.2 cm s^{-1}) than atrioventricular (AV, 0.19 ± 0.01 s; 83.7 ± 8.2 cm s^{-1}) and ventriculobulbar (VB, 0.30 ± 0.01 s; 64.5 ± 4.5 cm s^{-1}) values. Within each heart, AV and VB valve dimensions were the same (~ 5.5 mm^2); velocity and flow duration differences accounted for equal flow volume. In summary, we 1) provide evidence that trout compensate for maturation-associated hypertension and hypervolemia, 2) highlight functional differences between salmonid and mammalian hearts and 3) establish new reference data for cardiac electromechanical coupling in teleosts.

43.3 COTTON, C.J.; University of Wyoming, Laramie; *ccotton@uwyo.edu*

Protein Conservation in Spontaneous and Facultative Hibernators: the White-tailed Prairie Dog (Cynomys leucurus) and the Black-tailed Prairie Dog (Cynomys ludovicianus)

White-tailed prairie dogs are spontaneous hibernators that undergo regular, low temperature torpor bouts throughout the winter, while black-tailed prairie dogs are facultative hibernators that utilize sporadic, moderate temperature torpor bouts during the winter. The primary objectives of this study were to assess the abilities of these two species to 1) conserve skeletal muscle morphology, protein and strength, and 2) utilize labile protein in the small intestine and liver during the winter season of reduced activity and food intake. Masses and protein concentrations of the extensor digitorum longus (EDL), soleus, liver, and small intestine were compared before and after hibernation in both species. Skeletal muscle strength and fiber morphology were also analyzed for the EDL and soleus in all groups. Despite utilizing vastly different hibernation strategies, both species experienced a similar extent of muscle atrophy and strength loss during the hibernation season. After examining 17 parameters related to muscle atrophy and labile protein use during the hibernation season, only the change in cross-sectional area of slow oxidative fibers was found to differ significantly between the two species. Therefore, it appears that hibernation strategy has little effect on protein use and the retention of skeletal muscle strength during the winter season. Our findings do, however, show that both hibernation strategies permit a high degree of skeletal muscle conservation, especially when compared to muscle disuse atrophy models.

46.3 COVERDILL, A.J.*; CLARK, A.D.; RAMENOFSKY, M.; University of Washington; *alexac@u.washington.edu*

A comparative study of migratory behavior in white-crowned sparrows (Zonotrichia leucophrys)

Expression of migratory restlessness (MR) in captive birds has been considered a characteristic of migratory species. Paradoxically however, a few resident species also express MR. To address this issue, we describe migratory behavior to include the quiescent phase (QP), a transitional state between daytime activity and nocturnal flight, and specific behaviors that define nocturnal MR such as beak-up and beak-up flight, as identified in Gambel's white-crowned sparrow (*Zonotrichia leucophrys gambelii*). Analysis of migratory behavior may further our understanding of nocturnal activity in captive birds and reflect migratory strategy. Thus, we compared three related species, which represent a spectrum of migration from long-distance flight to residence, under spring photoperiods. The long-distance migrant, *Z.l.gambelii*, expressed QP for a mean duration of 75min prior to dark phase. All individuals showed MR consistently with high frequency throughout the night. The short-distance migrant, *pugetensis*, expressed QP for a mean of 60min immediately following onset of night. MR was observed in 66% of individuals with variable frequency. In *nuttalli*, the resident race, QP was absent. The latter birds were nocturnally active at low intensity and only 33% expressed actual MR. Migratory fattening was apparent only in the migratory species. These results support observations that resident congeners of migratory species show nocturnal activity but this activity may not represent expression of migration but a predilection for nocturnal movement within confines of a territory. In light of these data, application of a more specific definition of migratory behavior may prove to be the most revealing in evaluating the spectrum of migratory strategies among the pacific races of white-crown sparrows.

15.3 COWART, J. D.*; PAWLIK, J. R.; Univ. of North Carolina Wilmington , Univ. of North Carolina Wilmington; *jdc1234@uncw.edu*

Resource allocation in coral reef sponges: the trade-off between reproduction and chemical defense

Sponges have evolved effective methods to avoid, discourage or tolerate predation. Chemically defended sponges live relatively free from predation. In contrast, coral reef predators commonly graze upon sponges that lack chemical defenses. Why then do chemically undefended sponges persist on coral reefs? They may be allocating energy otherwise used for the production and maintenance of secondary metabolites to increased sexual reproduction. To test this hypothesis, tissue from 2 chemically defended (*Amphimedon compressa* and *Ircinia campana*) and 2 chemically undefended (*Iotrochota birotulata* and *Xestospongia muta*) Florida reef sponges were monitored using histological methods for the presence of eggs, embryos and larvae. Fecundity was calculated using the average densities of eggs, embryos and larvae in a 0.5 cm^2 area of tissue in 3 individuals per species prior to spawning. The average egg sizes for the chemically defended sponges were 270.6 ± 15.7 µm and 481.1 ± 67.1 µm (mean ± SD) respectively, while those for the chemically undefended sponges were 492.5 ± 40.5 µm and 92.4 ± 7.0 µm respectively. The chemically defended sponges produced fewer offspring (1.3 ± 1.4 eggs and 0.3 ± 0.5 eggs in a 0.5 cm^2 area of adult tissue respectively) than the chemically undefended sponges (4.6 ± 1.4 eggs and 19.1 ± 5.7 eggs in a 0.5 cm^2 area of adult tissue respectively). These preliminary trends suggest that chemically undefended sponges are allocating energy otherwise used for the production and maintenance of secondary metabolites to increased sexual reproduction. Continued monitoring of a total of 10 Florida reef sponge species (5 chemically defended and 5 chemically undefended) will provide additional information supporting or negating our hypothesis.

32.4 COX, Robert M*; MUNOZ-GARCIA, Agusti; JURKOWITZ, Marianne; WILLIAMS, Joseph B; Ohio State University; *cox.541@osu.edu*

β-Glucocerebrosidase activity in stratum corneum of House Sparrows following acclimation to high or low humidity

Skin is an important avenue for water loss, so environmental conditions that necessitate water conservation should favor mechanisms that reduce cutaneous water loss (CWL). Skin resistance to CWL is conferred by a barrier of lipid molecules located in the stratum corneum (SC), the outer layer of the epidermis. In mammals, SC barrier function depends upon the conversion of cerebrosides to ceramides by the enzyme β-glucocerebrosidase (β-GlcCer'ase). Avian SC contains both cerebrosides and ceramides, suggesting that plasticity in CWL may be mediated by changes in β-GlcCer'ase activity and resultant SC lipid composition. We tested this hypothesis by acclimating House Sparrows (*Passer domesticus*) to either dry or humid conditions and then measuring β-GlcCer'ase activity from SC homogenates. Our results provide the first characterizarion of β-GlcCer'ase activity in any non-mammalian vertebrate. Relative to non-acclimated controls, both dry- and humid-acclimated sparrows had significantly elevated β-GlcCer'ase activity at 21 d post-acclimation. Across individuals, we found negative correlations between β-GlcCer'ase activity and both CWL and SC ceramide content. Although dry- and humid-acclimated sparrows did not differ in β-GlcCer'ase activity, these results are consistent with our findings that both humidity treatments caused a reduction in CWL and similar changes in SC lipid composition. Our results demonstrate physiological plasticity in CWL and provide tentative support for a role of β-GlcCer'ase in mediating this response. However, our results refute the hypothesis that ambient humidity is the primary stimulus for CWL acclimation and indirectly suggest that temperature may have an overriding effect on acclimation.

28.3 COX, L.N.*; MOOI, R.; Auburn Univ., Alabama, California Acad. Sciences, San Francisco; *rmooi@calacademy.org*

An atypical type taxon: Phylogenetics and biology of the echinid Echinoidea

The Echinidae Gray, 1825 is a well-known, widely distributed group of sea urchins. Their ubiquity in the northern Atlantic, particularly the genus *Echinus*, gave rise to the earliest concepts of the Echinoidea itself. The echinids live in a wide range of habitats from the deep-sea to the intertidal. In spite of the familiarity of some echinids, their systematics remain very poorly known. There have been no species-level phylogenies of this group, nor have there been any attempts to support the monophyly of its constituent genera. We performed a phylogenetic analysis using 40 morphological characters assessed from nearly all the species of *Echinus* Linnaeus, 1758; *Gracilechinus* Fell & Pawson, 1965; *Dermechinus* Mortensen, 1942; *Sterechinus* Koehler, 1901; *Polyechinus* Mortensen, 1942; *Stirechinus* Desor, 1856; plus putative outgroups *Psammechinus* Agassiz and Desor, 1846; *Paracentrotus* Mortensen, 1903; *Parechinus* Mortensen, 1903; *Loxechinus* Desor, 1856; and *Strongylocentrotus* Brandt, 1835. The analysis supports monophyly of *Sterechinus*, but not of either *Echinus* or *Gracilechinus*. The validity of *Gracilechinus* is questionable given that it is based on a single, homoplastic feature. The bizarre, cucumber-shaped echinid, *Dermechinus*, is more closely related to *Sterechinus*, forming with it an exclusively Antarctic clade. The monophyly of the Echininae Mortensen, 1903 is supported, but there are no non-homoplastic characters distinguishing it from the Parechininae Mortensen, 1903. The results of this study suggest the need for radical taxonomic revision, in conjunction with molecular studies. However, with this first phylogeny, aspects of the biology, bathymetry, and biogeography of the echinids can be explored.

66.5 COX, C.L.*; SECOR, S.M.; University of Alabama; *clcox@bama.ua.edu*

Intestinal hydrolase activity of the Burmese python, Python molurus

For the Burmese pythons, the dramatic postprandial upregulation of intestinal nutrient uptake is predictably matched with concurrent upregulation of intestinal hydrolase activity. Therefore we measured from the Burmese python the postprandial response of the activity of two brush border enzymes, aminopeptidase-N (APN) and maltase, from five sites of the small intestine. Intestinal mucosal samples were collected from fasted snakes, and snakes 0.25, 0.5, 1, 2, 3, 4, 6, 10, and 15 days following consumption of rat meals equaling 25% of body mass. Mucosal samples were assayed for APN activity using l-leucyl-naphthylamide (LNA) as the substrate, and maltase activity using maltose as the substrate. APN activity peaked at three days postfeeding (5-fold of fasted levels) and returned to fasted levels by day 10. APN activity was highest in the proximal four fifths of the intestine, with the distal one fifth exhibiting notably lower activities for all time-points. APN capacity, defined as the summed ability of the small intestine to hydrolyze LNA, peaked at three days postfeeding at more than 10-fold of fasted capacities, and returned to fasted levels by day 15. Maltase activity was undetected in fasted animals, and increased to barely detectable levels at two days postfeeding. The concomitant postprandial upregulation of intestinal morphology, nutrient transport rates, and enzyme activities illustrate for the python the matched regulation of their intestinal performance.

33.3 CROSHAW, Dean A.; Savannah River Ecology Laboratory; *croshaw@srel.edu*

Fitness consequences of polyandrous mating for female marbled salamanders

Female polyandry occurs to some extent in a very high proportion of species. Because mating likely involves considerable fitness costs to individual females, theory predicts that polyandrous females gain fitness benefits that outweigh the costs, allowing the behavior to be maintained in extant populations. Potential benefits are non-genetic (or material) and genetic, with only the latter likely to occur in species where males provide females with sperm only, as in most salamanders. Genetic benefits could involve increased genetic compatibility between parents, genetic variation among offspring, quality of paternal genes, and quality or attractiveness of sperm. In the first study of the evolutionary consequences of polyandry in an ambystomatid salamander, we compared fitness correlates of monandrous and polyandrous marbled salamander clutches from semi-natural breeding arenas at the egg, hatchling, and metamorph stages. Larvae from polyandrous and monandrous clutches, determined by genetic paternity assignment, developed together in competition within high density field enclosures until metamorphosis. Survival to metamorphosis was significantly greater for polyandrous clutches than monandrous clutches. Our study provides the first evidence of increased survival of larvae produced by multi-male mating in an amphibian. I discuss these potential genetic benefits in terms of competing hypotheses to explain the evolution of polyandry.

3.11 CUNNINGHAM, Gregory B.*; STRAUSS, Venessa; RYAN, Peter G.; Univ. of Cape Town/Swarthmore College, South African Foundation for the Conservation of Coastal Birds, Univ. of Cape Town; *gcunnin1@swarthmore.edu*

First experimental evidence demonstrating that African penguins (Spheniscus demersus) have a functioning sense of smell

Procellariiform seabirds (albatrosses, petrels and shearwaters) have received much of the focus when studying avian olfaction. These birds are known to be attracted to a variety of food, and food-related, odors at sea. Penguins, however, are subject to similar types of environmental pressures while foraging, and have to locate patches of small prey items in an immense ocean. To date, few researchers have investigated whether penguins may use odors when foraging. Using a Y-maze we investigated the responses of captive African penguins (*Spheniscus demersus*) at a rehabilitation center to dimethyl sulfide (DMS), an odor that is associated with primary productivity and shown previously to be used by procellariiforms as a foraging aid. We also investigated how wild penguins at Robben Island, South Africa, responded to odors deployed along walking paths in their colony. Our experiments revealed that African penguins can detect and orient to DMS at biologically relevant concentrations. Thus, similar to procellariforms, penguins might use DMS as an olfactory cue to locate productive areas of the ocean where they subsequently forage for individual prey items via diving. Moreover, this study provides the first experimental evidence for a functioning sense of smell in a penguin.

6.9 CURTIS, DL*; MCGAW, IJ; University of Nevada, Las Vegas; Bamfield Marine Sciences Centre, University of Nevada, Las Vegas; Bamfield Marine Scienes Centre; *curtisd4@unlv.nevada.edu*

Balancing the demands of physiological systems in the Dungeness crab, Cancer magister and the blue crab, Callinectes sapidus

Decapod crustaceans inhabiting estuaries are often subjected to salinity fluctuations that occur on varying spatial and temporal scales. The osmoregulatory ability of a given species may dictate the energetic demands associated with salinity changes. The Dungeness crab, *Cancer magister*, is classed as a weak osmoregulator and unfed crabs showed no change in oxygen uptake when exposed to low salinity. In contrast, an efficient osmoregulator, the blue crab, *Callinectes sapidus*, which is highly tolerant of low salinity exhibits an increase in oxygen uptake in low salinity. Feeding and digestion causes a general increase in metabolic parameters, commonly referred to as specific dynamic action (SDA). When postprandial animals are exposed to environmental challenges the added cost of digestive processes may result in different physiological responses. We hypothesized that less efficient osmoregulators may not be able to balance the demands of osmoregulation and digestion concurrently; therefore a prioritization of events will be seen. For efficient osmoregulators, it was hypothesized that the crabs would be able to sum the demands of these two systems. In this study, when *Cancer magister* fed in seawater, there was an increase in oxygen consumption. However, when 1 h postprandial crabs were exposed to 50% or 75% SW, a dose dependant decrease in oxygen uptake occurred. In *Callinectes sapidus*, feeding and exposure to low salinity both resulted in an increase in oxygen uptake. The results of this study suggest that osmoregulatory ability may dictate the metabolic responses to feeding and digestion in low salinity, and has important implications for modeling the energetics of crustaceans inhabiting estuaries.

31.5 CYR, N.E.*; ROMERO, L.M.; Tufts University; *npoiri01@tufts.edu*

Chronic stress alters the avian cardiovascular and glucocorticoid stress response

The activation of the stress response to noxious stimuli is essential to survival in animals, however long term activation of the stress response may have critical medical and physiological consequences. To better understand the hormonal and cardiovascular changes caused by stress, we implanted heart monitors into wild caught European starlings, *Sturnus vulgaris*, and measured heart rate (HR) and corticosterone (CORT, the primary avian stress hormone) under baseline, acute stress, and chronic stress conditions. To induce chronic stress we used a chronic stress protocol (CSP) consisting of 5 stressors (loud radio, cage tapping, cage rolling, novel voice, and bag restraint) administered randomly for 30 min for 4 times/day over 16 days. In birds, the catecholamines epinephrine and norepinephrine both bind to &beta -adrenoceptors to mediate HR. We injected propranolol (&beta -adrenoceptor blocker) into 7 acutely stressed birds and in 8 chronically stressed birds to determine the &beta -adrenoceptor mediated changes in HR during acute and chronic stress. We found that both body weight and CORT decreased throughout chronic stress, which mirrors the results of a previous study in starlings. The CSP altered both basal and acute stress-induced HR. The 24 hour basal HR cycle immediately following the CSP was significantly lower than prior to the CSP. Basal HR at night decreased throughout the CSP and increased following its completion. In contrast, Basal HR during mid-morning increased at the end of the CSP. Restraint-induced tachycardia increased at the beginning of the CSP, but then significantly decreased at the end of the CSP. Propranolol caused a significant decrease in HR during acute stress, but only slightly decreased tachycardia in chronically stressed birds most likely because the HR response was already damped. Overall, the cardiovascular stress response was significantly altered in chronically stressed birds.

47.7 CZARNOWSKI, M.R.*; LOMBARDO, M.P.; POWER, H.W.; Rutgers University, Grand Valley State University; *czar@wildbehavior.net*

Hormone-behavior correlations vary with energetic stress in breeding male tree swallows (Tachycineta bicolor)

We previously demonstrated that clipping the primary wing feathers of breeding male tree swallows (*Tachycineta bicolor*) decreased certain parental care behaviors such as nestling feeding rate. Contrary to expectation, however, we did not find treatment group to affect hormonal stress response or immunocompetence. This current analysis examines the way physiology interacts with our manipulation in predicting behavioral variation during the breeding season. Our findings suggest that clipping changed the way in which internal physiology relates to observed behaviors. For example, control birds displayed a significant positive correlation between humoral immunocompetence and feeding rate (Spearman rho= 0.636, p

57.4 DALEY, M.A.*; BIEWENER, A.A.; University of Michigan, Ann Arbor, Harvard University, Cambridge; *mdaley@umich.edu*

Distal hindlimb muscles play a key role in stability of running over rough terrain

Using a novel obstacle treadmill experiment, we test the hypothesis that distal limb muscles rapidly modify work output for stabilization tasks. We examine the *in-vivo* force-length performance of the lateral gastrocnemius (LG) and digital flexor-IV (DF) of guinea fowl as they negotiate camouflaged obstacles that repeat every 10-12 steps. We expect the LG and DF to differ in stabilization performance due to differences in architecture. Although both have pinnate, short fibered architecture, the DF has a long, compliant tendon that crosses all of the distal joints, whereas the LG has a relatively short, stiff tendon. The results confirm that the LG and DF play distinct roles, consistent with observed differences in architecture. The LG acts as a length-dependent actuator', producing energy when the limb begins stance in a more crouched posture. The DF acts as a velocity-dependent actuator' absorbing or producing energy depending on how rapidly the limb is loaded. The results suggest that intrinsic mechanical factors explain much of the change in distal muscle performance, enabling rapid posture and load dependent changes in limb work. Additionally, the DF might act as an important sensor, eliciting rapid proprioceptive feedback that excites agonist muscles through heterogenic reflex pathways. These muscles provide a direct link between limb posture and limb energy performance that likely helps maintain stability and prevent injury during running over rough terrain. The results provide further support for the idea that limb muscles exhibit a proximo-distal gradient in function and motor control. Further, they provide insight into potential performance tradeoffs of different muscle-tendon architectures for efficiency, stability and agility.

S10.4 DANIELT, T.L.*; KOEHL, M.A.R.; Univ. Washington, Seattle, Univ. Californica, Berkeley; *danielt@u.washington.edu*

The role of computation, engineering, physics and mathematics in learning biomechanics

Biology is undergoing a revolution -- it is becoming a highly quantitative science dealing with exceedingly massive data sets and exquisitely complex systems. It is a field that must now exploit computational horsepower and advanced engineering applications to understand complex systems (from molecules to nervous systems to moving animals) involving many interacting factors. At the center of this lies comparative biomechanics, a discipline soaked in quantitative questions. Here lies significant synergism between the life sciences and engineering and mathematical sciences, spurring the development of advanced computational, analytical and technological tools. Yet mathematical and quantitative approaches, despite their great promise, remain foreign to many biologists - a situation that can hamper significant progress. Although the advent of powerful computational tools and analytic methods heralds new progress in biology, it also presents a fundamental dilemma: state-of-the-art mathematical and computational reasoning far exceeds what students in the life sciences are currently taught. To address this issue we have developed computational tools for teaching biomechanics via Matlab and Mathematica. Our goal is to improve learning and to help bridge the gap between theory and experiment. We emphasize mechanical design principles and fluid and solid mechanics to explore how organisms work (from cells to populations). This integration allows students to ask new questions and apply a series of experimental and computational designs to build and test models of form and function. Because it is not as established as other disciplinary areas, biomechanics can be enhanced by the presence of peer-reviewed activities such as these models in the SICB digital library.

69.7 DANOS, N.*; LAUDER, G.V.; Harvard University; *ndanos@oeb.harvard.edu*

Ontogeny of fin function during routine turning in zebrafish (Danio rerio)

The importance of fin function in fish maneuvering has been highlighted by several recent studies. We are interested in the ontogeny of these functions in a model organism, the zebrafish *Danio rerio*, during routine turns interpreted as part of its food searching pattern. Dorsal view high-speed videos of 22 fish performing routine turns were captured at 1000 fps and 1024x1024 megapixel resolution. Fish ranged in size from 0.38 to 2.0 cm in fork length (FL). The images were analyzed using Digital Particle Image Velocimetry (DPIV) software with the algorithm applied to the light image of the animal instead of laser-illuminated particles in the water. This allowed us to automatically track the movement of the zebrafish body and the pectoral and caudal fins at high spatial and temporal resolution without the necessity of manually digitizing individual points. From the resulting data the following kinematic variables were collected: maximum fin velocity during a turn both in m/s and relative to body velocity at the base of the fin, maximum body curvature, angular velocity of the head, maximum and final angle of the turn and turn duration. The slope of the log-transformed variables against log-FL was compared to the predictions from geometric models of isometry. The angular variables, angular velocity and turn angle always had negative slopes which never exceeded -1. The single time variable examined, turn duration, was independent of log-FL. Velocity variables did not follow a consistent trend; some showed a slight negative slope and some a slight positive slope (always

20.9 DAVIS, J.E.*; ADDIS, E.A.; O\'BRIEN, S.; WINGFIELD, J.C.; University of Washington; *jedavis@u.washington.edu*

Range Expansion and Neuroendocrine Modulation in Puget Sound White-Crowned Sparrows (Zonotrichia leucophrys gambelii)

The Puget Sound white-crowned sparrow (*Z. l. pugetensis*) has a historic breeding distribution limited to the Pacific coast of Oregon and Washington. In contrast, Gambel's white-crowned sparrows (*Z. l. gambelii*) breed predominantly in Alaska and northern Canada south to several high altitude sites in the northern Cascade Mountains of Washington State. Previous studies have shown that gambelii at northern and southern parts of their range express a highly modulated stress response during the breeding season, such that subsequent corticosterone increase is higher during the territory and mate selection, and lower during parental care. This may be an adaptation to the short-breeding season and high cost/benefit ratio associated with extreme environments, allowing flexibility in coping behavior early in the breeding season while making birds relatively resistant to stress-induced reduction in parental behaviors. Historic accounts have shown little or no overlap in the breeding territories of gambelii and pugetensis. However, climate change and the human disturbance of previously forested areas seem to have provided an opportunity for pugetensis to colonize alpine habitats thus bringing these two subspecies into contact. This range expansion into alpine habitat also presents pugetensis with new challenges, including extremes of weather, limited food sources, and a shortened optimal breeding period. In addition, several of these recent high-altitude populations display gambelii-like morphological and behavioral traits, indicating potential hybridization. The distribution, morphology, behaviors and modulation of the adrenocortical responses to stress observed in several high and low altitude breeding populations is presented.

19.5 DAVIS, J.R.**; DENARDO, D.F.; Arizona State University, Tempe; *j.davis@asu.edu*

The effect of hydration state on activity in a free-ranging Sonoran Desert lizard, the Gila Monster, Heloderma suspectum.

North American deserts can present significant challenges to animals because of variable, often extreme temperatures and limited energy and water resources. Challenges to fundamental physiological processes (e.g., thermoregulation, energy balance, and osmoregulation) are exacerbated most during summer drought due to the combination of high temperatures and low energy and water availability. Under such conditions, activity of many animals is constrained resulting in trade-offs between fundamental physiological processes. In reptiles, environmental temperature is most often identified as a proximate factor constraining activity, yet the widespread and reliable response to rainfall in desert reptiles suggests that water availability may also be an important proximate factor directly influencing activity patterns. To separate the influence of water availability from those of temperature and seasonality, we used a variety of physiological and biotelemetric approaches to conduct a manipulative field experiment testing the hypothesis that activity is constrained by an animal's hydration state. We randomly assigned 24 radio-telemetered, temperature datalogger implanted Gila Monsters, *Heloderma suspectum*, at a Sonoran Desert field site to one of two treatment groups: Water (H2O) or Control (CON). Once to twice monthly, H2O lizards received 50ml of water via an intragastric tube while CON lizards received a sham treatment. We measured plasma osmolality, body mass, and tail volume monthly, and used temperature-based activity estimation (TBAE) to estimate activity patterns of each lizard. We then compared activity and body condition characteristics between the water-supplemented and control lizards to determine whether hydration state constrains activity in this species.

44.5 DAVIS, L.K.*; HIRAMATSU, N.; SULLIVAN, C.; HIRANO, T.; GRAU, E.G.; Hawaii Institute of Marine Biology, University of Hawaii, Kaneohe, Hokkaido National Fisheries Research Institute, Kushiro, Japan, North Carolina State University, Raleigh; *lkdavis@hawaii.edu*

Multiple vitellogenins and their physiological regulation by 17&beta-estradiol and two endocrine disruptors in the Mozambique tilapia, Oreochromis mossambicus

Sequence analysis revealed three distinct vitellogenin (Vg) types, categorized as VgA, VgB, and VgC, in the Mozambique tilapia (*Oreochromis mossambicus*), making this species one of only a few teleost species with three forms of Vg. The objectives of these studies were to characterize the physiology of multiple forms of Vg, by examining the effects of an intraperitoneal injection of 17-&beta-estradiol (E_2), and the estrogenic pesticides o,p'-DDE and heptachlor on their hepatic expression in male fish. A single injection of E_2 at 5 &mug/g body weight into male tilapia significantly increased plasma levels of Vg within 1 day and continued to increase over the 5 day experiment. Hepatic expression of all three Vg genes increased markedly 1 day after E_2 injection, and high levels of expression were maintained until day 5. The expression pattern of estrogen receptor &alpha (ER&alpha) showed an identical pattern to Vgs A-C, suggesting a mediating role in Vg regulation. In a second experiment lasting 10 days, fish were given a single injection of 100 &mug/g o,p'-DDE, heptachlor, or 5 &mug/g E_2. Similar to the first experiment, plasma Vg and expression of Vgs A-C and ER&alpha were significantly increased by E_2. While neither pesticide had an effect on plasma Vg, expression of Vgs A-C were significantly increased by o,p'-DDE, but not heptachlor after 10 days. ER&alpha mRNA levels were not altered by either pesticide. These data suggest that within 1 day, E_2 increases plasma Vg by stimulating expression of Vgs A-C and ER&alpha while o,p'-DDE and heptachlor do not act via the same mechanism at the dose used in this study.

44.10 DAVIS, L.K.; HIRANO, T.; GRAU, E.G.*; Hawaii Institute of Marine Biology, University of Hawaii, Kaneohe; *lkdavis@hawaii.edu*

Vitellogenin induction by commercial fish food: possible implications in endocrine disruptor studies

In a number of teleost fish, male plasma has been found to contain substantial levels of 17&beta-estradiol (E_2) and in certain cases, vitellogenin (Vg), a female-specific precursor of egg yolk protein. The presence of E_2 and Vg in males raises questions about their etiology and may complicate assessment of environmental endocrine disruptors by masking their effects. In order to examine whether components of commercial fish food might induce Vg production, we measured Vg levels in male tilapia (*Oreochromis mossambicus*) that were fed either commercial feed, commercial feed treated with E_2 (5 &mug/g of feed), or a diet consisting of 50% squid and 50% mixed vegetables. Fish were fed for 40 days and sampled every 10 days. Plasma Vg in fish fed commercial feed remained constant at 3-7 mg/ml, while levels of fish fed E_2 significantly increased to 45 mg/ml. Plasma Vg of squid/vegetable-fed fish declined over time to often undetectable levels. Expression of three Vg genes (Vgs A-C) in the liver of squid/vegetable-fed fish, decreased to 0.6 - 3.2% of levels in control fish after 40 days while gene expression of Vgs A-C in E_2-fed fish increased by up to 25 fold. In a short term experiment, a single injection of 5 &mug/g E_2 increased plasma levels of E_2 and Vg within 24 hours. A single injection of a high dose of o,p'-DDE (100 &mug/g) also increased gene expression of Vgs A-C, but did not alter plasma Vg levels. We hypothesize that E_2, most likely from the fish meal component of the feed, induces gene expression and production of Vg in male tilapia. Sustained use of this diet will maintain Vg production, a protein with no known function in male fish. Reducing Vg production by feeding an estrogen-free diet may provide a more sensitive and suitable model to assess the effects of environmental endocrine disruptors.

40.4 DAVIS, M.C.*; DAHN, R.D.; SHUBIN, N.H.; Univ. of Chicago; *marcusd@uchicago.edu*

Hox genes and paired appendages: Paddlefish put a new spin on the fin.

Hox genes play an essential role in the development of vertebrate fins and limbs. During early appendage development in zebrafish and tetrapod (chick, mouse) model systems the pattern of Hox expression is highly conserved. However, at later stages there are a number of striking differences. For example, zebrafish and tetrapods both exhibit the same early pattern of 5' HoxD expression, but tetrapods possess a second phase of HoxD expression at later stages in the nascent autopod. Likewise, early HoxA expression appears conserved in each group, yet distinct spatial and inhibitory differences appear at later stages of limb development that are not observed in zebrafish fins. Based, in part, on these observations it has been proposed that the autopod is a developmental novelty'. However, an alternative hypothesis is that zebrafish may have lost or modified portions of an ancestral Hox program that is retained in tetrapods. Here we demonstrate the presence of tetrapod-like biphasic HoxD expression in the paired fins of a basal ray-finned fish. Like zebrafish and tetrapods, the paddlefish *Polyodon spathula* exhibits an early posterior expression of 5' HoxD genes in nested domains. In contrast to zebrafish, *Polyodon* possesses a second phase of 5'HoxD expression in the distal fin bud. Furthermore, this expression exhibits the same inverted domains across the A-P axis of the distal appendage that has been observed in the tetrapod hand/foot. Together, these results suggest that the autopod is an elaboration or expansion of a previously existing developmental program and not a developmental novelty per se. These results also support the notion that zebrafish (and presumably teleosts in general) are derived in the loss or modification of aspects of late stage Hox expression during fin development.

70.3 DAY, SW*; WAINWRIGHT, PC; Rochester Inst. of Tech., Univ. of California, Davis; *steven.day@rit.edu*

The forces exerted by suction feeders on their prey

Suction feeders feed by generating a flow of water that quickly transports prey into their mouth. All of the forces that the predator exerts on the prey item are caused by this temporally and spatially varying water flow. Because successful prey capture depends on the predator overcoming any movements and forces that the prey uses to escape, the nature and magnitude of these forces is key to a full understanding of suction feeding performance. We identify three forces associated with the generated flow field: drag, acceleration reaction and the pressure gradient force. Using a simple mathematical model parameterized with empirical data from feeding bluegill we explore the relative magnitude of these forces under three encounter scenarios: an immobile mid-water prey, a similar prey that executes an escape response, and a prey that grips a substratum. In all three scenarios the pressure gradient is the largest of the three forces. However, the relative magnitude of the forces varied in the different scenarios, indicating that inferences about the nature of forces experienced by prey must be made with reference to the conditions surrounding the interaction. The historical tendency to ignore the pressure gradient when considering forces generated by suction feeders results in severe underestimates of the forces experienced by the prey. Our simulations suggest that suction feeders can enhance the forces that they exert by increasing the pressure gradient that prey are exposed to. This can be accomplished temporally doubling the rate of increase in fluid velocity doubles force due to the pressure gradient, or spatially halving the size of the mouth and maintaining a constant fluid velocity at the mouth opening doubles the magnitude of the pressure gradient force experienced by a prey item at the mouth aperture. Supported by NSF IOB-0610310.

S9-1.2 DEAN, M.N.*; SUMMERS, A.P.; Univ. of California Irvine; *mdean@uci.edu*

Cranial design and feeding mechanisms of batoid fishes

The two major groups of elasmobranch fishes likely diverged from a cartilaginous and suction-feeding common ancestor, yet underwent a drastic evolutionary divergence in body form. While sharks are largely fusiform, rays and their relatives, even those secondarily evolved to a pelagic lifestyle, are dorsoventrally flattened. This limited morphospace apparently exerted no limitation on feeding niche: batoids have near complete overlap with the myriad feeding modes exhibited by sharks, ranging from dietary specializations (e.g., anguilliform prey, hard prey), to piscivory to filter feeding on a giant scale. Since the batoids are so close to two-dimensional we have examined the evolutionary trajectory of skeletal element associated with feeding in dorsoventral projection radiographs. In a few cases we check the validity of the 2-D assumption with 3-D imaging. There is considerable musculoskeletal diversity in the batoid clade, and using phylogenetic independent contrasts we find that variation lies mostly in length, width and angular variation in the elements of the first two visceral arches (particularly the paired hyomandibulae) and variation in the joints between them. Functional diversity also arose by elaboration and decoupling of the ventral muscles associated with these arches and the pharynx, resulting in a dexterous feeding mechanism capable of hydrodynamic prey manipulation. Musculoskeletal trophic morphology can exhibit impressive diversification despite gross-scale architectural limits imposed by the environment or phylogenetic history.

S9-1.5 DEBAN, S.M.; Univ. South Florida, Tampa; *sdeban@cas.usf.edu*

Evolution of feeding mechanics in amphibians

The three major groups of living amphibians have diversified in feeding biomechanics, in both larval and adult phases of their life history. Caecilian larvae have morphology that is consistent with suction feeding, while juveniles of viviparous and direct developing species and adults have been observed to use only jaw prehension in both terrestrial and aquatic situations. Caecilians have evolved a unique biting mechanism concomitant with a burrowing lifestyle. Among anurans, most tadpoles are suspension feeding planktivores, but some have independently evolved a predatory, suction feeding lifestyle. Adult frogs have diversified in terrestrial prey capture mechanisms by elaborating tongue projection along two biomechanical pathways, relying on inertial or hydrostatic elongation of the tongue, which is entirely soft tissue, but many species retain short tongues and pronounced lunging. Suction feeding is known to have evolved once in aquatic adult frogs, but many aquatic taxa use jaw prehension. Salamander larvae are universally predatory suction feeders, but some taxa lack a free-living larval stage. Aquatic adults suction feed using retained larval morphology or novel adult morphology, or use jaw prehension when biomechanically incapable of suction feeding. Terrestrial salamanders have evolved elaborate tongue projection along three biomechanical pathways, or retain short tongue pads and emphasize jaw movements in feeding. Salamanders are unusual in that feeding mechanics are strongly influenced by life history; sharing of features across metamorphosis via heterochrony appears to be more prevalent than in caecilians and anurans, perhaps because movements of the hyobranchial apparatus are critical to both salamander tongue protraction and suction feeding, and and not in jaw prehension and anuran tongue projection.

8.10 DEMES, Brigitte; Stony Brook University; *bdemes@ms.cc.sunysb.edu*

Reconstructing the loading environment of long bones from in vivo strain data

The *in vivo* strain measurement method has proven to be an important tool for exploring the interface between skeletal loading and bone shape. Strains recorded from multiple sites around the circumference of long bone shafts can be used to characterize the normal strain distribution in bone cross sections and determine the position of the zero-strain neutral axis. To correctly reconstruct the direction of the external bending moment from such data, the geometry of the cross section must also be considered. Using primate long bones as an example, angular discrepancy between bending axis and neutral axis is explored. If the principal moments of area are similar ($I_{max} \sim I_{min}$), orientations of bending and neutral axes are similar, no matter in which plane the external moment acts. With $I_{max} >> I_{min}$, bending and neutral axes are concordant only in bending around the principal or symmetry axes. Bending around other axes (asymmetric bending) results in a shift of the bending axis away from the neutral axis, towards the minor or weaker principal axis. For many primate long bones, with I_{max}/I_{min} ratios $max/I_{min} = 1.5$, the discrepancy in angles is 10º at most. At $I_{max}/I_{min} > 1.5$, however, asymmetric bending becomes an issue and must be considered when reconstructing the external bending moments from *in vivo* strain data. Fortunately, standard engineering equations are available that describe the directional relationship between the bending axis and the neutral axis, and can be used for axis corrections in highly asymmetric bones. The bone biology literature has paid little attention to asymmetric bending, despite its potential for producing erroneous results when reconstructing bone loading environments. Supported by NSF BCS 0548892

66.2 DENARDO, D.F.*; HOFFMAN, T.C.M.; Arizona State Univeristy, Tempe; *denardo@asu.edu*

The use of pseudoserpential thermometry to assess the impact of nest site selection and facultative endothermy on the thermoregulation of embryonic development in pythons

Temperature has considerable effects on embryonic development that influence viability, developmental rate, offspring morphology, and offspring performance. For most oviparous reptiles, females influence the thermal environment of their developing embryos solely through nest site selection. Pythons, however, brood their eggs, and some species are facultatively endothermic during this time. Assessing the relative importance of nest site selection and heat production on the thermoregulation of developing python embryos is technically difficult in living individuals, as heat production by a female cannot be experimentally controlled. Therefore, we used automatic, adjustably endothermic, latex models to assess the impacts that endothermic capability, daily nest temperature cycle, and clutch size have on the thermal environment of the clutch. Results demonstrate that clutch thermoregulation would be more effective with increasing endothermic capability and that the benefit of facultative endothermy increases with an increase in the amplitude of the daily nest site temperature cycle. These results suggest that facultative endothermy during brooding provides female pythons with greater spatial and temporal nest site selection.

S1-5.4 DENNY, MW; Stanford University, Hopkins Marine Station; *mwdenny@stanford.edu*

Facing Up to the Reynolds Rap: Foiling Faux Pas in Formulation Fouling Forces

Reconsideration of the Reynolds-number-dependent drag coefficient of wiffle balls has led to a re-evaluation of velocities associated with breaking waves. Modulated by the topography of rocky shores, local velocities in the surf zone may reach 35 m/s, considerably higher than previously suspected. The spatial and temporal variation in the imposition of these maximum wave-induced velocities can have substantial consequences for benthic organisms. Drag associated with a velocity of 35 m/s is sufficient to eliminate some algal species altogether, and can dislodge a substantial fraction of mussels, the dominant competitor for space. When drag is coupled with the temporally random effects of impingement forces, biological consequences are even more severe: even acorn barnacles can be dislodged. The upwardly modified velocity estimates reported here help to explain the role hydrodynamic forces play in maintaining the spatially and temporally variable pattern of species abundances on wave-swept intertidal shores

2.4 DENVER, Robert/J*; WILLIAMSON, Keith/E; Univ. of Michigan; *rdenver@umich.edu*

Evolutionary conservation of nuclear hormone receptor response elements: thyroid hormone regulation of the basic transcription element binding protein 1 gene.

Nuclear hormone receptors (NRs) regulate gene expression by binding to consensus hormone response elements (HREs). HREs may be located within the gene promoter, far upstream of the transcription start site, or within intronic regions. Thyroid hormone (T_3) plays critical roles in animal development, and earlier we showed that a T_3 responsive gene, basic transcription element binding protein 1 (BTEB1) is induced by the hormone in the brain of tadpoles and neonatal rodents. Furlow and Kanamori (*Endocrinology* 143:3295) identified a T_3 response element (TRE) in the *Xenopus laevis* BTEB1 gene ~6 kb upstream of the transcription start site. Here we describe the mapping of a TRE in the mouse BTEB1 gene within an evolutionarily conserved region of ~200 base pairs located 3.2 kb upstream of the transcription start site. Gel shift assays showed that TR-RXR heterodimers bound with high affinity to the putative mouse BTEB1 TRE. The TRE acts as a strong response element in transfection assays using a minimal heterologous promoter. In the mouse neuroblastoma cell line N2a[TRβ1], T_3 treatment (30 nM) caused rapid upregulation of BTEB1 mRNA. Chromatin immunoprecipitation assay combined with quantitative PCR showed that TRs associated with the mouse BTEB1 TRE *in vitro* and *in vivo*, and T_3 treatment resulted in hyperacetylation of histones 3 and 4 at the TRE site. Our results identify a functional TRE in the mouse BTEB1 gene, and suggest that natural selection has maintained the structure of this important enhancer element in vertebrates. (Supported by NIH grant 1R01NS046690-01 to R.J.D.)

47.4 DEVICHE, P.J.; Arizona State University; *deviche@asu.edu*

SEASONAL CHANGES IN BASAL AND STRESS-INDUCED PLASMA CORTICOSTERONE IN A SONORAN DESERT MALE SONGBIRD

Changes in baseline and stress-induced plasma corticosterone (CORT) concentrations have been documented in many avian species. However, few studies in intact free-ranging birds have investigated systematic variations of these concentrations throughout the annual cycle and how changes in plasma CORT relate to those of other hormones, particularly gonadal steroids. In adult male Rufous-winged Sparrows, *Aimophila carpalis* that were sampled in the field over a 1.5 year-long period, baseline plasma CORT changed seasonally. Hormone levels were high during the summer monsoon season (Jul-Sept) when birds were breeding and low during the fall post-breeding molt and throughout the winter non-breeding season. In one year but not the next, plasma CORT was as elevated in March, when males were beginning to develop testes and not yet in breeding condition, as during the summer breeding period. This yearly difference correlated with a difference in local precipitations, indicating that proximate factors associated with these precipitations may stimulate the hypothalamo-pituitary-adrenal axis. Capture and handling for 30 min stimulated CORT secretion. Baseline and stress-induced plasma CORT levels were individually correlated but the amplitude of the stress-induced response did not vary during the annual cycle, suggesting no seasonal change in sensitivity to acute stress. Baseline plasma testosterone (T) was seasonally high during the summer breeding season but low in March, indicating no consistent year-round relationship between the secretion of this hormone and of CORT. In addition acute stress, while increasing plasma CORT, consistently decreased plasma T by almost 50%. The results will be discussed with regards to our current understanding of the functional relationships in birds between the pituitary-adrenal and -gonadal axes.

68.8 DIJKSTRA, J.; University of New Hampshire; *dijkstra@cisunix.unh.edu*

Effects of salinity on mortality and heart rates of two introduced colonial ascidians, Botryllus schlosseri and Botrylloides violaceus

The role of abiotic factors in the establishment and success of invasive species remains difficult to determine for most ecosystems. However, examining this relationship is critical to predict the spread of invasive species. In this study we examine the mortality and physiological sensitivity of adult colonies of the colonial ascidians *Botryllus schlosseri* and *Botrylloides violaceus* using a combination of field and laboratory studies. Mortality and spatial dominance of colonial ascidians in the field were documented using 16 0.1m2 Plexiglas panels. Panels were deployed in July 2003 and photographed monthly at the mouth of Great Bay Estuarine Reserve in Newscastle, New Hampshire. Here annual salinity ranges from 33 ppt in the summer to 10 to 15 ppt in the spring. Adult colonies of each *B. schlosseri* and *B. violaceus* were exposed to abrupt salinity fluctuations (5, 10, 15, 20, 25, 30 ppt) in the laboratory. Heart rates were used to assess the condition of individual colonies and monitored daily for approximately two weeks. Results revealed that both *B. schlosseri* and *B. violaceus* experienced mortality after 1 day at 5 ppt and that their heart rates declined with decreasing salinity. Heart rates of *B. schlosseri* remained consistent between 15 ppt and 30 ppt and slowed at 10 ppt. Heart rates of *B. violaceus* were not significantly different between 20 ppt and 30 ppt but slowed at 15 ppt. The laboratory results corresponded to those in the field that showed a marked decline in spatial dominance of *B. violaceus* but not *B. schlosseri* during periods of low salinity. These results will help to explain dominance patterns of *B. schlosseri* and *B. violaceus* among coastal and estuarine sites.

21.1 DILLON, M. E.*; CONG, G.; DUDLEY, R.; University of Washington, Seattle, Sichuan University, Chengdu, PRC, University of California, Berkeley; *dillonm@u.washington.edu*

Bumblebee flight kinematics under natural and experimental variations in air pressure

Despite the challenges of flying in reduced density air, bumblebees (genus *Bombus*) thrive on mountains. Flight at high altitudes (reduced air density) may require compensatory changes in wing motions, in addition to changes in flight morphology. In particular, an increase in the wingbeat frequency or in the stroke amplitude can aerodynamically offset a reduction in air density. We predicted that bumblebees increase stroke amplitude to fly at high altitudes. We tested this prediction by videotaping hovering bumblebees collected across a steep altitudinal gradient (900-4500 m) in western China. We also asked whether bees resident at high altitudes increase stroke amplitude similarly to low altitude residents exposed to high-altitude conditions (and vice-versa). To do so, we measured wingbeat kinematics of bumblebees hovering at the barometric pressure of the capture site, as well as over a range of hyper- and hypobaric conditions (within a field-portable flight chamber in which pressure was altered with a hand pump). As predicted, stroke amplitude increased significantly with altitude. To our surprise, bumblebees exhibited interspecific compensatory kinematics: high altitude bees flew with lower stroke amplitudes relative to low altitude bees at any given pressure. Given that stroke amplitude has an upper limit of 180 degrees, we hypothesize that high altitude bumblebees reduce stroke amplitude during normal hovering to preserve the margin for supplementary power production.

27.4 DOLCE, J.L.*; WILGA, C.D.; University of Rhode Island; *jdol6206@postoffice.uri.edu*

Taxonomic Significance of Gill Slit Morphology in Extant Sharks

The number of gill slits that an elasmobranch species possesses is often used for taxonomic classification. However, other characteristics of the gill slits that have been overlooked appear to have taxonomic significance. In this study, the length of each slit, spacing among the slits, and position of the slits relative to the pectoral fin were measured on approximately 45% of extant shark species with each order of sharks represented in the data set. Some factors that may be correlated with gill slit morphology were also investigated, including history, body type, and habitat. Four different gill slit length character states, two spacing character states, and five gill slit position character states exist among the species studied. Characters were mapped on an existing phylogeny to examine phylogenetic relationships. A principal components analysis (PCA) was performed to group the characters into descriptive units and explore relationships between the character states, habitats, and body types. Multiple character states exist among orders but are consistent within an order. This suggests that gill slit morphology is influenced by phylogenetic relationship. Slit length loads low on PC1, and body types one and four also load low on PC1. Slit spacing loads low on PC2 with only orectolobiform species in body type three loading low as well. The number of slits over the pectoral fin loads low on PC3 with only orectolobiform species in body type three loading low on PC3. No relationship among species by habitat was detected, nor was a relationship for body types two and three other than those found for the orectolobiform species in body type three. Some correlations among the three gill slit character states were detected; however, phylogeny is a better indicator of gill slit morphology than body type or habitat.

S1-1.3 DORGAN, K.M.*; JUMARS, P.A.; ARWADE, S.; University of Maine, Johns Hopkins University; *kelly.dorgan@umit.maine.edu*

Burrowing in muddy sediment by crack propagation

Marine muds are elastic solids through which animals move by propagating a crack-shaped burrow. Dilations previously considered anchors serve to exert radial compressive stress that, through elastic behavior of the medium, focuses axial tensile stresses strongly at the tip of the burrow. This focused stress breaks adhesive bonds, propagating a crack for the animal to follow. The force required to propagate a crack by the polychaete Nereis virens has been measured in gelatin, an analogue of muddy sediment, using photoelastic stress analysis. Numerical modeling confirms experimental observations in gelatin and is used to determine the effect of differences in mechanical properties between sediment and gelatin. Newly calculated forces are lower than previously measured and call into question the reputed great expense of burrowing as a form of locomotion, although data on metabolic cost of transport are lacking.

S6-1.2 DORUS, S; University of Bath; *T.L.Karr@bath.ac.uk*

Expansion of sperm gene families in D. melanogaster

Although new gene creation is one crucial process in the evolution of biological novelty there remain many questions surrounding evolutionary processes immediately following gene duplication. Here, we analyze the expansion of two sperm gene families, CG17450 (a tektin-like gene) and Mst35B (a high-mobility box gene), during *D. melanogaster* evolution to better understand the early life of a new gene. Interestingly, these recent duplicates evolve in a manner consistent with the historical selective forces influencing their parental genes. For example, the Mst35B gene pair have diversified rapidly in a manner consistent with the divergence of their parental gene within the melanogaster subgroup. Notably, this evolution has been concentrated within the high-mobility box domain suggesting functional diversification and/or neofunctionalization in this regulatory DNA-binding domain. Finally, these genes are significantly overexpressed in the testis and encode integral sperm proteins suggesting that gene creation may be an influential process in sperm evolution. The broader implications of the role gene duplication may play in shaping sperm evolution will be discussed.

12.4 DOUGLAS, J. M.*; CRONIN, T. W.; CHIOU, T. H.; DOMINY, N. J.; RUTOWSKI, R. L.; Arizona State University, University of Maryland, Baltimore County, University of California, Santa Cruz; *jondouglas@asu.edu*

Light habitats and the role of polarized iridescence in the sensory ecology of neotropical nymphalid butterflies (Lepidoptera: Nymphalidae)

Recent hypotheses suggest the detection and exploitation of polarized light in a signaling context may have adaptive value in forest habitats, where illumination varies greatly in spectrum and intensity. Here we test whether polarized iridescence and forest light habitats are evolutionarily correlated by investigating the extent to which neotropical lepidoptera exhibit polarized iridescence, and evaluating the types of habitats in which polarization tends to be found. We limited our examination to species belonging to the Nymphalidae found within Costa Rica. Polarized specimens were distinguished using a polarizing filter and images indicating the degree of polarization with a color coding system. Adult flight habits and associated light environments were obtained from the literature. A significant correlation (Yates Chi^2 = 40.177; d.f. = 1; $P < 0.0001$) was found between polarized reflectance patterns of butterfly wings and forest light habitats. We then constructed a phylogeny of the Nymphalidae from the literature and performed a phylogenetic concentrated changes test, with the Papilionidae as an outgroup (Maddison, 1990). This test shows robust support for the correlated evolution of polarized reflectance patterns with life in forest environments suggesting a strong selective force on the wing patterns forest butterflies. These results are consistent with the hypothesis that the utilization and detection of polarized light has adaptive ecological value in forest habitats having complex ambient light conditions.

30.5 DRUZINSKY, R.E.; Governors State University; *r-druzinsky@govst.edu*

Feeding Mechanisms in Rodents

The Rodentia is a remarkably successful order, comprising roughly half of the extant species of the Mammalia. Rodents share a suite of derived characters of the jaw apparatus. These characters include a single incisor in each quadrant of the dentition, upper and lower diastemata, and the absence of the articular eminence at the anterior end of the glenoid fossa. Together these characters form a biomechanical complex for gnawing. Traditionally the rodents have been divided into three categories - sciuromorphy, hystricomorphy, and myomorphy based on specialized arrangements of the jaw adductor muscles. Each of the three specializations is an anatomical solution that allows for rostral placement of jaw-closing muscles that have long moment arms, large physiological cross-sections, but relatively short fiber lengths. Numerous authors (e.g., Wood, 1973; Hartenberger, 1980) have suggested that these specializations of the rodent feeding apparatus are associated with chewing in which antero-posterior or propalinal movements are emphasized. But mechanical analyses demonstrate that it is more probable that sciuromorphy, hystricomorphy, and myomorphy are parallel evolutionary pathways for building a feeding apparatus for gnawing, and all have evolved more than one time.

35.1 DUBUC, Timothy R; University of Hawaii Manoa; *dubuc@hawaii.edu*

Regeneration in benthic ctenophores (Platyctenida)

Coeloplana and *Vallicula* species have a unique derived lifestyle compared to their pelagic relatives, including: a benthic habitat, loss of ctene rows, and a flattened oral/aboral body. Adult benthic ctenophores have a complex gastrovascular system laced with a rich fibrous network of muscle throughout their body. During asexual reproduction, an individual either buds a small peripheral portion of its body that eventually develops into a complete cloned adult, or divides in half, creating a new individual. This study uses confocal microscopy to track the development and reorganization of muscle fibers as well as the gastrovascular system through each mode of asexual reproduction. In development of a new asexually produced individual, the wounded side fuses together, and then tissue reorganization occurs. In budded individuals, the wounded side is where the first tentacle develops, followed by the development a complex gastrovascular system, a pharynx for feeding as well as a statocyst. Individuals that undergo transverse fission simply have to close the wounded area, and reconstruct the gastrovascular system while building a second tentacle and statocyst. Studying asexual propagation will shed light on how derived characters within the benthic ctenophores may have evolved.

S7-1.3.1 DUCH, Carsten; Arizona State University; *carsten.duch@asu.edu*

Form and Function of Identified Insect Motoneurons

Understanding complex neural circuitry requires an understanding of the functions of its basic components - individual neurons. A single neuron's dendritic tree may receive thousands of input synapses. Input integration and computation are strongly affected by synapse distributions, dendritic shape and active conductances. We ask two questions: First, do specific rules exist for dendritic architecture, synapse distribution, and ion channel distribution within complex dendritic trees to ensure behaviorally adequate firing output? Second, what are the developmental mechanisms to create complex dendritic trees with all proteins at the correct sites? We address these questions in holometabolous insects, like Manduca and Drosophila, because structure, physiology and function of identified neurons are modified in parallel during metamorphosis, allowing for studies that directly relate single neuron modifications to developmental changes in behavioral function. We analyze dendritic structure and synapse distribution by combining high resolution confocal microscopy, precise 3-D dendritic reconstruction and novel co-localization analysis tools. We find that stage-specific rules exist for dendritic shape and synapse distribution. Multi-compartment models test the impact of these rules for spatio-temporal synaptic input integration. Developmental mechanisms for establishing dendritic architecture are tested by genetic and electrophysiological manipulations, showing that various changes in the activity patterns of individual neurons affect their architecture in different ways. Finally, behavioral experiments indicate that altered structure and excitability of individual neurons in a motor network affect behavioral performance. A future challenge will be to integrate the different levels of analysis to create a comprehensive framework for understanding physiology and architecture of single neurons in the context of behavioral output.

62.1 DUCKWORTH, R.A.*; SOCKMAN, K.W.; University of Edinburgh, University of North Carolina; *rad3@duke.edu*

Evolution of avian personalities: adaptive variation or hormonal constraint?

The correlated expression of behavior across different contexts can reflect constraints to the independent evolution of behavior or a suite of behaviors favored by selection. Behavioral constraints are thought to result from the pleiotropic effects of hormones that simultaneously affect the expression of multiple behaviors. We tested the idea that testosterone, by affecting the expression of aggression across multiple contexts, underlies variation in aggressive personalities of western bluebirds (*Sialia mexicana*). Here, we show that testosterone levels are unrelated to males' aggressive phenotypes and instead vary closely with mating behavior. Moreover, male aggressive behavior was associated with distinct dispersal strategies highly aggressive males are superior competitors and are more likely to disperse, but invest very little in parental care, whereas non-aggressive males acquire low quality territories, are philopatric and invest highly in parental care. Thus, distinct aggressive personalities of western bluebirds are favored because they ensure that the trait necessary for success in a new environment aggression is reliably associated with the propensity to disperse. These results suggest that selection can decouple hormonal and behavioral variation when inflexibility in the expression of behavior is adaptive.

S1-3.2 DUDEK, DM*; SRINIVASAN, M; ROGALE, K; KUKILLAYA, R; HOLMES, P; FULL, RJ; Univ. of British Columbia, Princeton Univ., Univ. of California, Berkeley; *dudek@zoology.ubc.ca*

The Relevance of Resonant Frequency in Running Cockroaches Modeled by a Spring-loaded, Inverted Pendulum

An array of morphologically diverse runners, from insects to large mammals, display the dynamics of a spring-loaded inverted pendulum (SLIP) with the same dimensionless leg stiffness (Blickhan and Full, 1993). Such dynamics have been shown to be passively stable over the parameter and speed range of human locomotion. Our previous results of the stiffness of individual legs to the support tripod during running suggest that, in addition to the benefits of passive stability, cockroaches may benefit from reduced power expenditure by using stride frequencies at or near the resonant frequency of the spring-mass system. We approximated stance phase durations and leg sweep angles for a SLIP model of running animals using the method of Geyer et al. (2005), and compared them with numerical solutions of the full equations of motion. Approximations revealed how gravitational, elastic, and centrifugal forces influence periodic gaits, and showed that, unlike in vertical hopping, it is difficult to define a clear natural frequency for a given SLIP. We computed branches of such gaits with and without flight phases and with double-stance phases. We used stride data from running cockroaches to calculate the stiffness of the support tripod over a range of speeds. Dimensionless tripod stiffness ranged from 3-5.5. We also investigated stability for parameters representative of insects and mammals and showed that insect gaits as modeled by a single-stance leg SLIP are unstable over much of their speed range. This suggests that multi-legged support in stance, as in the double tripod gait of the cockroach, may be critical to insect performance. Funded by NSF FIBR.

S1-4.2 DUDLEY, Robert; Univ. of California, Berkeley; *wings@berkeley.edu*

From Vogelian Imagination to Gaseous Machinations: Animal Flight Performance in Variable-Density Air

Animal flight performance is typically studied at or near sea level within the contemporary atmosphere. Experimental alteration of the physical composition of gas mixtures, however, permits construction of novel flight media and the non-invasive manipulation of flight biomechanics and physiology. For example, replacement of atmospheric nitrogen with various noble gases yields a ten-fold variation in air density at a constant oxygen concentration. Normoxic reduction in air density elicits extraordinary biomechanical effort from flying animals; hummingbirds and euglossine orchid bees hovering in helium:oxygen gas mixtures demonstrate exceptionally high levels of power output. The physical effects of variable air density and oxygen availability across altitudinal gradients also strongly influence patterns of morphological and physiological adaptation in volant taxa. Furthermore, geophysical data suggest that both oxygen concentrations and total atmospheric pressure have changed dramatically during defining periods of metazoan evolution. In particular, global variation in atmospheric composition and density during the late Paleozoic may have influenced the initial evolution and subsequent diversification of pterygote insects, as well as the contemporaneous and taxonomically widespread phenomenon of arthropod gigantism.

S9-2.3 DUMONT, E.R.; UMass Amherst; *bdumont@bio.umass.edu*

The evolution of feeding mechanisms in bats: Balancing the costs of morphology and flight

By any standard, bats (Order Chiroptera) are a successful group of mammals. Roughly 25% of all mammal species are bats and they occupy all but the coldest and most remote regions of the earth. The evolution of flight and echolocation were certainly key innovations behind their success but that is only part of the story. Bats have diversified into trophic niches that range from insectivory, through carnivory, frugivory and nectar-feeding. While flight places fundamental constraints on the shape of the postcranial skeleton, the shape of the skull in bats is remarkably varied. Morphological studies of individual clades and sympatric assemblages demonstrate that variation in skull shape is clearly associated with trophic specialization. This is best illustrated by the New World leaf-nosed bats, which exhibit the broadest range of dietary adaptations and cranial morphologies within any mammalian family. Studies of feeding performance and feeding behavior coupled with biomechanical analyses of skull shape are beginning to hint at the processes linking skull shape and dietary adaptation within these bats. Field experiments demonstrate that species-specific biting behaviors during feeding are common. Modeling experiments further suggest that these feeding (loading) behaviors and skull shape are functionally linked. This structure-function association may be stronger among bats than other mammals because the energetic cost of flight increases with excess weight. If the skull of bats is under selective pressure for minimal mass, then it may be more streamlined to meet mechanical demands than the skulls of other mammals; even relatively minor differences in skull shape among species may represent significant functional divergence. These qualities make bats a unique model system for studying the evolution of diversity in skull morphology and its functional implications for the evolution of feeding strategies in mammals.

6.11 DUNKIN, R.C.*; WILLIAMS, T.M.; WILSON, D.; MATTHEWS, C.; Univ. of California, Santa Cruz, Wildlife Safari, Wildlife Safari; *dunkin@biology.ucsc.edu*

Seasonal Changes in Evaporative Water Loss in African Elephants L. africana

Elephants occupy habitats with seasonally sustained high temperatures and low water availability. Despite this, both the ecology and thermoregulatory physiology of elephants suggest that these large mammals are highly water dependent. Although they lack sweat glands, evaporative water loss (EWL) is considered important for heat dissipation in elephants but has not been systematically measured across body sites or seasons. To evaluate variability in EWL in this mammal, we measured skin surface temperature, heat flux, and EWL for three African elephants at Wildlife Safari in Winston, OR. Comparisons were made across seasons for 5 body sites before and after bathing. Our results indicate that surface temperatures of the belly, foot, and inner ear were similar and were higher than the temperatures at the shoulder for both dry (poC lower than those for all other body sites. Heat flux varied with body site, with thermal windows (e.g. inner and outer ear) showing significantly lower heat flux in winter than in summer ($p = 0.01$; $F = 7.5$). Heat flux from wet skin was generally higher than from dry skin, but this trend was not significant. Evaporative water loss from dry skin was 50% higher in summer compared to winter [mean ± SE (mg min^{-1}), summer = 7.09 ± 0.33 and winter = 4.74 ± .33] ($p = 0.02$; $F = 5.84$). When the skin was wet, there was no significant difference in EWL between seasons. If surface area is accounted for, EWL appears to significantly contribute to the high water demand of African elephants particularly during warm seasons. For an elephant with a surface area 20.7m^2, the water lost to evaporation in summer and winter is 107L day^{-1} and 72L day^{-1}, respectively. These values represent 47% and 32% of the average daily water consumption (225L day^{-1}) for this species. Such high levels of water consumption likely dictate the habitat requirements of this animal but may in part be mitigated by the hydrophilic properties of elephant integument.

10.6 DUNN, CD*; MATUS, DQ; HEJNOL, A; SEAVER, E; MARTINDALE, MQ; University of Hawaii; *cdunn@hawaii.com*

Assembling the Protostome Tree of Life: EST Data from Diverse Taxa

Key nodes in the animal phylogeny have remained unresolved despite the growing availability of datasets with many characters for a small set of taxa (genomic data) and better sampling of a small set of characters across many taxa (traditional molecular phylogenetic studies). Expressed Sequence Tags (ESTs) provide a relatively inexpensive means of collecting sequence data for many genes. Phylogenomic studies that include EST data have recently improved our understanding of several nodes in the animal phylogeny, but important taxa are still missing from these studies. In order to better resolve the animal phylogeny as a whole and to investigate the placement of important neglected taxa we have sequenced 1000-5000 ESTs from a diversity of animals including a bryozoan, phoronid, brachiopod, nemertean, myzostomid, acoel, rotifer, hemichordate, echiuran, sipunculid, and ctenophore. Various strategies for gene orthology assignment are presented along with animal phylogenies based on data from about 150 genes sampled across more than 45 diverse taxa. Implications for the evolution of development and body plans are explored in light of these new data.

S3-2.1 DYMOWSKA, A.K.*; SEIBEL, B.A.; University of Rhode Island; *agnieszka@mail.uri.edu*

Living in cold. Temperature compensation in pteropod mollusk, Clione antarctica.

In polar animals living at low temperatures, such as those experienced by *C.antarctica*, locomotory performance is constrained by slower generation of ATP[1]. Cold adaptation and acclimatization in ectotherms may result in increases in mitochondrial densities[2], surface density of cristae, and enzyme concentrations[3], presumably to increase aerobic capacity. All of the above were investigated in locomotory muscles of *C.antarctica* (habitat temperature -1.8ºC) and its temperate sister species *C.limacina* (habitat temperature 10ºC). Even though mitochondria occupied ~ 0.35 volume of slow-twitch muscle fiber in both species, changes in the relative proportion of fast- and slow-twitch muscle fibers made the volumes per muscle bundle much greater in *C. antarctica* (0.365±0.016) than in the temperate *C.limacina* (0.197±0.018). In fact, fast-twitch muscle was completely displaced in Antarctic congener. Differences were also observed in the mitochondrial ultrastructure. *C. antarctica* had approximately 1.7-times higher cristae surface density (58.157±1.351$\mu m^2/\mu m^3$) than *C. limacina* (34.272±0.826$\mu m^2/\mu m^3$). Further, in Antarctic species citrate synthase activity was twice as great in whole organism (2.965±0.169 unit g^{-1} compared to 1.408±0.141 unit g^{-1}) and almost four-times higher in the isolated locomotory muscles. These results indicate higher aerobic capacity in *C.antarctica* that enables it to swim routinely in polar waters of Southern Ocean at comparable rates as *C.limacina* in temperate waters of Northern Atlantic[4]. However, burst capacity is completely lost in *C. antarctica*, which relies instead on whole-body withdrawal and chemical defense for predator avoidance[4]. 1. Clark. 1983. Oceanogr. Mar. Biol., Annu. Rev. 21,341-453. 2. Johnston et al. 1998. J. Exp. Biol. 201, 1-12. 3. Crockett and Sidell. 1990. Physiol. Zool. 63, 172-288. 4. Borrell et al. 2005. J. Exp. Biol. 208, 2939-2949.

29.5 EGBERT, Jeremy R.*; SCHWABL, Hubert G.; Washington State University, School of Biological Sciences, Pullman, WA; *jeremyegbert@wsu.edu*

A novel experimental test of the relationship between plasma and yolk testosterone levels in the house sparrow

One example of a maternal non-genomic effect is the accumulation of maternally-derived steroids in the yolks of avian eggs, which have been shown to affect offspring growth and competitive ability. Higher female-female competition during breeding has been shown to correlate with increased yolk androgen levels, but the mechanism of this accumulation remains unknown. Competition between females may increase follicular steroidogenesis, after which the lipophilic steroids might either diffuse into circulation and into yolk in roughly equal proportions, or steroid concentrations in circulation and yolk could be regulated independently through active processes. To examine these possible relationships, captive, laying female House Sparrows were either challenged at the nest box by a novel female or left unchallenged. Yolks from subsequently laid eggs were fixed and stained so that a sample could be obtained from the yolk layer that was being formed at the time of the treatment period and blood sampling. Females responded behaviorally to the challenge by perching near the intruder and often exhibiting aggression. Concentrations of testosterone in the plasma and yolk layer were not different between treatments, which could indicate follicular steroidogenesis was not altered by the challenge. However, yolk testosterone concentrations were significantly more variable in challenged females. This might suggest a context-dependent effect of social competition on follicular steroidogenesis and subsequent yolk androgen levels. Since testosterone concentrations in the yolk layer and plasma were not correlated with each other, their levels may be regulated independently.

S1-5.6 ELLERS, O; Bowdoin College, Maine; *oellers@gwi.net*
Flow, temperature and the speed of life
On page one of his seminal work Life in Moving Fluids Steven Vogel describes a biologist who goes forth, thermometer in hand, and measures the effects of temperature on every parameter of life , perhaps with Arrhenius abused in the process. Temperature, notes Vogel, is, after time, our favorite abscissa. But few of us measure the rate at which fluids flow, however potent the effects of winds and currents on our experimental systems. Vogel, of course, introduced a paradigm shift that started a significant expansion in the consideration of flow. In my presentation I come full circle and consider how flow and temperature alter the speed of life, abusing Arrhenius in the process. Flow alters the speed of life because it affects transport of oxygen to animals and thereby alters the scaling exponent of metabolic rate with mass. Thus, for example, lower rates of transport of oxygen to small benthic animals low in a boundary layer may cause a slowdown in growth. Generally, changes in the metabolic scaling exponent will change the time to grow to 2/3 maximum size and thus change the pace or speed of life. Temperature alters physical parameters such as viscosity, enzyme kinetics and the anabolic von Bertalanffy transport coefficient in ways that change maximum size and fractional maintenance costs. These latter two variables are, of mathematical necessity, negatively correlated in the von Bertalanffy description of growth. I present data from sea urchins confirming this negative correlation; indeed, this negative correlation has been generally found for a wide range of organisms. The Arrhenius equation can be used to minimize scatter in this negative correlation, 30% of which is due to temperature. Thus, both flow and temperature alter the pace of life for marine ectotherms.

S4-1.7 ELSER, JJ*; KYLE, M; SMITH, M; NAGY, J; Arizona State University, University of Kansas Medical School, Scottsdale Community College; *j.elser@asu.edu*
Biological stoichiometry of tumors: a test of the growth rate hypothesis using paired biopsy samples of human tumors
The growth rate hypothesis proposes that there is a mechanistic association between growth rate and biological P requirement because increased growth rates generally require increased allocation to P-rich ribosomal RNA. This hypothesis has received wide support in previous physiological, ontogenetic, and inter-specific comparisons involving diverse biota from bacteria to fruitflies. Here we extend the hypothesis to the case of human cancer, as cancer usually results from accelerated proliferation of clonal cells. We determined the elemental composition and RNA/DNA contents of paired tumor and normal tissues for four organs (colon/rectum, liver, kidney, pancreas) using samples obtained via the NIH tumor tissue procurement network. Consistent with the growth rate hypothesis, tumor tissues had significantly higher P contents (% of dry weight) than paired normal tissues. RNA and DNA contents were also generally higher for tumor tissues and there were significant associations of P content with RNA content and with total nucleic acid content. However, the absolute magnitude of the contribution of P in RNA to overall P content (~10%) was relatively low compared to previous studies (~50%). This suggests that either our RNA determination method underestimates tumor RNA or that there is another pool of P-rich molecules at increased allocation in tumor cells. Our results suggest that tumor cells may be poor competitors for circulating P in the body and may be at a disadvantage, relative to normal tissues, if P supplies are limiting.

14.2 EME, John*; GWALTHNEY, June; OWERKOWICZ, Tomasz; BLANK, Jason/M; HICKS, James/W; University of California, Irvine; *jeme@uci.edu*
Growth, Metabolism and Exercise Endurance of American Alligator (Alligator mississippiensis) with and without Cardiac Shunt
All non-avian reptiles are capable of cardiac shunting, and crocodilians have two completely separate ventricles, allowing for only a right-to-left (R-L) shunt. This unique reptilian design allows for surgical removal of the ability to R-L shunt and inference of physiological function in its absence. Cardiac shunting is generally considered to have adaptive importance, however, without experimental evidence of reduced fitness, adaptive significance cannot be assumed *a priori*. We surgically removed the ability for R-L shunting in hatchling American alligator (5-months old; January-February 2006). We show that distal occlusion of the left aortic arch (LAo) is insufficient to eliminate shunting completely. It is also necessary to tie off the LAo proximally, at the ventricular base of the LAo and Right aortic arch below the foramen of Panizza. We are measuring body mass and snout-vent, total and head lengths of surgically modified (experimental'), sham, and control animals of similar age (N = 36, each group) every two weeks. Each group is further divided into 3 exercise sub-groups (N = 12, each sub-group): run, swim, and sedentary. Animals in the run and swim groups are exercised to exhaustion every other day on a treadmill or in a swim flume, respectively. Preliminary growth trajectories (i.e., slope) appear to be diverging between groups; however, exercise endurance does not differ between sub-groups. In addition, measurements of SMR, VO2max, specific dynamic action, and exercise endurance (swimming and running) will be presented. (This work is supported by NSF Grant IOB 0445680 to JWH)

S7-1.4.1 ENOKA, R.M.*; BARRY, B.K.; University of Colorado, Boulder; *enoka@colorado.edu*
The Neurobiology of Muscle Fatigue: 15 Years Later
Fifteen years ago, Stuart and Enoka published a review paper (J Appl Physiol 72: 1631-1648, 1992) on the neurobiology of muscle fatigue. The review emphasized that fatigue could be caused by a number of physiological impairments and that the dominant mechanism depended on the details of the task; that is, fatigue is not caused by any single mechanism. In hindsight, this principle of task dependency has resulted in the demise of attempts to answer the question, what causes muscle fatigue? However, the field has recently been energized by a similar, but sufficiently different, question: what causes task failure? The strategy has been to compare two fatiguing contractions and to identify the mechanisms responsible for the difference in the time to task failure. For example, when subjects exert the same net muscle torque with limb muscles and the task is either to sustain a submaximal torque (force task) or to maintain a particular joint angle (position task) for as long as possible, the time to task failure can be twice as long for the force task. The briefer duration for the position task is associated with a more rapid recruitment of the motor unit pool, despite the two tasks requiring each subject to exert the same net muscle torque and there being no difference in the amount of coactivation of the antagonists. The difference in the time to failure for the two tasks, however, is not constant and varies across muscles and with limb position. The influence of limb position underscores the significance of postural activity and the reflex pathways between muscles that are synergistic for one action but antagonistic for another. The task-failure approach affords new opportunities to examine the neurobiology of muscle fatigue in functionally relevant contexts. Supported by NINDS NS043275.

16.4 ERWIN, P. M.*; THACKER, R. W.; University of Alabama at Birmingham; *erwin@uab.edu*

Host-Specificity of Sponge-Associated Unicellular Cyanobacteria, Candidatus Synechococcus spongiarum

Tropical and temperature marine sponges worldwide commonly associate with a unique lineage of symbiotic, unicellular cyanobacteria in the genus *Synechococcus*. These symbionts may benefit their host sponges through the provision of fixed carbon, the production of chemical defenses, and protection from UV radiation. Previous molecular analyses of these symbionts using 16S ribosomal RNA (rRNA) gene sequences suggested a generalist host-symbiont association with little genetic differentiation, despite evidence for vertical transmission. To further investigate the genetic diversity and host-specificity of these symbionts, we characterized partial 16S rRNA and entire internal transcribed spacer (ITS) rRNA gene sequences from cyanobacterial symbionts of 32 sponge individuals, representing 18 species from Caribbean, North Atlantic, Pacific, and Mediterranean reefs. ITS sequence data exhibited 4 to 5 times the variability of 16S sequence data and resulted in a well-resolved phylogenetic tree that revealed 12 distinct symbiont clades defined by reciprocal monophyly and >5% sequence divergence among sister clades. Most symbiont clades displayed a high degree of host-specificity at the genus and species level; however, some clades were associated with taxonomically distant but sympatric host species. In several host species, multiple symbiont clades were identified from a single individual. Our results show the phylogenetic utility of ITS rRNA sequence data in resolving the fine-scale relationships and host-specificity of sponge-associated cyanobacteria. Genetic differentiation of symbiont clades may be correlated with variable physiological capabilities and environmental preferences of the symbionts, and thus variable benefits to their host sponges.

51.1 ESTES, Anne M. *; BRONSTEIN, Judith L.; PIERSON, Elizabeth A.; Univ. of Arizona; *amestes@u.arizona.edu*

Life in a fly: Exploring a variable endosymbiont environment

Our understanding of insect-bacterial symbioses stems from systems in which the endosymbiont experiences low variability in morphological and nutritional host environment. Holometabolous insect hosts that are both morphologically and nutritionally variable are understudied. Bacterial symbionts associated with variable endosymbiont environments may be more metabolically plastic than their endosymbiotic relatives in less variable host environments. We describe the symbiosis between the tephritid olive fly, *Bactrocera oleae*, and two enteric bacteria, *Erwinia dacicola* and *Pantoea sp.* The olive fly host undergoes both complete metamorphosis and a diet shift. As the fly switches from feeding on olives as larvae to nectar-feeding as adults, the bacteria may encounter a different set of nutrients and microhabitats. These bacteria are consistently associated with olive flies from climatically distinct sites across California and one site in Arizona. In the 356 individuals screened, 95% of the females and 90% of the males were infected with both bacteria. No olive fly individuals were found with only *E. dacicola*. Instead, 6.3% of animals had neither bacteria and 1.7% of animals had *Pantoea sp.* only. Both bacteria are found in all life stages of the fly. To determine the location of bacteria relative to host cells of the digestive systems, transmission electron microscopy was performed on both larval mycetocytes and adult oesophageal bulbs. Bacteria in the larval mycetocytes are intracellular, whereas the bacterial community is extracellular in the adult oesophageal bulbs. This work establishes that the two symbionts, *E. dacicola* and *Pantoea sp.*, are consistently associated with naturalized populations of *B. oleae* in the U.S., and begins to examine changes in these endosymbionts during host development.

45.4 ESTRADA, C.**; JIGGINS, C.D.; GILBERT, L.E.; Univ. of Texas, Austin, Univ. of Edinburgh, Univ. of Texas, Austin; *estradac@mail.utexas.edu*

Sexual Behavior, Intraspecific Signaling and the Evolution of Mimicry among Closely Related Species

Species that enjoy some measure of protection from predators due to their aggressive behavior or toxicity often exhibit warning colorations. When such aposematic color patterns are also used in intraspecific recognition, there is a possibility of signaling conflict if different species converge in color pattern due to mimicry. Despise the considerable amount of work on the origin and persistence of mimicry, very little is known about the constraints that such conflicts might impose on recognition and communication among mimetic species. Butterflies primarily use visual cues in mate location and recognition, and are a good model system to study such signaling conflicts. Differences in wing color patterns often keep closely related species reproductively isolated. At the same time, these color patterns are also used for protection as warning signals against predators. Using *Heliconius* butterflies (Nymphalidae: Heliconiinae) we examine levels of communication conflicts, and mechanisms that provide alternative mate recognition cues that reduce the potential of such conflicts between co-mimic species. We present results about the extent of interspecific attraction between two mimetic species *H. erato* and *H. melpomene*, which exhibit a series of pairs of geographic races that have converged in color pattern and habitat use in almost every locality across their range in Central and South America. We also discuss how larval diet specialization affects the the mating system in these butterflies, mitigating communication conflicts, and facilitating the evolution of mimicry among closely related species.

11.5 EVANS, A.N.*; IP, Y.K.; NUNEZ, B.S.; University of Texas Marine Science Institute, National University of Singapore; *aevans@utmsi.utexas.edu*

Regulation of interrenal steroidogenic mRNAs in the elasmobranchs Dasyatis sabina and Potamotrygon motoro

The steroidogenic acute regulatory protein (StAR) is critical for the production of steroid hormones, delivering cholesterol to the rate-limiting steroidogenic enzyme, cholesterol side-chain cleavage (SCC); the production of both sex steroids and corticosteroids requires further conversion by 3β-hydroxysteroid dehydrogenase (3β-HSD). Regulation of the genes encoding these enzymes in steroidogenic tissues is therefore necessary for the timely production of steroids required for vital physiological processes. We examined the regulation of StAR, SCC and 3β-HSD mRNA in the freshwater stingray *P. motoro* and euryhaline stingray *D. sabina* using quantitative PCR. To examine the effects of environmental salinity on mRNAs encoding these primary steroidogenic enzymes, freshwater *P. motoro* were challenged with 10 ppt salinity for one week. We then determined levels of interrenal gland StAR, SCC and 3β-HSD mRNAs. There was no significant difference in the relative levels of interrenal steroidogenic mRNAs in control vs. experimental animals; however lack of statistical significance was due to high levels of StAR and SCC mRNA in a single 10 ppt individual. Relative basal levels of StAR and SCC mRNA expression were determined in interrenal glands taken from freshwater and saltwater *D. sabina*. In addition, the *in vitro* regulation of StAR and SCC mRNAs by hormones involved in osmoregulation (angiotensin II and C-type natriuretic peptide) and stress (adrenocorticotropic hormone and 1α-hydroxycorticosterone) was investigated in *D. sabina* steroidogenic tissues. Future research will examine the role of interrenal steroidogenesis in the acclimation of *D. sabina* to fresh water.

S6-1.4 EXTAVOUR, Cassandra G M; University of Cambridge; *cgme2@hermes.cam.ac.uk*

Urbilaterian Reproduction: the evolution of metazoan germ cell specification mechanisms

A key focus of evolutionary developmental biology in recent years has been to elucidate the evolution of developmental mechanisms as a means to reconstructing hypothetical last common ancestors of various sister clades. Promiment among such reconstructions have been proposals as to the mythical "Urbilaterian", defined as the last common ancestor of the extant Biltaeria. Drawings of this animal now exist in many textbooks, including detailed information on the genetics and morphological processes that it used to construct its gut, heart, eyes, appendages, segments, and body region identities. Perhaps surprisingly, however, no explanations have been offered as to how this animal might have achieved the successful reproduction that must have been necessary for it to give rise to the lineages ancestral to today's diverse clades. I will examine the comparative data available to date on the specification of reproductive systems during development, with special emphasis on the cells containing the genetic hereditary material, the germ cells, and suggest a gonad structure and reproductive strategy for "Urbilateria".

14.3 FARMER, CG; URIONA, TJ*; STEENBLINK, M; OLSEN, D; SANDERS, K; Univ. of Utah, Salt Lake City, Utah Artificial Heart Institute, Salt Lake City, Health Sciences Center, Salt Lake City; *uriona@biology.utah.edu*

The value of the crocodilian left aorta to digestion

The crocodilian circulatory system has intrigued biologists for over 160 years but the functional significance of their four-chambered heart, which separates venous and arterial blood, and the retention of dual aortic arches, which enables venous blood to be shunted around the lungs, remains a mystery. This anatomy is widely believed to be adaptive, in part because of the control crocodilians have over blood flow through the left aorta. Crocodilians are the only vertebrate known to have an active internal heart valve that controls flow through the left aorta. Although many hypotheses have been put forward about the importance of this system to the wellbeing of the animals, they remain untested. Here we show the left aorta serves digestion by enabling venous blood to be sent to the stomach. In a group of juvenile American alligators we surgically removed the left aorta, resulting in a circulatory system that mimics that found birds and mammals, while another group underwent surgery without removal of the left aorta. Removal of the left aorta significantly slowed the rate of gastric acid secretion and rates of digestion of bone. Rapid rates of acid secretion may be particularly important to ectothermic reptiles because gastric acid secretion is highly sensitive to body temperature, yet competition for basking sites can limit the time small, lesser status animals can achieve their preferred body temperature and thus effectively secrete acid. In contrast, the warm and stable body temperatures of birds and mammals allow acid to be continuously secreted as necessary, albeit at a lower rate, eliminating the need for a conduit of venous blood to the stomach. Thus the retention of the dual aortic arches in crocodilians for digestive purposes does not support the hypothesis of an endothermic crocodilian ancestry.

25.2 FARKE, A.A.; Stony Brook University, New York; *afarke@ic.sunysb.edu*

Finite element modeling of head butting in the goat (Capra hircus)

Although cranial sinuses are often perceived to be functionless spaces within the skull, the locations and sizes of these sinuses may have important functional consequences. For example, large sinuses may reduce overall skull mass, weaken the skull, and change the path by which forces are transmitted through the skull. It has been proposed that the frontal sinuses of sheep and goats, animals that engage in sometimes quite forceful head butting, protect the brain by acting as shock absorbers. Under this scenario, it is predicted that the sinuses reduce the strain and strain energy density inside the braincase, among other effects. In order to test this hypothesis, two 3D models of the skull of the domesticated goat (*Capra hircus*) were created from CT scans. One model had a completely solid frontal, and the other had a space in the frontal representing the frontal sinus. Using finite element analysis, the models were loaded statically on the anterior surface of the horns, to simulate the forces of head butting. In general, the model with sinuses had higher magnitudes of strain than the model without sinuses. This is not surprising, given that the former has less bone to absorb and distribute forces than the latter. Additionally, the model with sinuses had higher magnitudes of both strain and strain energy density on the endocranial surface of the braincase; this counters the proposals that the sinuses function as shock absorbers. Alternative functions currently are being explored. Perhaps the inflated frontal bone of sheep and goats (contrasting with the relatively thin frontals in many other horned animals) protects the brain by separating it spatially from the horncores without causing a detrimental increase of strain in the walls of the endocranium.

65.1 FARMER, CG; Utah Artificial Heart Institute; *farmer@biology.utah.edu*

Unidirectional flow in the lungs of archosaurs

"A satisfactory answer has not been found to the question of the benefit of unidirectional air flow in bird lungs" (Meyer et al., 1981). Studies on pulmonary air flow of the sister group to birds, crocodilians, may provide insight into this question. American alligators have two very cavernous sac-like lobes of the lung immediately dorsal to the heart and great vessels. These lobes physically adhere to the pericardium. With each beat of the heart a mechanical tugging on these lobes occurs, which could agitate the lungs and the gases contained therein. This morphology, along with the striking similarity between the spiraling tapered tubes of the crocodilian lung with the dorso- and ventrobronchi of bird lungs, has lead me to investigate the possibility that unidirectional cardiogenic flow exists in crocodilians. Measurements of gas movements within the lungs have been made using hot bead anemometers both during apnea and during ventilation. During apnea, a small unidirectional pulse of air moves in the lung coincident with each heartbeat. Unidirectional flow also appears to occur during ventilation. The presence of unidirectional flow in the lungs of crocodilians indicates that the most parsimonious scenario for the evolution of this trait is that unidirectional flow arose long before the evolution of Aves in the common ancestor to birds and crocodilians. This common ancestor was in many respects more akin to extant crocodilians than to birds. For example these animals were terrestrial quadrupeds. Thus unidirectional flow in these animals could not have been an adaptation for flight. This ancestral stock probably had an ectothermic physiology and an intermittent pattern of breathing. Unidirectional flow may therefore have arisen in this lineage to take advantage of mixing of lung gases during apnea that can occur with the beating heart.

19.2 FERRER, R. P.*; ZIMMER, R. K.; University of California, Los Angeles; *rferrer@ucla.edu*

The consequences of olfaction for predation in a natural stream habitat

Despite significant advances in understanding the olfactory basis for predatory behavior in laboratory environments, little is known about the sense of smell in natural aquatic habitats. The California newt (*Taricha torosa*) inhabits mountain streams and feeds on, primarily, insects and other invertebrates. Here, we investigated the role of olfaction in determining newt foraging success. Time/activity budgets were established for individuals as they moved undisturbed in natural stream pools. Newts foraged selectively, emphasizing search for prey in leaf litter, as opposed to cobble or sand. Notably, leaf litter harbored significantly higher densities of potential invertebrate prey. To explore the role of olfaction in prey selection, newts were captured by hand, stomach contents flushed completely, noses blocked non-destructively with an inert silicon gel, and animals tagged and released. As a control, newts were treated identically, except that gel was placed on the forehead prior to tag and release. After 48 h, treatment and control animals were re-captured and their stomach contents flushed and examined. Newts with blocked noses consumed significantly less prey than their control counterparts. In fact, treatment animals hardly ate at all (mean of

70.1 FERRY-GRAHAM, L.A.*; GIBB, A.C.; Calif. State Univ./Moss Landing Marine Labs, Northern Arizona Univ.; *lfgraham@mlml.calstate.edu*

Cyprinodont premaxillary protrusion and prey capture: does mechanism dictate behavior?

Premaxilla protrusion is thought to confer a number of feeding advantages in teleost fishes. Cyprinodontiformes (Atheriniformes, Acanthopterygii) exhibit protrusion where the descending process of the premaxilla does not rotate anteriorly to occlude the sides of the open mouth during prey capture. Previous kinematic study of Gambusia (Poecilidae: Cyprinodontiformes) revealed that the premaxilla retracts fully prior to jaw closure and thus does not serve to reduce the distance between the upper and lower jaws, as is seen in most fish with jaw protrusion. We hypothesized that this is a functional consequence of the immobile descending process and/or the manner in which momentum is transferred to the premaxilla. We examined multiple cyprinodont taxa to assess variation in the mobility of the descending process, identify potential mechanisms that transfer momentum to the premaxilla, and determine the functional consequences of variation (e.g., contribution of the premaxilla to jaw closing). Individuals ($N \geq 4$) of each species were imaged at 250-500 fps during prey capture to quantify cephalic movements, and cleared and stained specimens were used for morphological analysis. Cyprinodont species differed in the contribution of the premaxilla to jaw closure, although there was no difference in the mobility of the descending process of the premaxilla or in the apparent mechanism of momentum transfer. Therefore, the underlying mechanism does not prevent the premaxilla from contributing to mouth closure. Further, it appears an individual can alter the contribution of the premaxilla to mouth closure on an event-specific basis. This may reflect a foraging ecology where prey items are sucked or picked from the substrate, water column, or surface. This flexibility is unusual, as most teleosts employ a stereotyped movement of the premaxilla for suction feeding.

49.5 FIELMAN, K.T.*; HOFMANN, G.E.; Auburn Univ., UC, Santa Barbara; *fielman@lifesci.ucsb.edu*

Genome-Enabled Insight into Biogeographic Patterns of Marine Larval Thermotolerance

The role of larval thermotolerance in setting marine species' biogeographic distribution and abundance patterns is unclear and little is known of the underlying genomic-scale molecular physiology. We compared heat shock survivorship among plutei raised at 6C from cold-adapted white (*S. pallidus*) and green (*S. droebachiensis*) urchins with their more eurythermal red (*S. franciscanus*) and purple (*S. purpuratus*) congeners raised at 15C. White/green larvae had 100% mortality at 23C versus 26C for red/purples, consistent with the rank order of adult habitat and larval rearing temperatures. However, white/green larvae tolerated a greater relative increase (16C) versus the red/purples (10C). Notably, this difference contrasts with the current average habitat temperatures and biogeographic distribution patterns of each species, suggesting that simple predictions of response to change from existing biogeographical information may not be possible without further physiological information. Comparative molecular insight into the species' distinct responses was obtained by transcriptional profiling. Expression patterns were evaluated in purple and green urchins at 0, 5, and 10C above the larval rearing temperatures using macroarrays of >100,000 larval sequences. Species-specific differences were especially evident within the core processes of ribosomal assembly and protein synthesis. Strong up regulation of these genes was observed for purples, whereas a weaker induction or strong down regulation was typical for greens. Similarly, strong down regulation of 18S and 28S ribosomal RNAs in purples contrasted with moderate up regulation in greens. Thus, differences in the transcriptional response to thermal stress may ultimately underlie the distinct thermotolerance and distribution patterns among congeners.

50.5 FILORAMO, N.I.; SCHWENK, K.**; Univ. of Connecticut, Storrs; *kurt.schwenk@uconn.edu*

Hydraulic Delivery of Chemicals to the Vomeronasal Organs in Squamate Reptiles: A Comparative Morphological Study

Despite growing evidence for the importance of vomeronasal chemoreception in the sociobiology of lizards and snakes, the biomechanics of this process are poorly understood. Vomeronasal chemoreception can be divided into three mechanical tasks: retrieval (transfer of environmental chemicals to the tongue tips); stage 1 delivery (delivery of chemicals into the oral cavity near to the vomeronasal fenestrae); stage 2 delivery (delivery of chemicals into the vomeronasal organs). Retrieval occurs through diffusion of scent molecules into the fluid covering the tongue tips. Stage 2 delivery is caused by suction generated within the VNOs. The prevailing theory of stage 1 delivery is based on snakes. It suggests that the forked tongue tips are wiped against sublingual plicae on the floor of the mouth as the tongue is retracted; the plicae are then elevated against the palate and the vomeronasal fenestrae. Snakes are highly derived compared to most lizards in having reduced, narrow, forked tongues that are retractile within a sheath and modified, pronounced sublingual plicae, making the generality of this theory questionable. In most lizards the tongue is not forked, is non-retractile and the sublingual plicae are unmodified or weakly developed. We show that there is complementarity of upper and lower mouth surfaces reflecting the shape of the foretongue. At closure, palatal glands and sublingual plicae are apposed, sealing the tongue within a snug-fitting chamber. We suggest that chemical-laden fluids on the tongue tip surfaces are transported instantaneously, either through compression or capillarity, to the vomeronasal fenestrae. Elevation and compression of sublingual glands might express fluid dorsad, flushing the tongue tips and aiding this process.

58.2 FINKLER, M.S.; Indiana Univ., Kokomo; *mfinkler@iuk.edu*
Differences in organ mass and hematology between male and female Spotted Salamanders (Ambystoma maculatum) during the reproductive season.
Spotted salamanders display pronounced sexual dimorphisms in body size, metabolism, migratory behavior, and whole-animal performance during the reproductive season. Here, I investigated potential differences in heart, liver, gonad, and reproductive duct mass, as well as potential differences in RBC counts, Hct, and total [Hb] between males and females before and after reproduction. Females had larger hearts than males but smaller livers. Moreover, female wet liver mass was lower after reproduction than before. Pre-reproductive ovary mass was 11.7x greater than pre-reproductive testes mass, but post-reproductive ovary mass was only 2.4x that of post-reproductive testes mass. Oviduct mass was 3.9x greater before reproduction than after, whereas mesonephric duct mass was 2.6x greater before reproduction compared to after. Although pre-reproductive males and females had similar RBC counts, post-reproductive females had lower RBC counts. Both Hct and [Hb] were higher in males than in females, and both were lower after reproduction than before reproduction in females. These findings suggest that the degree of reproductive organ proliferation is greater in females than in males. Moreover, post-reproductive decreases in liver mass and hematological parameters observed in females suggest that physiological costs of reproduction (e.g., stored energy reserves, aerobic capacity, etc.) may be greater in females than in males. Such costs may underlie behavioral, demographic, and morphological dimorphisms in Ambystomatids.

50.8 FISH, F.E.*; BOSTIC, S.A.; NICASTRO, A.J.; BENESKI, J.T.; West Chester University; *ffish@wcupa.edu*
Death roll of the alligator: mechanics of a new twist on an old spin
Crocodilians, including the alligator (*Alligator mississippiensis*), perform a spinning maneuver to subdue and dismember prey. The spinning maneuver, which is referred to as the death roll , involves rapid rotation about the longitudinal axis of the body. High-speed videos were taken of juvenile alligators (mean length=0.29 m) performing death rolls in water after biting onto a pliable target. Spinning was initiated after the fore- and hind limbs were appressed against the body and the head and tail were canted to the longitudinal body axis. With respect to the body axis, the head and tail were bent at 49.2º and 103.3º, respectively. The head, body and tail rotated smoothly and freely around their individual axes of symmetry at 1.6 Hz. In order to visualize, test and evaluate variation in individual components of the death roll sequence, we constructed and animated a 3-D model. The simulated death roll allowed us to alter viewing angles and kinematic parameters to match those observed and measured in recorded sequences as well as isolate individual parameters for further testing. To understand the dynamics of the death roll, we mathematically modeled the system. The maneuver results purely from conservation of angular momentum and is explained as a zero angular turn. The model permits the calculation of relevant dynamical parameters. From the model, the shear force, which was generated at the snout by the juvenile alligators, was 0.012 N. Shear force was calculated to scale with body length to the 4.2 power. When scaled up to a 3 m alligator, shear force was calculated at 134 N. The death roll augments the limitations of the feeding morphology of the alligator. Shear forces generated by the spinning maneuver increase disproportional with alligator size, allowing dismemberment of large prey.

S10.3 FISH, F.E.; West Chester University; *ffish@wcupa.edu*
The topic of Biomechanics - Why is this a good first topic for SICBDL and how are new topics brought in?
As a model for the future development of topics to be included in the SICB Digital Library, biomechanics was chosen. Biomechanics looks at the ways organisms deal with mechanical matters. The topic includes analysis of internal and external forces, structural systems, growth, and movement. Biomechanics thus integrates biology with physics and engineering. Biomechanics is an interdisciplinary topic with considerable current activity. Although the topic has wide appeal, there has not been the development of a comprehensive educational resource on this topic. A biomechanics website was developed (http://www.sicb.org/dl/biomechanics.php3) that includes laboratories, sample problems, and bibliography. Sample experiments that can introduced in student laboratories will be presented in this session, including allometry of bones, effect of wing geometry on flight characteristics, force production during burrowing, mechanics of fracture, and mechanics of domes and eggs. New topics will be integrated into the SICBDL that are not repeated by other organizations, and provide educational opportunities in new and emerging fields. These topics should be integrative and comparative across taxonomic and organizational levels.

41.4 FISLER, Shara; Aquatic Adventures Science Education Foundation; *sharafisler@aquaticadventures.org*
Sea the Future of Science: Increasing Diversity through Cross Sector Collaboration
The lack of diversity in the scientific community has led to a call to action within government, academic institutions, and industry. In response to this need, a team of marine educators and researchers established the BAHÍA program, aimed at creating a model for systemic change. Through this program youth explore career opportunities in marine science fields, build their knowledge of the sciences and their own capabilities, become better prepared to attend college, and participate in a continuum of support that allow further study and exploration of the sciences. A focal point of the project brings students to a unique ecological preserve in Baja California, where they make meaningful contributions to authentic scientific research. The preliminary results demonstrate a diverse range of benefits including personal and academic growth of underserved youth, as well as important short and long term results for the scientific community.

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

Speed-dependent intrinsic caudal fin muscle recruitment during steady swimming in bluegill sunfish

There are 56 muscles that control modulation of the tail fin in teleost fishes. Although much research has been conducted on the fluid dynamic properties of the caudal fin in fishes, little work has been done on the intrinsic musculature that controls and shapes the fin. Five bluegill sunfish (*Lepomis macrochirus*) were anaesthetized and electrode wires were surgically placed into intrinsic caudal muscles, up to 13 at a time. A total of 24 intrinsic muscles were studied, and activity was correlated with synchronous recordings from myotomal fibers in the caudal peduncle. After recovery, fish swam at steady speeds of 0.5, 1.2, and 2.0 L s^{-1}, while filmed from lateral, posterior, and ventral views simultaneously at 250 frames s^{-1}. Video sequences of tail beats were digitized in 3-dimensions to quantify fin conformation. Caudal fin position was then compared to muscle activity recorded by electromyography (EMG) in order to determine the role of intrinsic caudal musculature. Comparison among speeds, as well as continuous EMG while increasing swimming speed, confirmed that muscle recruitment varies significantly with speed. At 0.5 L s^{-1}, the caudal fin was generally not used for propulsion, and swimming was accomplished primarily through body undulations. With increasing swimming speed, relative timing of muscle activity within each tail beat did not change; however, the number of muscles being used increased, as did the intensity of muscle activity. Active at 1.2 L s^{-1}, the supracarinalis and infracarinalis muscles acted on the dorsal- and ventral-most fin rays, respectively, to expand the surface area of the caudal fin. The interradialis muscles adducted individual fin rays and propagated a wave ventrally along the edge of the caudal fin, following activation of the hypochordal longitudinalis.

2.5 FOX, B.K.*; RILEY, L.G.; PIERCE, A.L.; HIRANO, T.; GRAU, E.G.; University of Hawaii, Manoa; *kaifox@hotmail.com*

Effects of fasting on growth hormone/insulin-like growth factor I axis in the tilapia, Oreochromis mossambicus

Effects of fasting on the growth hormone/insulin-like growth factor I (GH/IGF-I) axis were examined in Mozambique tilapia acclimated to fresh water (FW) or seawater (SW). Fasting of FW tilapia for 2 weeks water produced significant reductions in body weight and in specific growth rate. Fasting of FW fish also significantly reduced plasma IGF-I, but had no effect on plasma GH or glucose. In SW fish, fasting for 4 weeks also significantly reduced body weight and specific growth rate. Plasma GH and pituitary GH mRNA levels were significantly elevated in fasted fish, while plasma glucose, IGF-I and hepatic IGF-I mRNA levels were significantly reduced. Plasma GH and IGF-I were significantly and negatively correlated in fasted SW fish. Fasting was without effect on hepatic GH receptor (GHR) mRNA levels in SW fish. The fact that fasting elicited increases in GH and decreases in IGF-I production without affecting GHR expression suggests a possible development of GH resistance in SW tilapia. These results suggest potentially disparate responses in the GH/IGF-I/GHR system during fasting between FW and SW-acclimated tilapia. Inasmuch as GH plays important roles in SW acclimation in the tilapia, fasting may affect the GH/IGF-I axis in SW tilapia more profoundly than in FW fish. We have recently identified the second GHR (GHR-2) in the tilapia. The effects of fasting and re-feeding on expression of the two GHRs will also be presented. Supported by grants from NSF (IOB 04-17250 and 05-17769).

S1-4.6 FOX, J.L.*; MYHRVOLD, C.A.; DANIEL, T.L.; University of Washington; *jessfox@u.washington.edu*

Sensory Encoding in the Gyroscopic Halteres of the Crane Fly Holorusia

Insect flight requires coordination of many sensory and motor circuits over several time scales. Since muscle activity must often be modulated at a rate faster than can be achieved by visual circuits, rapid mechanoreception is crucial. The most conspicuous examples of specialized mechanosensory organs are the halteres of Dipteran insects. Derived from hindwings, halteres are densely packed with mechanoreceptive sensillae at their bases and are known to act as gyroscopes in flight, during which they oscillate at the same frequency as the wings (approximately 28 Hz). Despite a long history of analysis of halteres and their importance as mechanoreceptors, the encoding properties of their afferent neurons have not been examined. To determine the sensory capabilities of these gyroscopic organs, we performed intracellular recordings of axons in the haltere nerve of the crane fly (*Holorusia rubiginosa*) while stimulating the haltere in a biologically relevant manner. We used high-speed videography of crane flies in free flight to examine the natural motions of the haltere and based our stimulus parameters on the angles and frequencies observed. We found that the haltere nerve contains neurons that can encode stimuli up to at least twice the natural frequency. Because the haltere neurons can encode oscillations at twice the wingbeat frequency, they have the capacity to capture and transmit information about Coriolis forces that occur during simultaneous oscillation and rotation of the haltere during flight. This capability of the haltere neurons indicates that they are an important component of Dipteran flight control. Our recording techniques, combined with our data about the natural motion of halteres during flight, will allow us to further examine the details of their function as gyroscopic mechanoreceptors.

32.5 FRANK, T.M.; Harbor Branch Oceanographic Institution, Ft. Pierce, FL; *frank@hboi.edu*

Are there physiological differences between the photoreceptors of juvenile and adult ontogenetic migrators?

For all visually competent organisms, the driving force behind the adaptation of photoreceptors involves obtaining the best balance of resolution to sensitivity in the prevailing light regime, as in increase in sensitivity often results in a decrease in resolution. In the aquatic environment, obtaining this balance may be quite difficult for species that under ontogenetic migrations, as they live at shallower depths with relatively bright light as juveniles, and migrate to deeper darker waters as adults. Metamorphosis from the larval stage to the post-larvae (juvenile) is clearly the opportune time for the photoreceptor to undergo dramatic changes in both structure and visual pigment complement to adapt to different light environments. However, a number of crustaceans have juvenile stages that are found up to 500 meters shallower than the deep living adults, and very little is known about how these two life history stages deal with these substantially different light environments. Data will be presented on two life history stages of the ontogenetically migrating lophogastrid *Gnathophausia ingens*. Live, visually competent juveniles (175-250 m) and deep-living adult stages (650-750 m) were collected with an opening/closing Tucker Trawl fitted with a closing cod-end. Recordings of the electroretinogram (ERG) were utilized to determine the spectral sensitivity of the juveniles, as well as the temporal dynamics of the photoreceptors in both life history stages. Results indicate that juveniles have slightly greater short wavelength sensitivity than adults, but the only differences in temporal dynamics appear to be related to the warmer temperatures occupied by the shallower living juveniles. Supported by NSF Grant #IBN-0343871.

21.6 FRAZIER, M.R.**; HUEY, R.B.; BERRIGAN, D.; Univ. of Washington, Seattle; *mfrazier@u.washington.edu*

Hotter is Better: Thermodynamics Constrains the Evolution of Insect Population Growth Rates

Biochemical and physiological adaptations enable diverse ectotherms to survive and reproduce in very different temperature regimes, but whether these adaptations fully compensate for the thermodynamically depressing effects of low temperature on rates of biological processes is debated. If such adaptations are fully compensatory, then temperature-dependent processes (e.g., digestion rate, population growth rate) of cold-adapted species will match those of warm-adapted species when each is measured at its own optimal temperature. Here we show that cold-adapted insect species have much lower maximum rates of population growth than do warm-adapted species, even when we control for phylogenetic relatedness. This pattern also holds when we use a structural-equation model with phylogenetically independent contrasts to analyze alternative hypotheses that might explain this correlation. Thus, although physiological adaptations enable some insects to survive and reproduce at low temperatures, these adaptations do not overcome the tyranny of thermodynamics, at least for rates of population increase. Indeed, the sensitivity of population growth rates of insects to temperature is even greater than predicted by a recent thermodynamic model. Our findings suggest that adaptation to temperature inevitably alters the population dynamics of insects. This result has broad evolutionary and ecological consequences.

S2-2.1 FREITAS, R; ZHANG, G; COHN, MJ*; Department of Zoology and The University of Florida Genetics Institute, Gainesville, USA; *cohn@zoo.ufl.edu*

The Origin of Vertebrate Fin Development

The origin of paired appendages was a major evolutionary innovation for vertebrates, marking the first step towards fin- (and later limb-) driven locomotion. The earliest vertebrate fossils lack paired fins but have well-developed median fins, suggesting that the mechanisms of fin development were assembled first in the midline. We have found that shark median fin development involves the same genetic programs that operate in paired appendages, although median fins arise predominantly from somitic (paraxial) mesoderm, whereas paired appendages develop from lateral plate mesoderm. Despite their different embryonic origins, paired and median fins utilize a common suite of developmental mechanisms to specify fin position, number and morphological pattern. By extending our analysis to lampreys, we show that the molecular mechanisms for fin development originated in somitic mesoderm of early vertebrates, prior to the origin of paired fins. The origin of paired appendages was associated with re-deployment of these mechanisms to lateral plate mesoderm.

29.6 FRENCH, S. S.*; MCLEMORE, R.; VERNON, B.; JOHNSTON, G.I.H.; MOORE, M.C.; Arizona State University; *ssfrench@asu.edu*

Corticosterone modulation of reproductive and immune systems trade-offs in female tree lizards: Long-term corticosterone manipulations via injectable gelling material

Physiological trade-offs may arise because multiple costly processes compete for the same limiting resources. While direct competition for resources has been demonstrated between reproduction and immune function, the regulation of this competition remains unclear. Corticosterone (CORT) is a likely mediator due to both its role in mobilizing energy stores throughout the body and regulating physiological responses to stressors. We therefore manipulated CORT concentrations and resource availability in pre-reproductive and reproductive female tree lizards (*Urosaurus ornatus*) to test the hypothesis that CORT regulates the distribution of limiting resources between the reproductive and immune systems. To manipulate circulating concentrations of CORT we utilized a novel method of hormone implantation. The polymeric compound was injected in liquid form and was allowed to gel *in situ* providing a slow release delivery device where the hormone-treated animals had plasma CORT concentrations comparable to high physiological concentrations. This method of hormone delivery eliminated the application of additional wounds to the animal or repeated handling required by other methods. We found that CORT treatment suppressed immune function, but only when animals were energetically compromised. Specifically, wound healing was suppressed in all CORT-treated reproductive animals and in all CORT-treated animals (pre-reproductive and reproductive) undergoing food restriction. The context-dependent action of CORT renders it adjustable to changing environmental conditions and may allow for the strategic suppression of specific functions depending on resource availability.

S4-1.6 FROST, P.C.*; EBERT, D.; SMITH, V.H.; Trent University, Canada, Universität Basel, Switzerland, University of Kansas, USA; *paulfrost@trentu.ca*

Ecological stoichiometry of host-parasite interactions: effects of elemental food quality on host responses to infectious disease

The life-history of host organisms can be significantly altered by both their nutrition and by infectious disease. For example, life history characteristics of a freshwater crustacean, *Daphnia magna*, responds strongly to elemental food quality and to infection by the spore-forming bacterium, *Pasteuria ramosa*. Despite these singular effects having received considerable study, the interactive effects of infectious disease and diet quality on organismal life-history characteristics remain largely unstudied. We examined how life-history characteristics in *Daphnia magna* respond to bacterial infection in animals consuming different elemental food qualities (i.e., different P content). We provided the *Daphnia* (infected and uninfected) with high food quantity and monitored for growth rates, reproduction, and survival over 24 days of the experiment. After six days, bacterial infection had no significant effect on daphnid growth rates regardless of their dietary P. Similar to previous studies, infected *Daphnia* consuming high food quality typically produced one or two broods before losing their reproductive capabilities. On the other hand, infected *Daphnia* grown at mildly P-limiting conditions showed extended periods of reproduction or reversed bacterial-induced sterilization. Infected *Daphnia* consuming low P food showed higher mortality rates compared to uninfected controls. In contrast, no differences in mortality rates were found between infected and uninfected *Daphnia* consuming P-rich food. It thus appears that bacterially-mediated changes in key life-history characteristics (involving mortality and reproduction) of *Daphnia* that respond to elemental food quality. Ultimately, these effects of nutrition on host-parasite interactions would potentially influence the spread of infectious diseases and their role in ecosystems.

3.3 FUXJAGER, M.J.*; LOHMANN, K.J.; Univ. of North Carolina, Chapel Hill; *mattjf@email.unc.edu*

Geomagnetic Navigational Markers for Hatchling Sea Turtles: Invisible Guideposts for a Transoceanic Migration

Hatchling loggerhead sea turtles (*Caretta caretta*) from eastern Florida undergo long-distance migrations in the north Atlantic gyre, a current system that encircles the Sargasso Sea. Previous studies indicated that hatchlings exposed to regional magnetic fields that exist at crucial boundaries of the gyre (i.e., locations where turtles risk drifting off course) responded by swimming in directions that would, in each case, help turtles remain within the current system and advance along the migratory pathway. To investigate further the magnetic navigational system of loggerheads, we exposed hatchlings to several additional magnetic fields, including some that exist along the migratory route, one that exists in the center of the Sargasso Sea, and one that exists in a location north of the gyre where turtles are unlikely to go. When subjected to the fields along the migratory route, turtles responded by swimming in directions that appear likely to help them stay within the gyre current. In addition, turtles exposed to a magnetic field found in the Sargasso Sea were significantly oriented, with a mean angle toward the southwest. Turtles exposed to the field replicating one that lies north of the gyre oriented randomly. These results imply that the magnetic guidance system of hatchling loggerhead sea turtles is more complex than previously thought. Loggerhead hatchlings respond not only to fields that exist at critical boundaries of the gyre, but also to fields that exist elsewhere in the gyre and to fields that exist in at least some locations outside the main migratory pathway.

S2-2.5 GALIS, F.*; METZ, J.A.J.; Leiden University; *f.galis@biology.leidenuniv.nl*

Novelties: interactions between genetics, development and selection.

Evolutionary changes involve changes at the genotypic and phenotypic level. Changes at the genetic level lead to developmental changes at the phenotypic level and these developmental changes lead to changes in the adult phenotype. Selection acts at the level of the phenotype, this determines whether genetic changes can invade populations or not. For a full understanding of evolutionary novelties, one needs to understand the processes that leading to or constraining changes at all organizational levels and the links between the levels. Evolutionary changes of units at different levels are discussed and the complex relationship between changes of different levels. Novelties at all levels consist of A) Changes in the interaction within a unit -> novel function B) Changes in the interaction between units -> novel function A) and B) are often preceded by C) An increase in the number of units. We discuss the importance of factors that constrain evolutionary changes at different levels and that usually prevent them from happening. Particular emphasis will be on duplications and homeotic changes in vertebrates as examples and on developmental and pleiotropic constraints that result from the coordination between patterning and morphogenetic processes during early organogenesis (phylotypic stage). Subsequently we discuss factors that facilitate changes, sometimes relatively drastic ones, again using duplications and homeotic changes as examples. Special emphasis will be on what domestication, as experiments in evolution, can teach us about evolutionary novelties, in particular about the importance of a combination of directional and relaxed selection.

16.1 GANGLOFF, M. M.*; SIEFFERMAN, L. M.; HALANYCH, K. M.; Auburn University, Indiana University; *ganglmm@auburn.edu*

Cryptic biodiversity and phylogenetic patterns in the wide-ranging freshwater mussel genus Elliptio in southeastern North America.

North America possess the world's greatest diversity of freshwater mussels (Bivalvia: Unionidae and Margaritiferidae) yet nearly 70% of its ~300 species are considered to be imperiled. Freshwater mussel conservation has been hampered by a high degree of taxonomic ambiguity resulting from few morphological characters and extreme phenotypic plasticity. For example, a recent list compiled by the American Fisheries Society recognized 36 taxa within *Elliptio*, making it the most species-rich unionid genus in North America. Although several *Elliptio* taxa are wide-ranging, >50% appear endemic to one or a very few river systems. However, due largely to taxonomic ambiguity, only 2 have received U.S. federal protection. We examined 2 mtDNA genes (CO1 and NAD1) from 20 putative *Elliptio* taxa from rivers on the Gulf and Atlantic slope and the Florida Peninsula. Phylogenetic analyses revealed that *Elliptio*, as currently recognized, is paraphyletic. The Interior (Mississippi) Basin endemic *E. dilatata* appears to be only distantly related to other *Elliptio* taxa occurring in smaller, Gulf and Atlantic slope drainages. Additionally, we found evidence of at least 2 cryptic taxa within Gulf drainage *E. complanata* and *E. icterina*. Relationships between other putative *Elliptio* taxa are occluded by relatively short branch lengths and poor bootstrap support for many nodes. Additional markers may be required to increase phylogenetic signal strength. Future studies will evaluate the ability of other mitochondrial genes to elucidate phylogeographic patterns and species boundaries within *Elliptio* lineages.

1.5 GARB, J. E.*; DIMAURO, T.; VO, V.; HAYASHI, C.Y.; University of California, Riverside; *jessica.garb@ucr.edu*

Evidence from silk proteins for the single origin of spider orb-webs by the early Cretaceous.

The orb-web is a spectacular evolutionary innovation that enables spiders to capture flying prey. Spiders build their wheel-shaped orb-webs from a suite of silk proteins, which are products of a single gene family. Orb-web construction is characteristic of many species in the superfamilies Deinopoidea and Araneoidea. Though strikingly similar, notable differences between deinopoid and araneoid orb-webs suggest that the orb-web architecture convergently evolved in these two lineages. Yet, cladistic analyses of morphological and behavioral characters indicate that deinopoids and araneoids are sister groups and share a common orb-weaving ancestor. This result implies a unique instance of orb-web evolution, followed by its occasional loss or extreme modification. By constructing and surveying spider silk gland expression (cDNA) libraries, we show that deinopoid and araneoid spiders possess similar silk proteins utilized in orb-web construction. Further, phylogenetic analyses of the spider silk protein family confirm close relationships between deinopoid web-building silks and their araneoid counterparts. Our results indicate that the common ancestor of deinopoids and araneoids possessed the key silk proteins involved in orb-web construction, favoring the hypothesis for the orb-web's single origin. We can estimate the age of this common ancestor with spider fossils from early Cretaceous amber (~136 million years old). Accordingly, the orb-web's origin must also minimally date to this period.

26.1 GARTNER, G.E.A.*; HICKS, J.W.; MANZANI, P.R.; ANDRADE, D.; GARLAND, T.; Univ. of California, Riverside, Univ. of California, Irvine, Instituto de Biociencias, Rio Claro Brazil, Instituto de Biociencias, Rio Claro Brazil; *ggart001@ucr.edu*

Predictors of heart position in snakes

Snake cardiovascular systems must resist strong gravitational pressure gradients when assuming vertical postures during climbing or rearing. Thus, arboreal species might be expected to have hearts placed more anteriorly. Aquatic species, on the other hand, might be able to have hearts placed in a more posterior position because external hydrostatic pressure would counteract internal pressure gradients. A previous non-phylogenetic analysis of snake head-heart distance was partially consistent with these ideas, finding the heart located 15-25% of total body length from the head in terrestrial and arboreal species, but 25-45% in aquatic species (Seymour 1987). It also found that viperids had relatively posteriorly placed hearts, regardless of habitat. We analyzed an independent data set of 108 species (mostly from South America) from 4 major Alethinophidian families using both conventional phylogenetically based statistical methods. Considering all 108 species and controlling for snout-vent-length (log-log transformation), heart position showed strong phylogenetic signal ($P << 0.001$, $K = 1.224$ [see Blomberg et al. 2003]). We then categorized species as terrestrial, aquatic, semi-aquatic, arboreal or fossorial and performed analysis of covariance with SVL. Arboreal species were significantly different from terrestrial species, the former having hearts placed more posteriorly, i.e., opposite to what might be expected. Viperids also had relatively posteriorly placed hearts, irrespective of habitat, consistent with Seymour's finding. Data for additional taxa will be required to further elucidate the relationships between habitat, phylogeny, and heart position in snakes.

S1-1.5 GAYLORD, B*; REED, D.C.; RAIMONDI, P.T.; WASHBURN, L.; Univ. of California, Davis, Univ. of California, Santa Barbara, Univ. of California, Santa Cruz; *bpgaylord@ucdavis.edu*

Ecomechanics of macroalgal spore dispersal in coastal environments: Insights from theory and experiment

Passively dispersing propagules are often transported across a range of scales, with impacts on both local and regional population processes. In *Macrocystis pyrifera*, the giant kelp, patterns of spore dispersal influence rates of self-fertilization and inbreeding depression as well as levels of connectivity among forests. We used a combination of theoretical and experimental approaches to examine short- and long-distance spore dispersal in this important foundation species. Results of a physically based model were compared to settlement data acquired using spore collectors positioned around solitary kelps and an experimental kelp forest. Findings indicate that short-distance dispersal patterns quantified over brief durations are noisy due to stochastic effects of turbulence. Waves also smear dispersal distributions, reducing distinctions between point sources (i.e., solitary kelps) and area sources (i.e., forests composed of spatially distributed individuals). Temporally averaged dispersal distributions follow a lognormal-Gaussian form explicitly coupled to current speed. Functional expressions that describe such patterns provide additional first-order benchmarks. They suggest tremendous rates of spore release, exceeding 100 million spores per individual per day. Fertilization and recruitment appear possible at distances beyond 1 km, modulated by current speed, forest size, and the duration of viability of gamete-producing life stages derived from spores. Within forests where settlement is high, levels of self-fertilization may reach 10% or more. Such characteristics influence propagule supply, population connectivity, and inbreeding in this key nearshore seaweed.

50.2 GEERINCKX, T.*; GENBRUGGE, A.; ADRIAENS, D.; Ghent University; *tom.geerinckx@ugent.be*

The erectile cheek-spine apparatus in the bristlenose catfish Ancistrus (Loricariidae, Siluriformes), and its relation to the formation of a secondary skull roof

In the neotropical catfish family Loricariidae the opercle has been decoupled from the lower jaw, and has also lost its function in expiration. While many loricariid species have a small and slightly mobile opercle with reduced opercular musculature, within the hypostomine subfamily a novel opercular mechanism has developed that erects a tuft of enlarged odontodes anterior to the opercle. This defensive mechanism is examined in *Ancistrus* cf. *triradiatus*. The opercle has a prominent anterior process and the orientation of the reinforced articulation hinge to the hyomandibular bone has shifted. The opercular musculature is well developed, with a hypertrophied dilatator operculi, that extends deep inside the skull roof bones and toward the midline, over the brain, but below the superficial skull roof. Hence the frontal, sphenotic, parieto-supraoccipital and compound pterotic bones consist of a dorsal, superficial part and a deeper part separating the brain from the muscle: two functional skull roofs are thus formed. The impact on the path of the cranial sensory canals is substantial, moving canals away from the skull surface. Hypertrophy of cranial muscles is known from many teleosts, but the invasion of such large muscles into the skull, that is drastically modified and literally hollowed out, has never been described before. These cranial modifications are greater in males than in females, related to the territorial behavior of the former, in which the erectile spines are used.

6.8 GEFEN, E.; University of Nevada, Las Vegas; *gefene@unlv.nevada.edu*

Carbohydrate catabolism and its role in water balance of the sand scorpion, Smeringurus mesaensis, during desiccation

Adult *Smeringurus mesaensis* (Vaejovidae) were desiccated at 30ºC and 15-30%RH to 2.5, 5.0, 7.5 and 10% loss of initial mass. Oxygen consumption and CO_2 emission rates at mass loss levels of 7.5 and 10% were significantly lower than initial values ($p<0.001$). No significant effect of sex on metabolic rate was observed at any mass loss level. Initial respiratory quotient (RQ) values of ~1.0 indicate carbohydrate catabolism. Despite losing mass, scorpions maintained their hydration state using metabolic water and water previously bound to carbohydrates. However, the availability of metabolic and bound water decreases with the drop in metabolic rate as desiccation progresses. Interestingly, decreased metabolic rates coincided with RQ values higher than 1.0. This may suggest lipid synthesis from a carbohydrate source, thus resulting in the release of more bound water than if carbohydrates were catabolised for metabolic needs only.

50.10 GEORGI, Justin A; Stony Brook University, Stony Brook; *justin.georgi@hsc.stonybrook.edu*

Semicircular Canal Morphology as Evidence of Locomotor Behavior in Amniotes

The vestibular system is a critical component of the neural control of locomotion in vertebrates. In the vestibule, macular endorgans transduce linear movements of the head and the semicircular ducts transduce the rotational movements. Integrated in the cerebellum with visual and proprioceptive inputs, the vestibular signals provide vital information about movement relative to the environment, and drive stabilization reflexes. The semicircular ducts leave distinct canals through the bones of the posterior braincase. These bony semicircular canals preserve some of the morphologies that determine the functional parameters of the semicircular ducts: *e.g.* response time, signal gain and frequency range. Thus, the semicircular canals represent the function of a neurological system via discrete bony correlates. Therefore, since the semicircular ducts should have morphologies that attune the system parameters to specific qualities and modes of locomotion and since some of these morphologies can be determined by examination of the semicircular canals, it has been hypothesized that there are correlations between semicircular canal morphology and locomotion. Semicircular canals represent a possible way, independent of post-cranial morphology, to verify hypotheses about locomotion in extinct vertebrates. To test this hypothesis, the semicircular canals of a broad array of amniotes were examined using Computed Tomography (CT). Shape analysis of the semicircular canals in carnivorans, turtles, varanids and crocodilians shows that despite phylogenetic shape differences, there is a consistent pattern of shape change that correlates with the terrestrial to aquatic locomotor transition. This pattern is most observable in the anterior semicircular canal where the maximum distance of the canal from the utricle is reduced in aquatic taxa.

45.2 GERHARDT, H. C.; HUMFELD, S. C.*; MARSHALL, V. T.; University of Missouri-Columbia, University of Illinois; *humfelds@missouri.edu*

Geographic variation in the advertisement call of Hyla arenicolor

The canyon treefrog, *Hyla arenicolor*, is a cryptically colored treefrog that inhabits rocky canyons throughout the southwestern United States and Mexico. Although populations occur in a fairly wide variety of habitats (seasonal watersheds in the xeric Sonoran and Chihuahuan Deserts to permanent streams in the relatively mesic Colorado Plateau), regions containing these sources of water are often separated by vast areas of arid country. One consequence of the low gene flow between such isolated populations is large interpopulational genetic differences (with sequence divergences as high as 13.7%). Phylogenetic analysis has revealed three deeply divergent mtDNA lineages that inhabit nonoverlapping geographical regions. To test whether the communication system of this species has changed in concordance with genetic changes, we recorded advertisement calls produced by 155 male *H. arenicolor* from several populations in each of the three clades. We analyzed the calls in terms of spectral content (low and high frequency spectral peaks, relative amplitude), gross temporal properties (call duration, call rate, number of pulses, pulse repetition rate) and fine temporal properties (pulse duration, pulse rise and fall times, number of subpulses). The magnitude of interpopulational variation in call characteristics does not match genetic variation, and here we suggest some testable explanations for this discrepancy

9.7 GERMAN, R.Z.*; CROMPTON, A.W.; THEXTON, A.J.; Johns Hopkins University, Harvard University, King\\\'s College, London; *rz.german@jhmi.edu*

The Ontogeny of Epiglottal Movement during Swallowing in Mammals

In mammalian feeding, the path that food takes crosses the airway. The function of the epiglottis, the superior cartilage of the larynx, during swallowing is debated and developmental changes in its function unknown. To test the role this structure plays during the pharyngeal swallow, we placed radio opaque markers in the palatopharyngeal arch, tip of the epiglottis and bases of the thyroid and basihyoid cartilages in infant pigs. We measured the passage of liquid from the valleculae to the esophagus in lateral and dorso-ventral views by videofluroscopy. Prior to a swallow, the dorsal rim of the larynx was firmly held within the sphincter formed by the palatopharyngeal arch, maintaining a patent airway. During a swallow in the youngest animals, liquids reached the esophagus via the piriform recesses by moving around the stationary epiglottis. As animals matured, but still prior to weaning, the epiglottal tip moved rapidly backwards during a swallow, even though the milk continued to travel lateral to the laryngeal opening. In such swallows the palatopharyngeal sphincter closed and the tip of the epiglottis moved backwards protecting the airway opening. Within a few days epiglottal flipping became increasingly regular, until about the time of weaning, when flipping occurred consistently, and milk always traveled over the epiglottis during a swallow. The movement of the epiglottis during swallowing matures prior to the start of the consumption of solid food, and is implicated in the functional separation of the food pathway and airway.

70.5 GERRY, S.P.*; DEAN, M.N.; SUMMERS, C.D.; WILGA, ; Univ. of Rhode Island, Univ. of California, Irvine; *sgerry@mail.uri.edu*

Asynchronous bilateral jaw muscle activity in two species of elasmobranchs

Complex prey processing in higher vertebrates is characterized by unilateral activation of the jaw musculature, permitting freedom of movement through partial decoupling of the sides of the head. This has had limited demonstration in lower vertebrates where the symphyses between the halves of the jaw tend to be more flexible than those of mammals, suggesting that the flexibility in the lower vertebrate feeding mechanism lies within the morphology of the jaws and not their muscular control. Using electromyography, we demonstrate asynchronous bilateral jaw muscle activity in members of two major groups of elasmobranchs, spiny dogfish, *Squalus acanthias*, and little skates, *Leucoraja erinacea*. Both species possess flexible symphyses and are known to modulate their feeding behaviors in response to multiple prey types. Electrodes were implanted in an unpaired jaw opener (coracomandibularis) for reference and bilaterally in three of the jaw adductors: two divisions of the quadratomandibularis and the preorbitalis. In dogfish, electrodes were also implanted in a cranial elevator (epaxialis). During prey capture bilateral jaw muscle pairs were activated synchronously in both species, but asynchronously during prey processing. This illustrates a previously unappreciated flexibility of the elasmobranch feeding mechanism in that jaw muscle activity can be modulated both unilaterally and bilaterally in response to prey type. These findings imply that asynchronous activation of the jaw muscles is an ancestral characteristic of vertebrates and perhaps arose with the derivation of jaws.

37.5 GERVASI, S.S.; University of Michigan; *sgervasi@umich.edu*

Pond desiccation rate affects immune system responsiveness in a temporary pond breeding amphibian, the wood frog (Rana sylvatica)

Theoretical studies and empirical data predict that life history strategies are often determined by variation in an organism's environment. In response to environmental heterogeneity, many organisms have evolved some degree of plasticity in phenotypic expression. Phenotypic plasticity is especially prevalent among amphibians. For example, amphibians can avoid the direct threat of mortality due to pond desiccation by speeding up metamorphosis. This hormonally mediated response to pond desiccation is energetically expensive and may impose delayed costs. Energy directed toward the rapid completion of metamorphosis may be diverted away from the process of immune system development. Prometamorphic wood frog tadpoles were subjected to one of four desiccation regimes based on the rate of water removal. Each individual was subjected to a standardized immune system challenge at three weeks post metamorphosis. Phytohemagglutanin (PHA), a T-cell mitogen, was injected subcutaneously in all animals and caused a maximum skin swelling response within 24h. Individuals exposed to more rapid water desiccation regimes showed significantly faster developmental rates and significantly weaker skin swelling responses than individuals exposed to a constant, high volume of water. These results suggest that early stage stressors such as pond drying negatively impact certain aspects of immune system competence in metamorphs and possibly in juvenile and adult amphibians. These findings also imply that global climate change in the form of escalating climate variability may indirectly impact susceptibility of amphibians to a variety of emerging pathogens.

37.6 GIBB, A. C.*; FERRY-GRAHAM, L. A.; Northern Arizona University, Moss Landing Marine Laboratories; *Alice.Gibb@nau.edu*

Life history strategy affects escape performance of endangered Colorado River fish species

Many native fishes of the Colorado River are Cypriniformes (Teleostei). Because cypriniform fish have no parental care and produce eggs with small yolks, their larvae are free swimming when the axial skeleton and fins have not yet formed. Many introduced game fish are in the teleost orders Perciformes (e.g. largemouth bass; Centrarchidae) or Salmoniformes (e.g. brown trout; Salmonidae). Salmonid eggs have large yolks, and larvae become free swimming at an advanced state of morphological development; centrarchids have parental care of eggs and young larvae. Thus, these species become free swimming as advanced larvae (i.e. near metamorphosis), when the axial skeleton and fins approach adult morphology. We measured escape response performance (time to complete preparatory phase, max. velocity, time to max. velocity) from larvae and juveniles (20-70 ind.) from three species (each representing one of the three teleost lineages) in the laboratory. For all species, improvements in performance were correlated with the development of specific adult morphologies (e.g. the caudal fin), and small juveniles produced more effective escape responses than did larvae. We suggest that cypriniform fish populations may be reduced by predators because larvae are free living but produce ineffective escape responses. The creation of a series of dams and reservoirs on the Colorado River exacerbates this problem. Decreased water temperature retards development of native fishes, extending their period of increased vulnerability. Decreased turbidity improves the ability of visual predators (particularly introduced nektivores) to target larvae in the water column. Finally, damming modifies the habitat in a manner conducive to the nesting success of introduced game fish, and does not confer any benefit to native fishes.

26.2 GIFFORD, M.E.*; MAHLER, D.L.; HERREL, A.; Washington University, Harvard University, University of Antwerp; *gifford@biology2.wustl.edu*

Repeated evolution of morphology, performance, and behavior in Hispaniolan lizards: a population-level analysis

Variation in habitat characteristics among populations and species is thought to impose different selective pressures on organisms. Among lizard species, the degree of vegetative structure in an area has been shown to influence a combination of traits (both behavioral and morphological). Among populations, similar patterns may be expected, but few studies have addressed population-level variation. In this study we examined predator avoidance behavior, morphology, whole animal performance capacity, and predation intensity in three phylogenetically independent population pairs of Hispaniolan lizards (*Leiocephalus*) inhabiting environments that differ in amount of vegetative cover. We present evidence that predation intensity does not differ between open and cluttered habitats but that the interaction between predation and habitat structure influences the correlated evolution of morphology, performance, and behavior. This pattern is repeated between populations in two species suggesting that this suite of traits may be adaptive, although plasticity cannot be ruled out at this point.

S2-2.4 GILBERT, S.F.*; BENDER, G.; YIN, M.; CEBRA-THOMAS, J. A. ; Swarthmore College, Millersville University; *sgilber1@swarthmore.edu*

Trunk neural crest cells contribute to plastron and nuchal bones in turtles

The plastron of the hard-shelled turtle *Trachemys scripta* contains nine bones. These bones develop by intramembranous ossification within the dermis. The three anterior plastral bones (the paired epiplastra and the endoplastron) are thought to be homologues of the clavicles and intraclavicular bone, respectively; while the remaining three pairs of plastron bones are believed to be homologous to gastralia (floating ribs) of other reptiles. The plastron bones have two distinct phases of development. In the first phase, a band of cells condenses to form an aggregate, while in the second stage, these aggregates form bony matrix. A similar pattern is seen in the nuchal bone, the most anterior bone in the carapace. Our studies provide evidence that the plastral and nuchal bones are each derived from trunk neural crest cells. We show that the cells forming these bones stain positively for HNK-1, FoxD3, p75, and the alpha subunit of the platelet-derived growth factor receptor. Each of these antigens is a marker for skeletogenic neural crest cells. These plastron-forming cells appear to be a late-migrating population of neural crest cells, emerging from the neural tube at stage 17, more than a week after the other neural crest cells have left. We have shown by DiI labeling that this is a migratory cell population. In addition, we demonstrate that the gastralia of the alligator also stains positively for HNK-1. These studies show that the turtle trunk neural crest is capable of naturally forming dermal skeleton, and that the plastral bones form in the same manner as the facial bones. It is possible that to become skeletogenic, these neural crest cells must either lose posterior Hox gene expression and/or be placed in an environment that will support skeletogenic gene expression.

S1-3.6 GOLDMAN, D.I.*; KORFF , W.L.; WEHNER, M.; BERNS, M.S.; FULL, R.J.; Univ. of California, Berkeley, Caltech; *digoldma@berkeley.edu*

The Mechanism of Rapid Running in Weak Sand

Locomotion on granular media is unlike locomotion on rigid ground because during a step the material begins as a solid, becomes a fluid and then re-solidifies. The fluidization and solidification depend on the strength of the material and can affect limb penetration depth, time to re-solidify and propulsive force. Legged animals could use a drag mechanism to paddle feet through sand or could rely on mechanisms by which appropriate limb trajectory and toe use rapidly solidify the material. To study how the fluidizing properties affect speed in rapidly running lizards and crabs, we used a fluidized a bed of of 250 µm glass spheres (30x16 cm^2 area by 8 cm deep). A constant flow rate Q of air through the bed below the onset of fluidization set the material strength. We measured the average speed, foot impact depth, and time of foot contact as a function of material strength for a desert dwelling generalist lizard *Callisaurus draconoides*, the sand-specialist Mojave fringe-toed lizard *Uma scoparia*, an arboreal gecko *Pachydactylus bibroni*, a generalist lizard *Sceloporus olivaceus* and the fastest land invertebrate, the ghost crab *Ocypode quadrata*. Crabs and geckos decreased speed by three-fold as foot impact depth increased by a factor of two. Surprisingly, the performance of *S. olivaceus* was comparable to that of the sand adapted *U. scoparia* suffering only a 10% decrease in speed (always > 1 m/sec) as Q increased to fluidization. *C. draconoides* maintained high speed (>1.5 m/sec) even on completely fluidized sand. Terrestrial lizards used long toes to solidify the material rapidly relative to stance duration resulting in stance duration being controlled by the animal, not by the substrate's stopping strength.

S3-2.2 GOLDTHWAIT, S.*; STEINBERG, D.; MCGILLICUDDY, D.; Humboldt State University, Virginia Institute of Marine Science, Woods Hole Oceanographic Institute; *sg65@humboldt.edu*

Elevated Zooplankton Biomass in Mid-Ocean Eddies

Physical factors ultimately determine the course of biological events in the ocean because processes such as mixing, advection, turbulence, and diffusion affect the distribution, production, and behavior of pelagic organisms. Physics influences biology on many scales, from ocean basin circulation to turbulence affecting single cells. The currents, fronts, and eddies that comprise the oceanic mesoscale are energetic and ubiquitous features of ocean circulation. As mesozooplankton play a fundamental role in food web interactions and the flux of material out of the surface waters, changes in mesozooplankton community composition due to physical perturbation by eddies could affect biogeochemical cycling. As part of the Eddy Dynamics, mIxing, Export, and Species composition (EDDIES) project we followed the evolution of 2 distinct features in the Sargasso Sea, a cold-core eddy and a mode-water eddy. Zooplankton biomass in the upper 150 m was enhanced for both eddies at 752 mg m^{-2} and 674 mg m^{-2}, respectively, compared with an average of 462 mg m^{-2} for summer samples collected near Bermuda. Zooplankton biomass was enhanced on the periphery of the cold-core eddy, with a 1.5 fold increase in vertical migrators such as euphausiids and shrimp. In the mode-water eddy, peak zooplankton biomass occurred at eddy center but was highly variable over time. Copepods and euphausiids inside both eddies had elevated gut chlorophyll concentrations. Shifts in zooplankton community composition and grazing rates were also reflected in sedimenting fecal pellets. Zooplankton fecal pellets are a primary mechanism of carbon transport from surface waters into the ocean interior. Inside the eddy features, the number of zooplankton fecal pellets sinking out of the euphotic zone was up to 2 fold higher than background, accounting for 20-35% of total carbon flux.

52.4 GOODMAN, R.M.; Univ. Tennessee, Knoxville; *rmgoodman@utk.edu*

Geographic variation and temperature-induced phenotypic plasticity of cell size in the lizard Anolis carolinensis

Phenotypic plasticity at the cellular level has been suggested to relate to plasticity of body size and geographic variation in body size associated with latitude and environmental temperature in ectotherms. The current study is the first examination of geographic variation in cell size in an ectothermic vertebrate connected to experimental investigations of temperature-induced plasticity. Sizes of bodies and red blood cells (RBCs) were collected from wild caught, adult, female lizards (*Anolis carolinensis*) from four populations along a latitudinal transect in the southeastern United States. Eggs from three populations were collected and maintained in the laboratory at two different incubation temperatures. At hatching, sizes of bodies, RBCs and epithelial cells of offspring were collected. Cell sizes (RBCs) of adult females will be examined to determine whether geographic variation of cell size and/or a relation of cell size to body size exists in natural populations. Cell sizes of offspring (RBCs and epithelial cells) will be examined to determine whether the following exist: influences of population origin, maternal effect, egg size, and temperature on cell size; relationship between cell size and body size; sexual size dimorphism in cell size and/or phenotypic plasticity of cell size; differences among populations in levels of phenotypic plasticity for cell size.

44.9 GRAHAM, E.R.; Saint Joseph\'s University; *eg259365@sju.edu*

The Transfer of PCBs into Holothurians via Plastic Particles

Plastic bottles, bags, and other products discarded in the ocean are weathered and degraded, causing tiny fragments to break off. Surveys have confirmed that tiny plastic fragments are common pollutants on the ocean surface, on beaches, and in the benthos. In addition to plastic particles, plastic pellets used in manufacturing also pollute the marine environment. Organisms mistake plastic fragments and pellets for food, and the effects of plastic ingestion are unknown for most marine species, especially marine invertebrates. Recent studies have concluded that plastic in an aqueous medium may adsorb and accumulate polychlorinated biphenyls (PCBs) in levels higher than ambient seawater; therefore, ingesting plastic particles may increase PCBs in susceptible organisms. I have been working on an investigation to determine if plastic pollution in the form of tiny particles and pellets exposes deposit-feeding holothurians to additional PCBs. I have concluded that 0.25mm-4.0mm plastic particles are present in subtidal sediment where holothurians reside, and deposit-feeding holothurians will ingest those plastic particles. After a series of feeding trials using *Thyonella gemmata*, *Holothuria floridana*, *Holothuria grisea*, and *Cucumaria frondosa*, I quantified and characterized the amount of plastic particles ingested per species, and compared the ingestion of plastic to that of sand. In separate trials, I allowed *Holothuria floridana* and *Holothuria grisea* to feed on Aroclor-contaminated polyvinyl chloride particles over two weeks, and I calculated the concentration of PCBs transferred from the plastic into the organisms, and from the plastic into the ambient water and sand. The final experiment in this investigation will measure the concentration of PCBs in plastic particles extracted from subtidal sediment, thereby confirming that plastic particles in the benthos could contribute to PCB uptake if ingested.

23.4 GRASSO, Frank W.; Brooklyn College, the City University of New York; *fgrasso@brooklyn.cuny.edu*

Sucker-Arm Coordination in Octopus During Grasping and Manipulation of Objects

In natural settings octopuses use their arms and suckers in a variety of dexterous manipulation tasks, such as extracting prey from crevices and burrows, opening bivalve shells and arranging middens as barriers in front of their den entrances. Octopuses attach multiple suckers to surfaces for a power grasp which enables the octopus to move objects relative to its body. To transport or reposition objects octopuses have been observed to project an arm from their body, attach a group of distal suckers and pull an object to toward them by shortening the arm. They have also been reported bend the arm once suckers adhere producing dynamic joints where needed to move the object. The former behavior is loosely analogous to squid tentacle extension and prey capture. The later parallels vertebrate jointed manipulation albeit via dynamic joint induction. We investigated octopuses' use of suckers in object relocation tasks under controlled, reproducible laboratory conditions. Because larger suckers can generate larger adhesion forces we hypothesized that octopuses would prefer to use larger suckers toward the base of the arm when they were available for tasks requiring the arm to employ relatively greater force. We found, that a squid-like approach (deploying distal, and therefore small, suckers and then shortening the arm)was not commonly used in the tasks studied. Instead, in many cases the animals used combinations of arm-bends and different functional groups of suckers dynamically assigned to different roles. When animals were restricted to the use of a single arm they preferred significantly, to use suckers in the middle of the arm to support this coordinated arm-sucker activity. These results are consistent with a pattern of sophisticated sucker-arm coordination and are contrary to a view of suckers as passive agents reflexively supplying adhesion in reaction to surface contact.

S1-3.5 GRAVISH, N*; WILKINSON, M; AUTUMN, K; Lewis & Clark College; *autumn@lclark.edu*

Work of Detachment is Controllable in Gecko Setal Arrays

Gecko setae are anisotropic in adhesive function. Comprised of thousands of angled hairs, setal arrays attach strongly when dragged along their natural curvature. Dragging against curvature produces low friction and no adhesion. We discovered that the mechanical work of detachment in the normal axis (G_n) for setal arrays is anisotropic, likely as a consequence of setal structure. Previously we found that house geckos (*Hemidactylus garnotii*) running vertically detached their feet in 15 ms without measurable effects on center of mass kinetic energy. This suggests that the work to detach a setal array can be quite low. We measured the dynamics of detachment in isolated tokay gecko (*Gekko gecko*) setal arrays to determine G_n at angles of 30° to 150°. A detachment vector pointing away from and normal to the substrate corresponds to an angle of 90°, and 0° is parallel to the surface, in the direction of natural setal curvature. For angles below 120°, G_n was constant and more than three orders of magnitude greater than the thermodynamic interfacial energy predicted for van der Waals forces. This suggests that energy is lost internally to the setal array, greatly increasing G_n. For detachment angles above 120°, G_n became negative indicating that elastic energy from setal compression was released. Energetically optimal detachment paths occurred at angles above 120°. Thus the easiest method for a gecko to detach its toes may be a small push away from the body. The control of adhesive energy through modulation of the applied force vector has utility in the design of climbing robots and setal adhesives. A simple angled rigid beam model of the seta predicts anisotropy in G_n suggesting that this property will be replicable in synthetic adhesive microstructures. Support: DARPA N66001-03-C-8045, NSF-NIRT 0304730, DCI/NGIA HM1582-05-2022, Emhart, J&J Dupuy-Mitek.

38.5 GRAYSON, Dina L.*; HARRISON, Jon F.; FEWELL, Jennifer H.; Arizona State University; *Dina.Grayson@asu.edu*

Why do Africanized honey bees have higher metabolic capacities than Europeans?

Africanized honey bees (AHB, *Apis mellifera scutellata*) are a highly successful invasive species that has spread throughout the neotropics by out-competing, hybridizing with, and replacing existing European honey bees (EHB mainly *Apis mellifera mellifera*). It has been hypothesized that one mechanism contributing to their success is higher metabolic capacities leading to increased foraging, or dispersal. Although metabolic capacity has consistently been higher in foraging AHB than EHB, the link between metabolic capacity and any advantageous behaviors has remained unclear. Additionally, many hypotheses regarding the proximate causes of metabolic capacity differences, such as that higher metabolic capacities in AHB are the result of smaller body size, have never been conclusively tested. I tested three hypotheses that could explain why AHB have higher metabolic capacities than EHB. First, I showed that differences in larval rearing environment could not explain higher adult metabolic capacity in AHB by rearing AHB and EHB in shared and independent environments. Second, I showed that differences in body size could not explain differences in metabolic capacity by comparing AHB and EHB of similar sizes. Third, I showed that foraging load mass was not affected by metabolic capacity by evaluating unloaded metabolic capacity and load mass on the same individual bees. Overall, our results support the idea of a genetic basis for metabolic capacity in honey bees that can not be explained by differences in body mass or by selection on AHB to carry larger loads. Supported by NSF IBN 093410 to JHF, JFH, & GJH.

29.3 GREIVES, Timothy*; MASON, Alex; SCOTTI, Melissa-Ann; KETTERSON, Ellen; KRIEGSFELD, Lance; DEMAS, Gregory; Department of Biology and Center for the Integrative Study of Animal Behavior, Indiana University, Bloomington, IN 47405 USA, Department of Psychology and Helen Wills Neuroscience Institute, University of California, Berkeley, Berkeley, CA 94720 USA; *tjgreive@indiana.edu*

A role for kisspeptin in seasonal reproduction?

Most temperate zone species exhibit seasonal breeding, coordinating reproduction with optimal environmental conditions. This coordination requires integration of relevant environmental signals by the hypothalamo-pituitary-gonadal (HPG) axis. Photoperiod provides a noise-free cue, triggering gonadal regression or hastening recrudescence via direct actions on the HPG axis. Kisspeptin, a recently identified peptide hormone, induces secretion of pituitary gonadotropins in laboratory animals. Because seasonal breeding is associated with changes in HPG activity, seasonal variation in secretion or sensitivity to kisspeptin in response to photoperiod may underlie seasonal changes in reproduction. To test this idea, Siberian hamsters (*Phodopus sungorus*) were held in long (LD 16:8) or short (LD 8:16) days for 2 or 8 weeks and differences in hypothalamic kisspeptin staining and gonadotropin (LH) response to injections of kisspeptin were compared. Short-day housed (non-reproductive) animals displayed a marked reduction in kisspeptin staining in the AVPV compared with long-long-day, reproductive animals, whereas short-day animals displayed increased kisspeptin staining in the ARC. Kisspeptin injections significantly elevated LH levels in both long and short day hamsters. These data indicate that kisspeptin release from the hypothalamus changes in response to photoperiod whereas exogenous kisspeptin induces LH secretion, regardless of photoperiod. Ongoing studies will examine the precise role of kisspeptin in mediating reproduction in seasonally breeding animals.

28.11 GUERRERO-FERREIRA, R.C.*; NISHIGUCHI, M.K.; New Mexico State University; *ricardo@nmsu.edu*

Identification of luminescent symbionts from the genera Uroteuthis, Loliolus, and Euprymna (Mollusca: Cephalopoda)

Luminescent bacteria in the family Vibrionaceae (Bacteria: γ-Proteobacteria) are commonly found in complex, bilobed light organs of sepiolid and loliginid squids. Although morphology of these organs in both families of squids is similar, the species of bacteria which inhabit each host has yet to be verified. We utilized sequences of 16S ribosomal RNA, luciferase α-subunit (*lux*A) and the glyceraldehyde-3-phosphate dehydrogenase (*gap*A) genes to determine phylogenetic relationships between 63 strains of *Vibrio* bacteria, which included representatives from different environments as well as unidentified luminescent isolates from loliginid and sepiolid squid from Thailand. A combined phylogenetic analysis was used including biochemical data such as carbon use, growth and luminescence. Results demonstrated that certain symbiotic Thai isolates found in the same geographical area were included in a clade containing bacterial species phenotypically suitable to colonize light organs. Moreover, strains isolated from a particular squid host were found phylogenetically related to more than one bacteria species in our phylogeny. This research presents evidence of species of bacteria that have not been previously described as symbiotic strains colonizing light organs of Indo-West Pacific loliginid and sepiolid squids, and supports the hypothesis of a non-specific association between sepiolid and loliginid squids and marine luminescent bacteria.

S3-1.5 HADDOCK, Steven H; MBARI; *haddock@mbari.org*

Comparative feeding ecology of the phylum Ctenophora

Comb jellies (Phylum Ctenophora) are gelatinous macroplankton which propel themselves using rows of ciliary "paddles". They are predators on other plankton, often using cilia and sticky cells (rather than stinging cells) in a variety of ways to capture their prey. Most studies of their feeding and ecology have focused on a few readily available species, particularly the lobate *Mnemiopsis*. While this work has given interesting insights into many particulars of ctenophore feeding, extrapolation from this "model" system does not seem to be broadly applicable to the rest of the phylum. The true diversity, both in the sense of species and behavioral adaptations, shows that ctenophores have adapted to essentially all marine habitats, and to a range of prey from protozoa up to large jellies, including some associations with very specific prey. A comparison of their feeding modes reveals a variety that perhaps rivals the range found in better-known terrestrial examples such as spiders.

49.6 HADFIELD, M. G.*; DUBUC, T.; TRAN, C; University of Hawaii at Manoa; *hadfield@hawaii.edu*

Attachment strengths of settling coral planulae.

The larvae of reef-forming corals must recruit to a world characterized by great surface complexity and turbulent water flow generated by ocean waves. Utilizing a precision turbulent flow apparatus, we have examined the attachment strength of planulae of the Hawaiian coral *Pocillopora damicornis* under conditions of set flow velocities. We have found that during early stages of attachment, when larvae have formed only initial mucus attachments to surfaces but have not initiated metamorphosis, resistance to removal is significant; they are not washed off by shear forces below about 15 Pascals. However, within 10 12 hours, metamorphosis has commenced and attachment strengths are considerably greater; maximum shear forces generated in the flow cell (50 100 Pa) either do not remove the newly settled individuals or do so only by physically damaging them. Additionally, preliminary measurements suggest that gregarious settlement, where two or three individuals attach to a surface in contact with each other, endows the settlers with significantly increased resistance to removal by fluid-shear forces. Together, these data indicate that planulae of *P. damicornis* are capable of making rapid and very strong attachments to reef surfaces and remain there under flow rates that occur under typical conditions on Hawaiian coral reefs.

2.6 HAGEMEISTER, A.L.*; SHERIDAN, M.A.; North Dakota State Univ., Fargo; *Alison.Hagemeister@ndsu.edu*

Somatostatin Inhibits Hepatic Growth Hormone Sensitivity by Activating the MAPK Signaling Pathway

Previously, we reported that somatostatins (SS) inhibit organismal growth by reducing hepatic growth hormone (GH) sensitivity and by inhibiting insulin-like growth factor-1 (IGF-I) production. In this study, we used hepatocytes isolated from rainbow trout to elucidate the mechanism(s) associated with the growth-inhibiting actions of SS. SS-14, a predominant SS isoform, stimulated tyrosine phosphorylation of several endogenous proteins, including mitogen-activated protein kinase (MAPK). SS-14 specifically activated phospho-MAPK in a dose-dependant fashion. This activation occurred within 5 minutes and disappeared after 1 hour. The MAPK inhibitor U0126 retarded SS-14-stimulated phosphorylation of MAPK. U0126 also blocked SS-inhibition of GH receptor (GHR) and IGF-I mRNA expression. SS-14 also activated MAPK in Chinese hamster ovarian cells transfected with trout SS receptor (SSTR) subtype 1A and 1B in a dose- and time-dependant manner. These results suggest that SS inhibits hepatic GHR and IGF-I expression by activating the MAPK pathway. Moreover, the activation of the MAPK pathway appears linked to the SSTR subtype 1 receptor. (Supported by NSF IOB 0444860.)

44.8 HAGSTROM, K. R. E.**; REYES, J.A.; PETSCHAUER, D.M.; KELLEY, K.M.; California State University, Long Beach; *rhagstro@csulb.edu*

Steroidogenesis Acute Regulatory (StAR) Protein, Aromatase (P450arom), 17beta-hydroxysteroid dehydrogenase (17beta HSD) and Location-associated Differences in Circulating Estradiol Concentrations in Wild Flatfish in the Southern California Bight Environment

Worldwide, endocrine disruption has been widely documented in wild, aquatic organisms. Surprisingly, despite the large human population affecting the marine environment of the Southern California Bight (SCB), endocrine disruption has not been well studied or documented in this region. We have uncovered evidence of endocrine disruption of two local flatfish species living in proximity to wastewater treatment plant (WWTP) outfall locations in the SCB. One of the observations is that flatfish residing near WWTP outfalls exhibit higher plasma levels of the female sex steroid, 17beta-estradiol (E2), with males exhibiting as high or higher levels than in females. To assess the underlying cell-molecular mechanisms of the elevated E2, particularly in males, three key steroidogenic enzymes leading to E2 synthesis are under study. Partial cDNAs for StAR, P450arom, and 17-beta HSD in hornyhead turbot (*Pleuronichthys verticalis*) and English sole (*Parophrys vetulus*) have been isolated, and their sequences are highly conserved with homologs from piscine and other vertebrate representatives. Results from quantitative real-time RT-PCR assays of gonadal tissues of flatfish from WWTP outfall and reference sites in Santa Monica Bay and Orange County's San Pedro Shelf will be presented and discussed in terms of potential impacts of anthropogenic contaminants. [Supported by Southern California Sea Grant Program NOAA#NA06OAR4170012, project # CE-17]

20.3 HAHN, TP*; CORNELIUS, JM; KELSEY, TR; Univ. of California Davis; *tphahn@ucdavis.edu*

Seasonal components of the reproductive schedules of North American crossbills (Loxia sp.).

Crossbills have been thought capable of initiating reproduction at any time of year, or maintaining it indefinitely, if food supply permits. However, at least the smallest North American form displays a fundamentally seasonal reproductive schedule, with autumn gonadal regression even if food supply remains at the late summer annual peak. It has been unclear whether this seasonality is unique to this highly specialized form or is a general feature of crossbills. Here we present evidence from several other crossbill forms indicating that the autumn collapse of the gonads, coincident with advancement of the annual plumage molt, is indeed a general feature of North American crossbills. Gonads of free-living birds regress during September or October even if food supply remains high enough to support subsequent winter breeding. This suggests some form of autumn refractoriness to environmental cues. Experiments already rule out absolute photorefractoriness typical of other temperate zone songbirds, leaving relative photorefractoriness or some kind of food refractoriness as possible explanations for the decline in reproductive competence in autumn. Viewed in a comparative context, this is highly unusual and likely represents an adaptive specialization to facilitate a flexible breeding schedule. Field work is ongoing to ascertain whether these birds ever maintain reproductive competence through the autumn under exceptionally favorable conditions. Comparative experiments will help clarify the extent to which crossbills' extraordinary reproductive patterns are the result of adaptive specializations of their cue response systems, or of conditionally plastic outputs of phylogenetically conserved cue response traits.

S3-1.8 HALANYCH, K.M.*; STRUCK, T.H.; Auburn Univ., University of Osnabrück; *ken@auburn.edu*

"Evolution of holopelagic annelids" or "Going pelagic when your relatives are stuck in the mud"

Annelids are most commonly thought of as soil dwelling or benthic organisms. However, several annelid lineages have adopted a holopelagic existence. Some groups, such as tomopterids, are fairly well-known and familiar to students of marine plankton samples. Other groups, including typhloscolecidae and *Poeobius*, are less familiar as they occur in deep water or open oceans. One common feature of annelid lineages that have adapted a holopelagic existence is the considerably modified morphology compared to their benthic relatives. They often lose key morphological features such as segmentation or chaetae. This study examines the origins of various lineages of holopelagic annelid species using molecular phylogenetic data. An explicit attempt is made to understand how morphology is modified to allow for this change in habitat, and to look for common patterns across evolutionary lineages.

S1-5.5 HALE, ME*; WATERS, JS; LEE, WK; SOCHA, JJ; FEZZAA, K; WESTNEAT, MW; Univ. of Chicago, Arizona State Univ., Argonne National Laboratory, Argonne National Laboratory, Field Museum; *mhale@uchicago.edu*

Drawing inspiration from insect breathing and heaving conventional wisdom: Convective tracheal and air sac mechanisms in Drosophila visualized with x-ray imaging.

Since the early work of Steve Vogel on tethered flight, *Drosophila* has been a model for the biomechanics of movement. Recent advances in phase contrast imaging using synchrotron x-rays have provided opportunities to examine internal mechanics of respiratory movements in this species. The mechanism of gas exchange in small insects, such as fruit flies, has conventionally been viewed as a process driven by diffusion, with the role of convection being limited to autoventilation in the thoracic air sacs during flight. We observed three different convective mechanisms in the head and thorax of non-flying *Drosophila* that suggest an important role of convection in these small animals. First, we observed that head air sacs expand and collapse during the proboscis extension reflex (PER) indicating, as suggested by Lehmann and Heyman (J. Exp. Biol. 208, 3645), that PER can generate convection. Second, we recorded a long duration, low frequency inflation and deflation of the head air sacs that was not associated with visible motion (i.e. was not autoventilatory). Third, we discovered that tracheal tubes in the anterior thorax expand and collapse during periods of inactivity, indicating that convection in the thorax can be used in non-flight situations. We suggest that convective air transport is used for gas exchange even in some small insects for which diffusion alone has been thought to be sufficient. Supported by the University of Chicago under section H.28 of its contract W-31-109-ENG-38 to manage Argonne National Laboratory with a Board of Governors Seed Grant to MEH and WKL.

S4-1.2 HALL, S.R.*; NISBET, R.M.; SIMONIS, J.; CACERES, C.E.; Indiana University, University of California, Santa Barbara, Florida State University, University of Illinois; *sprhall@indiana.edu*

Parasites as consumers of resources: models for disease based on dynamic energy budgets

In some senses, parasites act as competitors for resources ingested by hosts. Furthermore, virulent effects of parasites frequently depend upon quantity and quality of resources ingested by their host. We illustrate this phenomenon with a *Daphnia*-fungus-phytoplankton system. *Daphnia* are pivotal zooplankton grazers in freshwater lakes and ponds, and they become infected inadvertently by spores of a fungal parasite (*Metschnikowia*) released from dead, infected hosts while eating phytoplankton. Once a host becomes infected, the parasite causes larger reduction in fecundity, kills its host more quickly, and produces increased number of spores per dead host as food levels increase. To explain these phenomena, we turned to a dynamic energy budget (DEB) model for the host. This DEB model tracks energy flow as it is ingested and stored; stored energy is then allocated to growth, maintenance, reproduction, and production of parasites within the body of the infected host. Parasites kill the host by starving it. Using this simple model, we readily captured the signature of resource-enhanced virulence in our laboratory experiments. This model can also produce opposite patterns if hosts pay an energetic cost to kill parasites (through an immune response). A similar model structure built on the variable-stores (Droop) model can also capture resource-dependent effects of parasites on plants. Further modification of the DEB model shows how virulent effects of the parasite change if the parasite's stoichiometric composition differs from that of the host and the food ingested by the host. Thus, simple models that treat parasites as competitors for resources consumed by the host can capture key aspects of host-parasite interactions.

26.4 HANDELSMAN, C.A.*; NELSON, J.A.; CLAIREAUX, G.; Colorado State University, Fort Collins, CO, Towson University, Towson, MD, Station Méditerranéenne de l'Environnement Littoral, Sète, France; *Corey.Handelsman@colostate.edu*

Do morphology and swimming performance predict ecological performance in wild and cultured European sea bass (Dicentrarchus labrax)?

The ecological performance of animals can be considered a component of Darwinian fitness. Furthermore, in fish, body morphology and swimming performance are often measured in the laboratory but their contribution to individual success in the field is rarely evaluated. Therefore, this critical step in linking performance traits to individual fitness is frequently ignored. We assessed sprint swimming performance and body morphology in wild and cultured juvenile European sea bass (*Dicentrarchus labrax*) and found substantial variation in both. Moreover, individual sprint swimming performance was found to be repeatable on a daily basis and marginally repeatable following 5-months under simulated natural conditions. These repeatable differences in swimming performance make this test potentially useful as a fitness parameter. To examine one possible source of individual variation in sprint swimming performance and to evaluate our results within the morphology-performance-fitness paradigm, juvenile European sea bass of known performance underwent geometric morphometric analysis of lateral body morphology. Wild fish exhibited a more fusiform body shape and were capable of faster sprint velocities than cultured conspecifics. Replicate groups of wild and cultured fish were released into mesocosms for 14 weeks to simulate natural conditions. Ecological performance in the mesocosms was measured as successful foraging and evading avian predation. Wild fish outperformed cultured fish (35% vs. 0% survival). The significance of morphological variation and sprint performance to the ecological performance of European sea bass populations will be discussed. This project was funded by Funded by the U.S. NSF and CNRS and Ifremer (France).

S1-2.6 HANKE, W.*; LAUDER, G.V.; Harvard University, Cambridge; *whanke@oeb.harvard.edu*

Fish schooling: 3D kinematics and hydrodynamics

Fish can aggregate to groups generally termed shoals . In case of polarized and synchronized swimming behaviour, these special shoals are termed schools . Aggregating into groups can have various advantages for fish, including energy saving due to hydrodynamic effects. The possibility that fish might gain an energetic advantage from hydrodynamic effects in a school has been discussed for decades and was partly supported by experiments that quantified the tail beat frequency of the school members, but remains controversial. We are using three synchronized megapixel digital video cameras to image small (5-6 individual) schools of giant danios (*Devario aequipinnatus*) swimming at a range of speeds (1-6 L/s) at 1000 Hz. Two cameras are used to record the three-dimensional position of individual fish in the school while the third camera records particle image velocimetry (PIV) images to quantify water flow within the school. Two lasers are used to generate orthogonal light sheets to minimize shadows within the school. Our PIV system uses a custom laser-scanning system to sweep the laser light sheet through the volume occupied by the school at a high rate. This allows near-volumetric analysis of fish school hydrodynamics. Preliminary results indicate that the danios in a school, although not sustaining a fixed spatial pattern, can obtain a slight hydrodynamic advantage from schooling at higher swimming speeds. More species remain to be investigated to reveal possible differences in species from different ecological niches.

41.5 HANKEN, J.; Museum of Comparative Zoology, Harvard University, Cambridge, MA; *hanken@oeb.harvard.edu*

The future of university-based natural history museums: lessons from history

Contemporary natural history museums confront a future ripe with promise and uncertainty. This is especially so for university-based museums, which must compete both financially and intellectually with other deserving academic programs and suffer the frequent perception that they are irrelevant to modern biology. This predicament can be traced in part to an incorrect understanding of the unique and valuable contributions that natural history museums can make to research and teaching, and of the critical importance of scientific collections to these and broader societal activities. It also, however, reflects a significant narrowing of the intellectual breadth and academic scope of programs at many university-based museums, compared with those that prevailed when these same institutions were founded in the late 19th and early 20th centuries. To insure they have a place at the table in biology of the 21st century, university-based natural history museums need to expand their vision of acceptable core activities and subject areas, thereby integrating themselves more effectively with molecular biology, genetics and genomics, ecology, physiology and other compelling fields. Far from representing a heretical shift from the appropriate identity of a natural history museum, such actions will allow these institutions to hew more closely to the ambitious and central role of natural history museums that was envisioned when they were founded more than a hundred years ago.

40.5 HANNON, R,M*; KELLY, S,A; MIDDLETON, K,M; KOLB, E,M; POMP, D; GARLAND JR., T; Univ. of California, Riverside, Univ. of North Carolina, Chappel Hill; *rhann002@student.ucr.edu*

Phenotypic effects of the "mighty mini-muscle" allele in a large HR x C57Bl/6J backcross

Beginning with a base population of outbred Hsd:ICR mice, we produced four replicate lines of mice selected for high voluntary wheel-running (S lines), while also maintaining four non-selected lines as controls (C lines). During the experiment we discovered an apparent Mendelian recessive allele whose main phenotypic effect is to reduce hindlimb muscle mass by approximately 50%. Analyses show that the allele has been favored by the selection protocol, and it eventually went to fixation in one of the selected lines. Individuals homozygous for this allele exhibit various pleiotropic effects, including doubled mass-specific muscle aerobic capacity, larger hearts, lungs, livers, spleens, and kidneys, and longer, thinner hindlimb bones. To begin mapping of the genomic location at which the mutation resides, we crossed the fixed mini-muscle line to the inbred C57Bl/6J strain, and backcrossed the F1 to the mini-muscle line. We dissected approximately 400 backcross mice and found a 50:50 ratio of normal:mini-muscle phenotype, with no overlap in relative muscle mass, thus confirming the recessive nature of the allele on this new genetic background and indicating that this backcross population is highly suitable for eventual linkage mapping of the chromosomal position of the mutant allele. In the backcross population, mini-muscle individuals ran more on days 5+6 of a 6-day exposure to wheels, at higher average and maximum speeds, but not for more minutes per day. Mini-individuals were smaller in body mass. After adjusting for variation in body mass, mini-muscle individuals had relatively larger ventricles and spleens. Supported by NSF grant IOB-0543429 to T.G.

54.1 HARDY, KM*; KINSEY, ST; UNCW; *kmh6265@uncw.edu*

Morphological adaptations in large muscle fibers secondarily evolved for aerobic locomotor function

Swimming muscles of the blue crab, *Callinectes sapidus*, undergo extreme hypertrophic cell growth during post-metamorphic development, reaching dimensions that far exceed normal cells. The low cell surface area:volume and long intracellular diffusion distances associated with large cells compromise aerobic metabolism. While this does not impede contraction in the anaerobic light fibers, the rate of aerobic processes are limited. However, blue crabs have large dark fibers with a high aerobic capacity that power sustained swimming. It is likely that the dark fibers have evolved structural and physiological modifications to facilitate aerobic activity. For example, they have a network of intracellular subdivisions whose effective diameter is closer to that of a normal cell. We hypothesized that the dark fibers have metabolic functional units that are a constant size during development, but a contractile functional unit that grows hypertrophically to extreme dimensions. These fibers were expected to exhibit pronounced intrafiber perfusion to promote oxygen flux to the cell's interior, but incomplete cytoplasmic isolation between the individual subdivisions. To explore the microvasculature, we used wheat germ agglutinin to label the endothelial cells and microbeads to fill the vessel spaces. Both techniques confirmed the presence of an elaborate network of vessels in the dark fibers compared to the light fibers. To ascertain the degree of cytoplasmic connectedness between subdivisions we used fluorescence recovery after photobleaching to compare diffusion coefficients (D) between fibers types. As anticipated, there was a lower D in the dark fibers, owing to the ability of the subdivision walls to stop molecular diffusion. These unique modifications allow the dark fibers to retain aerobic activity in spite of their extreme dimensions.

43.2 HARLOW, H.J.*; LOHUIS, T.D.; LASKE, T.G.; GARSHELIS, D.L.; ROURKE, B.C.; IAIZZO, P.A.; Univ. of Wyoming, Laramie, Dept. of Fish & Game, Soldotna, Alaska, Medtronic, Inc., Minneapolis, Minnesota, Minnesota Dept. of Natural Resources, Grand Rapids, California State Univ., Long Beach, Univ. of Minnesota, Minneapolis; *hharlow@uwyo.edu*

Skeletal Muscle Conservation and Adaptive Fasting by Hibernating Black Bears

The black bear *Ursus americanus* represents a paradox among hibernating mammals. They remain in their winter den for 3 to 5 months in mild, continuous hypothermia (about 33ºC); all the while not eating or drinking but capable of remarkable mobility when disturbed. Fat is a major energy resource that correlates with plasma leptin levels. Fatty acid saturation index is relatively maintained throughout the winter. Plasma amino acid profiles and urea/creatinine ratios suggest bears are adaptive long-term fasters with an extended protein conservation phase. Many muscle groups remain stable throughout 120 days of fasting and inactivity, while others show only marginal atrophy. Skeletal muscle protein degradation is matched by synthesis; fiber morphology (number, size and myosin heavy chain isoforms) show limited alteration and use of labile protein reserves may help preserve myofibrilar protein. Bouts of daily muscular contractions in concert with protein conserving processes result in marginal loss of skeletal muscle strength measured *in vivo* and *in vitro*. When injured during the winter, bears demonstrate remodeling of dermal layers and remarkable wound healing. We found that small mammals entering either deep or shallow torpor achieve similar overwinter retention of skeletal muscle protein and strength. This may be in part due to the process of urea recycling. We have identified UTB urea transporters in the bladder and large intestine of small mammals which may work in concert with gut microbes to recycle urea important for skeletal muscle retention.

25.10 HARPER, C/J*; MCLELLAN, W/A; ROMMEL, S/A; DILLAMAN, R/M; GAY, D/M; PABST, D/A; UNC Wilmington; *cjh8891@uncw.edu*

The Gross Morphology and Fiber Architecture of the Melon in Bottlenose Dolphins, Tursiops truncatus

The melon is a uniquely derived lipid structure located in the odontocete forehead that functions to propagate echolocation sounds into the surrounding aquatic environment. To date, the melon's abilities to guide and impedance match biosonar sounds to seawater has been attributed to its unique fatty acid composition. The melon, though, is also a connective tissue structure that is acted upon by two groups of facial muscles the rostral and nasal plug muscles. The goals of this study were to investigate the gross morphology of the melon and to describe the connective tissue fiber populations within the melon. The melon's gross morphology was investigated by serially sectioning the dolphin forehead in three orthogonal body planes to identify the soft tissue connections between the melon and the surrounding muscles and blubber. The melon was also thin-sectioned in three body planes and polarized light was used to reveal the birefringent collagen fibers within the melon. The melon is reinforced by highly organized populations of connective tissue fibers, most of which appear to be tendons of facial muscles. Along the ventral floor of the melon, there is a horizontally oriented fiber population tethered between the right and left facial muscles. These fibers appear to mechanically separate the nasal plug from the melon and may have a retinacular function. The tendons of the rostral muscles traverse through the body of the melon and either join tendons from the contra-lateral muscles, or insert into the outer blubber. This morphology suggests that the facial and rostral muscles may produce shape change and/or pressure change within the melon, which may affect how sound propagates through the melon.

41.3 HARRIS, Michelle A.; University of Wisconsin-Madison; *maharris@wisc.edu*

Grading Student Lab Papers and Oral Presentations Fairly and Consistently Using Rubrics

Many of us require our students to write and orally present research papers and/or lab reports summarizing their lab work. We do this to assess how well our students understand key concepts embedded within and demonstrated by their lab activities. For our students, the process of writing and speaking about their lab work often helps them realize how well they understood or, very frequently, did not understand these key concepts. Student writing and oral presentations are therefore powerful instructional and assessment tools. The oral presentation and paper writing processes are very challenging for most students, particularly those new to the scientific research paper format. In the honors undergraduate Biology Core Curriculum (Biocore) Program at the University of Wisconsin-Madison, we have found that most students achieve excellent scientific communication skills only after completing multiple research papers and presentations. Students benefit even further when they have the opportunity to revise their papers and presentations after getting feedback from instructors and peers. Perhaps most importantly, we have learned the importance of using rubrics to make our expectations and grade assignment process transparent to our students. In this presentation I will summarize how we use detailed research paper and oral presentation rubrics to make our expectations explicit to our students and to help us assess each research project summary fairly and consistently. Comments from instructors and students regarding their use of the rubrics will be highlighted. I will provide attendees with copies of rubrics for standard research final papers, research proposal papers, and for evaluating oral research presentations.

28.9 HART, M.W.**; SUNDAY, J.; Simon Fraser Univ.; *mike_hart@sfu.ca*

Things Fall Apart

Phylogeographic studies of marine (and other) animals frequently report within-species genetic variation that is consistent with cryptic species diversity or hybridization. We reviewed a number of such studies with an eye toward developing a quantitative and objective rule-of-thumb for identifying candidate cryptic species (or hybrids). The method uses between-species application of parsimony network (or minimum spanning tree) methods developed for within-species phylogeography. A survey of recent marine phylogeographic studies shows that alignments of DNA sequences typically fall apart into a separate subnetwork for each Linnean species, with low statistical confidence (< the 95% connection limit) in the connections between sequences from different species. In contrast, DNA sequences from single species even those with broad ranges, complex biogeographic histories, or signatures of selection on the genetic markers typically produce single haplotype networks. In other cases, sequences from single Linnean species fall apart into multiple subnetworks that have been interpreted as evidence of cryptic species diversity or introgression. The result suggests that such network analyses (as a supplement to other methods of species identification) can provide an objective benchmark for flagging cryptic species and hybrids. We illustrate some applications and limits of this method relative to recent speciation events and new (sometimes controversial) efforts to document the diversity of life through mitochondrial DNA barcoding.

35.2 HARTENSTEIN, Volker*; YUAN, David; NAKANISHI, Nagayasu; JACOBS, David K.; UCLA; *volkerh@mcdb.ucla.edu*

Embryogenesis and metamorphosis of Aurelia aurita

We observed morphogenesis of the Aurelia aurita from embryogenesis, through the planula to early polyp using markers for nuclei (sytox), actin/myofibrils (phalloidin), neurons (Tyrosinated tubulin, FMRFamide, 5HT), dividing cells (Phosphohistone) cell death (Caspase 3) and TEM. Early embryos form a mono-layered blastula. At gastrulation, the future endoderm invaginates through the blastopore as a coherent epithelium. Endoderm then forms a solid inner mass of large vacuolated cells and the former blastopore is lost. Ectoderm develops as a pseudostratified epithelium, separated from the endoderm by a pronounced basement membrane with no interstitial cells. Cell division occurs in all embryonic tissues until shortly after gastrulation. FMRF-positive nerve cells differentiate within the ectoderm of the planula; they have T-shaped axons which extend at the endoderm-ectoderm boundary in antero-posterior direction. Neurons are located at the aboral pole and a cylindrical domain in the anterior half of the planula. At the onset of metamorphosis, neurons degenerate and are taken up into the endoderm, which also undergoes apoptosis. At the same stage, a secondary blastopore surrounded by four, later 8 tentacle buds appears at the oral pole of the metamorphosing animal. Secondary endoderm giving rise to the gastral cavity and the solid cellular stands filling the interior of the tentacles arise at the secondary blastopore, through invagination and delamination from the deep layers of the former planula ectoderm. Cell division occurs at the base of the tentacle buds, but not the extending tentacles themselves. A new set of intraepithelial neurons also arises at the tentacle base. Our data provide the anatomical framework for ongoing studies of gene expression and function in Aurelia development. The apoptosis of larval neurons and endoderm are novel observations.

6.10 HARTMAN BAKKEN, Bradley*; SABAT, Pablo; University of Wyoming, Laramie, Wyoming, USA, Universidad de Chile, Santiago, Chile; *bradley@uwyo.edu*

Mechanisms of water balance in hummingbirds

Hummingbirds face a curious osmoregulatory dilemma. To meet their high mass-specific energy demands, they regularly ingest multiples of their body mass per day in water; yet, with a high mass-specific rate of total evaporative water loss and no capacity to form hyperosmotic urine, they are prone to dehydrating quickly during fasts. How do hummingbirds resolve this quandary? To avoid overhydration, hummingbirds rely on two renal mechanisms. The most prevalent of which is to reduce water reabsorption, but the rate at which body water is filtered appears to be responsive to water loading as well. To lessen the likelihood of dehydrating during fasting periods, hummingbirds greatly reduce, and even cease, renal filtration. Although this water conserving strategy reduces body water losses in urine, total evaporative water loss rates in resting hummingbirds indicate they still dehydrate during natural, overnight fasts. We have identified the strategies hummingbirds use to resolve their osmoregulatory dilemma; however, it remains unclear how they tolerate both renal failure' and potentially severe dehydration.

7.5 HATCH, K.H.**; ROEDER, B.L.; AUGER, J.; BLACK, H.L.; BUNNELL, K.D.; Brigham Young University, Utah Division of Wildlife Resources; *khatch@byu.edu*

Effects of habitat, age, and sex on black bear carnivory: a stable isotope approach

Black bears (*Ursus americanus*) occupy diverse habitats in Utah, from alpine habitats, to montane forests, to mountain brush (including sage) in semiarid country. Bears are long-lived mammals, and in Utah old bears (10+ years) are relatively common, partly because hunting pressure is relatively light throughout the state. These conditions allowed us to ask how habitat, age, and sex affects carnivory in black bears. Visual observation of bears is time consuming and costly, and analysis of bear scats underestimates carnivory because meat is highly digestible; therefore, we analyzed $^{15}N/^{14}N$ ratios in the hairs of bears as a measure of their carnivory. Hairs, a vestigial premolar (for age determination by cementum annuli analysis), sex data, and location data were gathered from hunter-harvested bears checked at Utah Division of Wildlife offices in 2005. Our analysis showed that male black bears in Utah are more carnivorous than female black bears by approximately one-third of a trophic level. Carnivory increased with age for some hunt units within Utah, but not all. Finally, the ranges of the most carnivorous bears coincided with those parts of Utah where sheep are grazed, suggesting that these bears may utilize sheep as prey or carrion.

20.2 HAU, M*; BEEBE, K; CANOINE, V; SCHLINGER, BA; Princeton University; *hau@princeton.edu*

Seasonal variation in the endocrine regulation of aggressive behavior in a sedentary tropical bird

Evidence is accumulating from studies in temperate-zone male vertebrates that the endocrine regulation of aggressive territorial behavior differs seasonally. During the breeding season a combination of androgenic and estrogenic mechanisms appear to regulate male aggressive behavior, while during the non-breeding season either only estrogenic or non-sex steroidal mechanisms control male aggression. Research on sedentary neotropical spotted antbirds (Hylophylax n. naevioides) that defend a multi-purpose territory together with a long-term partner had suggested that testosterone is involved in regulating territorial aggression at all times of year. Here we experimentally test this notion in both male and female spotted antbirds. Free-living males and females responded to simulated territorial intrusion (STIs) with a live male decoy by displaying aggressive behavior of similar quality and quantity in the non-breeding season, the early and the middle of the breeding season. Circulating concentrations of testosterone after STIs in both sexes were low and seasonally invariant, but both sexes had increased plasma dehydroepiandrosterone (DHEA) concentrations during the non-breeding season. The combined administration of an androgen receptor antagonist (Flutamide) and an aromatase inhibitor (ATD) during the non-breeding season did not reduce aggressive behavior in captive spotted antbirds, while in a previous study a similar treatment during the breeding season did reduce aggressive behavior. These data confirm that aggressive behavior can be regulated by divergent endocrine mechanisms in different seasons, even in sedentary species that remain on the same territory with the same partner for many years. The specific endocrine mechanisms that regulate aggressive territorial behavior in spotted antbirds during the non-breeding season remain to be determined, but may include low concentrations of estrogens.

6.3 HAVIRD, J. C.*; CHOE, K. P.; EVANS, D. H.; University of Florida, Vanderbilt University; *j_havird@hotmail.com*

The evolution and possible function of cyclooxygenase in chordates

In mammals, prostaglandins (PGs) are involved in many physiological processes such as blood clotting, inflammation and regulation of vascular tone and osmoregulation. Cyclooxygenase (COX) is one of the major enzymes involved in PG synthesis. In mammals there are two COX subtypes, COX-1 and COX-2, but COX orthologues have been found in many chordates including the sea squirt (*Ciona intestinalis*). In the mammalian kidney, COX-2 generated PGs inhibit ion transport and support cell survival during salt loading and dehydration. Our lab has previously confirmed a COX-2 orthologue in the gills of the euryhaline killifish (*Fundulus heteroclitus*), and evidence suggests that COX-2 (and COX-1) generated PGs may influence ion and water balance in fishes. However, it is unknown whether ancestral chordates possess COX-1 and COX-2 or a precursor (COX-A and COX-B) as in found in the sea squirt. The goals of this project were to determine the COX cDNA sequence(s) from the following ancestral chordates: lancelet (*Branchiostoma lanceolatum*), hagfish (*Myxine glutinosa*), lamprey (*Petromyzon marinus*), and also the COX-1 sequence from the killifish and longhorn sculpin (*Myoxocephalus octodecimspinosus*); to determine the phylogenetic relationship between the chordate COXs and the osmoregulatory functions of COX in chordates. Using standard RT-PCR and cloning procedures, COX orthologues were found in all animals studied. Phylogenetic analysis suggests that lancelets, hagfish and lampreys have a COX precursor, and lack COX-1 and COX-2, as found in elasmobranchs, teleosts and mammals. Procedures such as qRT-PCR, tissue distribution analyses and immunohistochemistry suggest COX may play an omsmoregulatory role in most chordates.

31.2 HAYWARD, L.S.*; WASSER, S.K.; University of Washington; *lhayward@u.washington.edu*

PHYSIOLOGICAL MEASURES OF DISTURBANCE RELATED TO VEHICLE EXPOSURE IN THE NORTHERN SPOTTED OWL

We used non-invasive measures of fecal corticosterone metabolites to investigate the effects of vehicle exposure on physiology of the Northern Spotted Owl (NSO), *Strix occidentalis caurina*, in two complementary studies. The first study draws on samples collected throughout the range of the NSO in Washington, Oregon and California by collaborators involved in long-term demographic studies. Using these samples, we investigated the effect of proximity to road on NSO corticosterone. After controlling for the effects of sex, season and year, we found that proximity to road had a highly significant positive effect on levels of corticosterone. We also found that NSO in National Forests had significantly higher levels of corticosterone than NSO in National Parks. In contrast, presence of barred owl had no effect on corticosterone in the NSO. The second study involves the experimental application of acute off-highway vehicle exposure to NSO. We conducted our experiments in the Mendocino and Shasta-Trinity National Forests of Northern California with help from our partners in US Forest Service, US Fish and Wildlife and Blue Ribbon Coalition. We found that acute exposure to experimentally applied OHV use significantly increased corticosterone in male, but not female, NSO. This sex difference is consistent with previous work demonstrating that proximity to logging roads and intensely harvested forest correlates with higher glucocorticoids in male, but not female, NSO. Sex differences in demands associated with reproduction may underlie the variation in vulnerability to disturbance in this species

S1-4.3 HEDRICK, TL*; DANIEL, TL; Univ. of North Carolina, Chapel Hill; *thedrick@email.unc.edu*

Creating a flap: Different ways to wing it

Hovering insects appear to precisely maintain their position and orientation while flapping with nearly unchanging wing motions. However, simulations of hovering flight in the hawkmoth *Manduca sexta* suggest maintaining position and orientation over an extended series of wingbeats requires continual variation in wingbeat kinematics. But, the degree of inter-wingbeat variation employed by actual, rather than simulated, insects is poorly characterized, as are any tradeoffs between maintenance of position and the frequency of variation in wing kinematics. Here we analyze the variation in body position, orientation and the kinematics of wingbeats over extended sequences of hovering flight in *Manduca sexta*. We collected high-speed, three dimensional kinematics from six individuals feeding from a stationary flower in a laboratory flight chamber. Each flight sequence contained at least two seconds of continuous flight, allowing us to extract sequences of 60 or more wingbeats. The wingbeat kinematics were reduced to a series of 10 parameters specifying wing motions and abdominal flexions through a single wingbeat; these parameters are similar to the output from the simulated hawkmoth. The magnitude and rate of variation in the kinematic parameters was similar to that predicted by the simulation. However, the recorded kinematics also contained correlations between different parameters that were not present in the simulation results. For example, the amplitude of wing rotation about the spanwise axis was closely related to the mean forward sweep of the wing in the prior stroke. The mechanisms underlying such correlations are unknown, but may relate to sensory delays, dynamics of the mechanical system or some combination of these.

10.5 HEJNOL, A.*; MARTINDALE, M.Q.; Univ. of Hawaii, Honolulu; *hejnol@hawaii.edu*

The evolution of Bilateria insight from an acoel flatworm

Recent molecular phylogenies place the Acoelomorpha (Acoela + Nemertodermatida) as the sister to all remaining Bilateria before their split into Proto- and Deuterostomes. This phylogenetic position makes the acoel flatworms a key group to investigate for our understanding of the evolution of important features of the Bilateria, such as the mesodermal layer, an orthogonal nervous system with a brain and the position of the mouth and anus in relation to the body axis. Scenarios of the evolution of the Bilateria from over a century ago, as the Acoeloid-Planuloid-Hypothesis suggested already a common ancestor which is similar to the acoel flatworms we find today. To get more insights about the evolution of the bilaterian key features we investigated the expression patterns of genes used in proto- and deuterostomes to specifiy the axial patterning, mesoderm and orthogonal nervous system in the acoel *Convolutriloba longifissura*. Here we concentrate on the axial relationships and the origin of the mouth of the Acoela using the expression of anterior-posterior (HOX and paraHOX) and dorso-ventral patterning (e.g. *NK2.1* and *vax*) genes as well as the genes *goosecoid* and *brachyury*, which play a role in the determination of the mouth and anus. The genes specifying the dorsal-ventral axis show a similar pattern as it is found in protostomes and hemichordates, and the expression of *brachyury* and *goosecoid* mark the regions which take part in fore- and hindgut formation in the remaining Bilateria. Our results and the given position of the Acoelomorpha as the sister group to the remaining Bilateria strongly supports the Acoeloid-Planuloid-scenario of bilaterian evolution.

S2-1.3 HELMS, J.A.*; BRUGMANN, S.; ALLEN, N.; YOUNG, N.M.; Stanford University; *jhelms@stanford.edu*

Unraveling the basis for species-specific facial form

The human face shows remarkable variability and because of this it is oftentimes the singular feature used to distinguish and discriminate among individuals. Despite this exclusivity, the structural edifice of the face is so highly conserved that its underlying pattern is shared by nearly all vertebrates. One might then wonder, what forces act to establish the craniofacial bauplan? And what are the driving influences behind the divergence in craniofacial form? As Darwin and many other scientists speculated, the answer to both questions lies in natural selection- but the molecular pathways which establish the global organization of the face remain unknown. In this talk I will present new data that addresses this question, beginning with the identification of key pathways that control local proliferation within the emerging facial prominences and thus lead to species-specific variations in facial form. How much genetic change has to occur in order to generate such craniofacial diversity is still a mystery, but we explore this question by modulating these pathways in an incremental fashion, and observe the resulting variations in craniofacial morphology. In the end, our goal is a detailed understanding the tissue interactions that mediate normal craniofacial morphogenesis because this information provides much needed clues into the developmental steps that underlie species-specific craniofacial diversity.

9.3 HENNINGSEN, J.P.*; LAPPIN, A.K.; NISHIKAWA, K.C.; Northern Arizona University; *jhenning@nsm.umass.edu*

Cracking the weevil: behavioral plasticity of feeding as a function of prey hardness in the collared lizard

A number of studies have demonstrated that lizards modify their feeding behavior based upon prey characteristics. However, in their experimental design, few of these studies have considered natural prey items. Collared lizards (*Crotaphytus collaris*) provide a system for examining the effects of the hardness of prey on feeding behavior, as they regularly consume hard prey, particularly curculionid beetles (weevils). The diet of *C. collaris* also includes orthopterans, including gryllids (crickets). We used crushing tests with a force transducer to measure prey hardness and high-speed digital imaging (250 fps) of feeding sequences to examine the effects of prey hardness on feeding (i.e., prey processing) behavior. We found that (1) curculionids require an order of magnitude more force to crush than crickets, and (2) curculionids induced longer processing times and greater numbers of processing bites than did crickets. Studies that focus on natural extreme behaviors, such as this one, provide a powerful empirical basis for the study of adaptive morphological and behavioral evolution.

S3-1.7 HENRY, Jonathan/Q*; PERRY, Kimbely/J; MARTINDALE, Mark/Q; University of Illinois-Urbana, University of Hawaii, PBRC Kewalo Marine Laboratory; *j-henry4@uiuc.edu*

Molecular controls of axis specification and cell determination in marine invertebrate embryos and larvae

Recent advances in cell and molecular biology have permitted an understanding of cell interactions and molecular signalling pathways that control early development, more specifically those relating to the establishment of specific cell fates and axial properties that define larval and adult morphologies. Comparative work reveals a tremendous level of conservation, but also interesting differences between representative species. For instance, data suggests that beta catenin plays a key role in the transduction of signals involved in establishing cell fates along the animal-vegetal axis particularly related to the establishment of the endomesodermal lineages (e.g., gut) in the larvae and adults of various metazoans. New studies, including our own, indicate that this role is also conserved within representative protostome (lophotrochozoan) phyla. On the other hand, there are some significant differences found in certain species, even between members of the same phyla (e.g., Mollusca). All metazoan embryos set aside cells that serve as key inductive signaling centers ("organizers") that specify the fates of adjacent cells and entrain various axial properties. The establishment of the dorsal (D) organizer in the spiralian phyla (annelids, molluscs, etc.) relies on MAPK signal transduction, but there are interesting evolutionary differences related to the spatial and temporal activation of MAPK in the dorsal cell lineage of various spiralians. This report considers the evolution and function of these signal transduction pathways in metazoan development.

38.4 HENRY, J.R.*; HARRISON, J.F.; Arizona State University; *Joanna.Henry@asu.edu*

Does body size affect the safety margin for oxygen delivery in flying dragonflies?

It has been widely hypothesized that the evolution of insect gigantism during the late Paleozoic was permitted due to increased atmospheric oxygen levels at the time. One mechanism by which increased atmospheric oxygen levels might facilitate evolution of larger insects would be by enabling more efficient delivery of oxygen to tissues in larger animals. According to this hypothesis, larger extant insects should have a lower safety margin for oxygen delivery. Nevertheless, recent studies have shown that safety margins for oxygen delivery neither decrease with size in resting or hopping grasshoppers, nor with feeding *Manduca* caterpillars. However, perhaps these prior negative results occurred because they did not test insects during the conditions of maximal oxygen consumption -namely flight. We measured the oxygen-sensitivity of take-off capacity and flight metabolic rate for 12 species of dragonflies that vary by an order of magnitude in body size. Flight metabolic rates and flight times were measured in 2.5, 5, 7.5, 10, 15, 21 and 30% O_2 balanced with N_2 or helium. Atmospheric oxygen levels strongly affected flight metabolism and times, and hypodense atmospheres increased flight metabolic rates. However, data suggest that large body size is not correlated with a reduced safety margins for oxygen delivery. These results and other studies consistently suggest that insects match oxygen delivery capacity to need across size changes, due to morphological (increased tracheal densities) and physiological (increased convection) changes. Simple diffusive models of gas exchange that postulate a need for higher oxygen to enable oxygen delivery in larger insects should be abandoned. This research was funded by NSF grant IBN-0419704 awarded to JFH.

40.1 HERNANDEZ, L.P.; George Washington University, Washington, DC; *phernand@gwu.edu*

Hedgehog signaling in differentiation, growth, and maintenance of craniofacial features during larval development in zebrafish.

Hedgehog signaling has been shown to play an important role in proper craniofacial development. While the role of this signaling pathway in early embryonic development has been well documented in zebrafish, its role in growth and maintenance during later larval development has not been investigated. We have examined the role of the Hedgehog (hh)-signaling pathway on the growth and maintenance of the viscerocranium in the zebrafish, Danio rerio. Given that hh is expressed within the pharyngeal region until relatively late in development, it is likely playing an important role in maintenance of pharyngeal structures. Cyclopamine (CyA), a pharmacological agent known to block all hh signaling, was administered to embryonic zebrafish. Different treatment times (24 hours post fertilization [hpf], 36hpf, 48 hpf, 60 hpf, 72 hpf, 96 hpf) were used to determine the role of hh signaling during different developmental time points. When embryos were treated at the earlier time points (24hpf), the treated zebrafish did not develop branchial cartilages suggesting that hh-signaling is necessary for branchial arch differentiation. Later treatment times showed reduced growth of all pharyngeal cartilages as compared with controls. Moreover, experiments with later treatment times revealed that structures that had developed normally prior to treatment with CyA were not maintained once hh signaling was blocked. These findings suggest that the hh-pathway is not only important in branchial arch differentiation, but is also important for the growth and maintenance of the pharyngeal cartilages. Surprisingly, growth of the second pharyngeal cartilage, the hyoid, did not show significantly reduced growth. These findings suggest that a different genetic pathway may control hyoid growth.

S9-1.6 HERREL, A.*; SCHAERLAEKEN, V.; MEYERS, J.J.; METZGER, K.A.; ROSS, C.F.; University of Antwerp, Antwerp, Belgium, U. Massachusetts, Amherst, Brown University, Providence, University of Chicago, Chicago; *anthony.herrel@ua.ac.be*

The evolution of cranial design and performance in lepidosaurians: consequences of skull bone reduction on feeding behavior.

The evolution of cranial design in lepidosaurians is characterized by a general trend towards the loss of distinct cranial elements. The loss of the lower temporal bar in squamates was associated with an increase in the mass of the jaw adductors resulting in higher bite forces and a more efficient feeding behaviour. Among squamates the supratemporal bar was reduced at least twice independently which induced a large degree of mobility into the skull. In Gekkotans this was accompanied by a reduction of the postorbital bar, resulting in a pronounced intra-cranial kinesis, a reduction in bite force and a decrease in feeding efficiency. Gekkotans, however exploited the intracranial mobility to increase jaw movement velocity allowing them to capture more evasive prey. In varanoids, the loss of the supratemporal bar also resulted in a decrease in bite force which was, however, compensated by a general increase in body size, specialized dentition and novel prey transport mechanism. The extreme degree of intracranial mobility that arose from the extensive reduction of dermal bones in ophidians and some pygopodids came at a cost of decreased bite performance and increased prey handling time. However, macrostomatan snakes and pygopodid geckos exploited their intracranial mobility to efficiently transport relatively large prey with minimal prey reduction prior to swallowing. Specialisations towards durophagy or herbivory in squamates arose independently in most groups and were accompanied by a general fortification of the cranial bones, increased jaw muscle mass and bite forces. Thus lepidosaurians appear to be a model system to investigate the consequences of morphological changes on performance and behavior.

5.3 HESS, Christopher M*; O\'BRIEN, Sara; DAVIS, Jason; ADDIS, Elizabeth; WINGFIELD, John C. ; University of Portland, University of Washington; *hess@up.edu*

Effects of human disturbance and global warming on hybridization and gene flow in two subspecies of White-crowned Sparrows (Zonotrichia leucophrys)

Isolation is an important component in species formation and maintenance of biodiversity. This process of adapting to an environment can be inhibited by gene flow from neighboring populations. The earth is not a static place and periodically, environmental conditions change resulting in altered patterns of gene flow and causing certain taxa to expand or modify their range. There is increasing evidence that global changes at least indirectly caused by humans (i.e. global warming) have led to range shifts in groups such as *Drospophila*. Our field observations indicate that this process may also be occurring in vertebrates such as the White-crowned Sparrow in the state of Washington. The primarily lowland subspecies *Z. l. pugetensis* has increased its altitudinal range to the point that it now shares habitat with the montane subspecies *Z.l.gambelli*. We have observed individuals in the area of overlap that appear intermediate in both morphology and behavior, suggesting hybridization between the two groups, a pattern which was previously unknown in nature. To characterize the frequency of hybridization and to accurately document the rate of spread of alleles we are characterizing gene flow using neutral microsatellite markers. Ultimately, our estimates of gene flow will help us to predict the long term integrity of these two subspecies and begin understanding potential effects of global change on biodiversity.

2.7 HICKS-COURANT, Miranda L.*; CRESPI, Erica J.; Vassar College; *mihickscourant@vassar.edu*

Leptin enhances growth and development under disease exposure in Xenopus laevis tadpoles

Leptin is a cytokine hormone that is best known for regulating food intake, energy expenditure, and reproduction, but recent studies have shown that it also affects immune response in mammals. While leptin has evolutionarily conserved energy balance functions in amphibians, it is unknown if leptin also plays a role in immune function, or when its role in immune function develops. We tested the hypothesis that leptin facilitates immune responses in amphibians and that this function develops during larval stages. First, we used RT-PCR to show that the leptin receptor is expressed in the spleen of *Xenopus laevis* tadpoles and juveniles. Because the spleen is the main site of lymphocyte production, this result supports a potential role of leptin signaling in immune function in amphibians. We then conducted two experiments in which tadpoles were exposed to a gram-negative bacterial pathogen to determine if intra-peritoneum injections of recombinant *Xenopus* leptin into *X. laevis* tadpoles would enhance survivorship, growth, and development. We found that leptin injections significantly increased survival in tadpoles exposed to high concentrations of bacteria in aquarium water relative to the saline-injected tadpoles (ANOVA $p = 0.001$). In a subsequent experiment in which tadpoles were exposed to a weaker bacterial dose, leptin injections facilitated growth and development while saline-injected tadpoles significantly lost weight and slowed development relative to non-injected tadpoles. These data show that elevated leptin levels enhance growth, development, and survival during an infection, although we cannot determine the specific mechanism of leptin action at this time. Furthermore, our results support a novel role of leptin as a growth factor during early development that may also be important in humans and other mammals.

S10.2 HIEBERT, S.M.; Swarthmore College, Swarthmore PA; *shieber1@swarthmore.edu*

Why you need the SICB Digital Library: its place in current pedagogy

The science education literature, including several recent reports by the National Research Council on the current status of science education, provides insights into how the population of learners has changed in recent decades and how we as science educators can better address their particular strengths and weaknesses. These changes have resulted not only from the rapidly evolving technological environments in which our students have grown up but also from the changing goals and practices of K-12 education, which have created new gaps in science literacy in high school graduates. Simultaneously, the field of science education continues to improve our understanding of the ways in which students learn best, and the ways in which teaching practices can stimulate excitement, engagement, and acquisition of knowledge in the classroom. This presentation will discuss some of these pedagogical issues and the ways in which Digital Library materials are envisioned to address them. The goal of the Digital Library is to allow educators to keep their pedagogy up-to-date in the fields that find a special home in SICB, without having to invest large amounts of time generating all of their own materials and ideas.

27.3 HIERONYMUS, TL*; WITMER, LM; Ohio University; *th108702@ohiou.edu*

How Dinosaurs Build Beaks: Homology Between Avian Rhamphotheca and Diapsid Facial Scales

Studying the evolution of facial integument in non-avian dinosaurs requires an initial framework of proposed transformational homologs for various diapsid skin features, including facial scales and avian rhamphothecae. The most thoroughly developed homology concepts that link bird beaks and lizard scales were proposed before the advent of molecular development studies and modern phylogenetic systematics, and as such are ripe for re-examination in light of a large body of new evidence. In this study, specimens from 170 extant and extinct diapsid taxa were surveyed for the relative topology of skin features, dermatocranial elements, and osteological correlates (OCs) of trigeminal (CN V) innervation. An unexpected overlap between the OC of the maxillary nerve and the frontonasal mass (FNM) -derived premaxilla in extant birds suggests a possible caudal migration of FNM-derived ectomesenchymal cells that may play a role in pattern formation in the avian beak. The lateral plate of the compound rhamphotheca found in basal birds is more closely associated with the caudally projecting maxillary process of the premaxilla than with the dermatome of the underlying maxillary nerve, as would be expected if FNM ectomesenchyme exerts control over epidermal beak development in the maxillary rostrum. The inclusion of new nerve and bone data lends credence to an existing hypothesis of transformational homology between the rostral premaxillary and mandibular scales of squamates and the avian beak that was initially based solely on epidermal similarity. These results are congruent with the six parallel occurrences of premaxillary beaks in maniraptoran theropods, and may have heuristic value for investigating beak evolution in more distantly related taxa.

S9-1.3 HIGHAM, T.E.; Harvard University; *tehigham@ucdavis.edu*
Swimming, running and flying: the evolution of locomotion during prey capture
Locomotion is highly integrated with prey capture in predatory vertebrates including diverse groups such as fish, birds, snakes, lizards and mammals. For example, accelerating, decelerating and maneuvering can be important aspects of capturing evasive prey. Identifying trends among and across groups of organisms may provide considerable insight into general rules that constrain and facilitate the co-evolution of feeding and locomotor performance. The goals of this study are to first highlight, in a variety of vertebrate taxa, the components of feeding performance that rely on locomotion, and then present experiments involving suction feeding in fish. Moving fast during prey capture, whether swimming, flying or running, may incur a reduction in strike accuracy. Thus, a key question is whether animals that move fast during prey capture exhibit adaptations for relieving the constraints imposed by accuracy. If locomotion and feeding are highly integrated, then certain morphological and behavioral aspects of locomotion likely facilitate feeding on particular prey types. For example, different locomotor specializations are likely necessary for feeding on evasive *versus* sessile prey. Identifying the traits that enhance feeding on a particular prey type may provide insight into the diversity of locomotor morphologies and behaviors. For fish, a relatively large mouth, which implies a relatively large ingested volume of water, facilitates swimming fast during prey capture as there is a reduced need to strike accurately. For fish with smaller mouths, braking, which is achieved by extending the paired and median fins, is very important for maintaining accuracy. Thus, the diversity in fin morphology may be related to mouth size and feeding. This research was supported by NSF grant IOB-0444554.

19.1 HILL, PSM*; SHADLEY, JR; Univ. of Tulsa; *peggy-hill@utulsa.edu*
Variation in Gryllotalpa major burrow mouths: Why bother?
Most molecricket males in the Orthopteran family Gryllotalpidae produce sexual advertisement songs from constructed burrows in the soil. The surface openings, or mouths, of the burrows vary in number among species for which they have been described from none to six or more, and the burrow mouth and acoustic chamber it leads to have been useful in discriminating among species in the field. However, burrows of only a few of the 91 or so extant species have been described, and no within-species variation has been reported except for the prairie molecricket *Gryllotalpa major*, where we have found six distinct shapes to the single burrow opening at White Oak Prairie in Oklahoma, USA. Since the burrow mouth acts as the system radiator in molecrickets, an early hypothesis was that population-level variation in call parameters such as dominant frequency and amplitude of the advertisement call might be linked to the shape of the burrow mouth. However, we have been unable to support this hypothesis empirically and continue to seek a functional role for this non-trivial structural variation. The chirping songs males produce are directed toward flying females, who fly above an aggregation of calling males and then swoop down for a second pass closer to the ground before they land near a burrow and enter through the burrow mouth to mate (or not) underground. Nearby males ignore the airborne song but respond to a vibration component that propagates through the soil. We have been interested in how the chirping call, with its harmonic overtones and vibrational component, has evolved in a grassland habitat when most other molecricket songs worldwide are trills, and how all of this is related, if at all, to the variation in the burrow surface opening.

27.2 HOCH, JM; Stony Brook University; *jmatth@life.bio.sunysb.edu*
Development and functional variation of barnacle penis morphology
Barnacles are simultaneous hermaphrodites that reproduce by copulating with neighbors. To accomplish this, barnacles must extend their penis into the water column, locate receptive functional females and deposit sperm. This may take several minutes, during which the mating individuals are vulnerable to predators or disruption by wave action. This presentation addresses variation in penis functional morphology across environments and mating aggregations. First, I followed the development of the penis over the course of the year from barnacles in several locations. Confocal and traditional microscopy revealed the rapid growth of the penis within the month prior to the brief mating season and variation in musculature across environment. I measured the fertilization success rates of barnacles with different mate distances across a gradient of wave exposure to determine how far penises could reach. I then compared differences in morphology and condition of the penis to reveal functional consequences of penis variation. The data suggest that penises grow relatively longer when mates are more distant, but the increase in reach does not increase linearly. The ability to reach distant mates also decreases as wave action increases. Local mate competition theory for simultaneous hermaphrodites predicts changes in relative allocation to the sex roles based on mating group size. My data allows precise measurement of mating group potential for an individual barnacle and I discuss how this can be used to predict sex allocation within different environments.

62.3 HOFFMAN, AM*; TUTTLE, EM; Indiana State University; *hoffman@mama.indstate.edu*
Error in Non-Human Animals: the Effects of Motivation and Distraction on Animal Performance
In the everyday life of a human, mistakes are so common that they are reflected in numerous clichés and proverbs, and a large body of research exists on the subject of everyday memory failure. However, very little has been done to determine if animals other than humans are capable of making mistakes, and, if they are, to ascertain causes of those errors. Motivation and distraction are both known to impair performance in humans in predictable patterns. Our research seeks to determine if animals are subject to the same factors, and whether these disruptions affect humans and animals in a similar manner. We trained European starlings (*Sturnus vulagaris*) to perform a simple discrimination task on an electronic operant device/data logger. We then measured performance under varying levels of motivation (manipulated through food deprivation) and distraction (manipulated by adding noise and motion to the birds' environments). Patterns of error and implications are discussed.

48.6 HOFFMAN, T.C.M.**; WALSBERG, G.E.; DENARDO, D.F.; Arizona State University; *ty@asu.edu*

Triple partitioning of total evaporation reveals the cloaca as a site of thermoregulatorily important rates of evaporative cooling in Inca doves, Columbina inca

Because of the high latent heat of vaporization of water, evaporation is an important thermoregulatory mechanism in animals from diverse taxa. Among endotherms, evaporative cooling allows for thermostasis even under conditions in which an animal gains heat conductively, convectively, radiatively, and metabolically. Historically, avian evaporation has been studied from the standpoint that there are two primary routes of evaporation: the buccopharyngeal epithelia and the skin. This paradigm has ignored one of a bird's two primary orifices, the cloaca, as a potential site of thermoregulatory evaporation. Because columbiforms are superlative among avian species in their ability to tolerate extremely high ambient temperatures in nature, we measured rates of evaporation in Inca doves, partitioning total evaporation into its buccopharyngeal, cutaneous, and cloacal components at each of four temperatures. Buccopharyngeal evaporation and cutaneous evaporation increased throughout the range of air temperatures studied. At 30°, 35°, and 40°C, cloacal evaporation was negligible. However, at 42°C, the rate of evaporation from the cloaca nearly equaled that from the panting bird's mouth, indicating that cloacal evaporation can be important for thermoregulation and that it can be controlled. This suggests that some birds can respond to the conflicting demands for hydrostasis and thermostasis by conserving cloacal water at lower temperatures and evaporating cloacal water when other modes of heat-loss, including evaporation elsewhere, no longer suffice.

S5.10 HOLLAND, P.W.H.*; JIMENEZ-GURI, E.; PHILIPPE, H.; OKAMURA, B.; REINHARDT, R.; YOUNGER , R.; FURLONG, R.F.; University of Oxford, UK, University of Montreal, Canada, University of Reading, UK, MPI Molecular Genetics, Berlin; *peter.holland@zoo.ox.ac.uk*

More than one way to make a worm

Worms dominate bilaterian diversity. Worms can be defined as soft-bodied, flexible, muscular, motile, extremely elongate animals lacking skeletons, but otherwise worms vary greatly in terms of muscle layout, and presence or absence of segmentation, cuticle and body cavities. The worm shape has proved highly adaptable, and was probably instrumental in allowing animals to exploit a third dimension by burrowing through sediment. Phylogenetically, worms are usually considered paraphyletic being found in Ecdysozoa (e.g. nematodes, priapulids), Lophotrochozoa (e.g. annelids, nemerteans) and Deuterostomes (e.g. enteropneusts, amphioxus); in each case descendent from a worm-shaped bilaterian ancestor. Here we describe two other ways in which worms have evolved: one by convergent evolution of the worm-shaped body, the other by degeneration from a skeletal animal.

18.5 HOLZMAN, R*; DAY, SW; HIGHAM, TE; WAINWRIGHT, PC; Univ. of California, Davis, Rochester Institute of Technology; *raholzman@ucdavis.edu*

It's all in the timing: forces exerted on prey during suction feeding in Bluegill

Suction feeding is perhaps the most common prey capture strategy of fishes. During suction feeding, the predator opens its mouth and rapidly expands its buccal cavity, generating a flow field external to the mouth. The rapid expansion of the buccal cavity produces high fluid velocities and accelerations that persist only a short distance from the mouth (about half of one mouth diameter), and for a short time (a few ms). Therefore, the predator must carefully time its strike to maximize the forces exerted on its prey. Enhancement of the forces can be achieved by increasing water velocities and acceleration, but also through locating the prey closer to the mouth at the time of peak flow speed. The objectives of this study were to directly measure the forces exerted by Bluegill on their prey and to assess the ways in which the fish modified that force. Bluegill were allowed to feed on ghost shrimps tethered to a load cell that recorded force at 5000 Hz, with concurrent 500 Hz video of the feeding sequences. The fish exerted forces on their 23 mm prey ranging from 0.3-0.73 N. In accordance with the short duration of the strikes (time to peak gape of 6-10 ms), the forces recorded were brief and abrupt (5-11 ms from initiation to peak force). Force magnitude fell steeply after the time of peak force. A model incorporating drag, pressure, and acceleration reaction on the prey was used to test the effects of strike initiation distance on peak force and on the rate of increasing force. Comparisons of model output to empirical results indicated that Bluegill had an uncanny ability to time the strike so as to exert 97% of the peak possible force on the prey.

15.2 HONARVAR, Shaya*; O\'CONNOR, Michael P.; SPOTILA, James R.; Drexel University; *sh333@drexel.edu*

Density-dependent effects on hatching success in olive ridley sea turtles

Historically, the olive ridley arribada at Playa Nancite, Costa Rica has been one of the largest arribadas in the eastern Pacific with 100,000 nesting females in a year. Recently the olive ridley arribada at Playa Nancite has declined drastically. One hypothesis proposed to explain the decline on Playa Nancite is low hatching success such that recruitment to the population is insufficient to balance losses. This hypothesis was examined by density-dependent effects on hatching success and their underlying mechanisms by experimentally manipulating nest densities on the nesting beach. We set up four nest density treatments in 5 experimental blocks. Each block contained a control plot without nests, a low density plot with two nests, a moderate density plot with 5 nests and a high density plot with 9 nests per square meter. Only 70 eggs were relocated in each nest and 10 other eggs were weighed during relocation and 10 hatchlings per nest were weighed at emergence. The number of hatchlings per nest was counted in each plot. CO2 and O2 concentrations and temperature were measured in each plot both within a nest and in sand adjacent to a nest frequently during incubation. We found that experimental nest densities affected hatching success with highest density having lowest hatching success. Further, higher nest density lead to lower O2 levels and higher CO2 levels in the nest with greater changes in the latter part of the incubation. Highest temperatures were recorded in high density areas. Temperatures were lower in the sand surrounding the nest than in the nest. We found no statistically significant difference in hatching mass in different densities when compared to original egg mass. Long term failure in production of hatchlings due to historic high densities could contribute to the decline of arribadas on Playa Nancite.

S6-1.5 HOWARD, Daniel J.*; BRASWELL, W. Evan; New Mexico State University; *dahoward@nmsu.edu*

Exploring the Genetics of Conspecific Sperm Precedence in Two Ground Cricket Species

Allonemobius fasciatus and *A. socius* are closely related ground crickets that are reproductively isolated by conspecific sperm precedence. We have examined the genetic basis of this isolation through QTL studies and through expressed sequence tag (EST) analyses of three body parts that play important roles in fertilization: the accessory glands and testes of males and the spermathecae of females. In this talk, I will concentrate on the EST work, describing sequences that have diverged between the two species and patterns of gene exchange in sympatric populations. Of particular interest are sequences that have diverged quickly, with high dN/dS ratios, and do not cross the species boundary in sympatric populations.

50.9 HU, DL*; BUSH, JWM; SHELLEY, MJ; The Courant Institute, New York University; *dhu@cims.nyu.edu*

The Mechanics of Slithering

Snakes propel themselves over land using a variety of techniques, including a unidirectional accordion-like mode, lateral sinuous slithering and sidewinding. We explore these friction-based propulsion mechanisms through a combined experimental and theoretical investigation. Particular attention is given to classifying the gaits of snakes according to Froude number and the relative magnitudes of the frictional forces in the tangential and normal directions. While the term gait is usually used to describe a sequence of foot movements, here it refers to a sequence of undulations made by the limbless snake. In a simple mass-spring model, we prescribe the muscle activity of the snake and then calculate its motion as required by the torque and force balances on its body. A key feature of our model is that it allows us to rationalize the mode of locomotion of the snake on the basis of propulsive efficiency.

15.6 HRISTOV, N.I.*; BETKE, M; KUNZ, T.H.; Boston University; *hristov@bu.edu*

Lessons in history: colony size and population decline of Brazilian free-tailed bats at Carlsbad Caverns

The colony of Brazilian free-tailed bats (*Tadarida brasiliensis*) at Carlsbad Caverns is one of several well-known colonies of this highly gregarious and conspicuous species in North America. For over 80 years researchers have attempted to estimate the size of this colony with mixed results. Primitive methods and lack of repeatability have resulted in questionable estimates giving rise to poorly understood but highly popularized long-term trends. In this study, we present the most accurate and complete, seasonal, colony size estimates to date, based on a new census method - advanced thermal infrared imaging and computer vision processing. The size of the colony was estimated monthly from March through October in 2005 and 2006. Our results indicate large changes in the size of the colony within the same season and between seasons. Colony size estimates range from 67,602 to 793,838 bats, values that are lower than historical estimates for this location. In addition, consecutive daily estimates show large fluctuations in the size of the colony by as many as 290,000 individuals indicating that the colony is considerably more dynamic than previously suggested. Using realistic 3D simulations, paired with additional quantitative analyses of bat emergence behavior, we raise questions about the validity of early historic estimates that millions of bats once roosted in this cave, and prompt a reevaluation of the long-term pattern of decline that has been suggested for this species. The answer to these questions requires accurate, base-line data that incorporate seasonal and long-term observations. Thermal infrared imaging and computer vision processing provide a highly effective and reliable method for the accumulation of such data as has been demonstrated in the present study.

24.5 HUANG, H.-D.*; JENG, M.-S.; Academia Sinica; *symbiose@gate.sinica.edu.tw*

The chemically-mediated orientation and feeding behaviors by the hydrothermal vent crabs Xenograpsus testudinatus What makes them swarm in such high densities?

The crab *Xenograpsus testudinatus* lives at enormously high densities around the sulfur-rich hydrothermal vents found in shallow waters off Kueishan Island, northeastern Taiwan. During slack water, thousands of *Xenograpsus* crabs swarm out of the sulphur-rich crevices, and begin to feed on the sea floor near the vents spewing sulphurous plumes and bubbles. These crabs scavenge food particles and dead animals, mainly the zooplanktons killed by toxic vent plumes (Jeng et al. 2004). We hypothesize that *X. testudinatus* use chemical cues to aggregate and forage together. In laboratory, we tested crab responses to chemical cues from congeners, sulfur sands, Na_2S solution, and smashed shrimp meat. Crabs oriented toward odors of congeners and shrimp meat, but avoided sulfurous seawater. With presence of the food scent, *Xenograpsus* crabs stood high on their legs, and explored through substrate with their appendages. The frequencies of the foraging behavior, bringing pinches of surface sediment to the buccal region with their chelae, and processing with the mouth appendages, were also increased. We conclude that, instead of locating the sulfur from the vents, *X. testudinatus* use chemical cues from congeners to stay together and close to food sources. In their nutrient-poor environment, this foraging behavior enables these opportunistic feeders to maximize their efficiency in harvesting the plankton kill coinciding with tide currents.

64.5 HUGGINS, K.A.*; NAVARA, K.J.; HILL, G.E.; MENDONCA, M.T.; Auburn University, Ohio State University; *huggika@auburn.edu*

Long Term Performance Detriments In Songbirds With Extensive Carotenoid-Based Plumage Coloration: Are Carotenoids Toxic?

Although there is extensive literature addressing the beneficial effects of carotenoids as antioxidants and immune enhancers, there are also studies that indicate that high doses of carotenoids may have a toxic effect. Songbirds with carotenoid-based plumage tend to maintain high levels of circulating carotenoids in plasma, which could represent a potential tradeoff between maintaining brightness at the expense of carotenoid-related toxicities. To test this hypothesis, we maintained American goldfinch males on either a high (n=40) or low (n=40) dose lutein/zeaxanthan treatment for 60 days during molt. We sampled blood from animals before, during, and after supplementation, and analyzed samples for glutathione as a measure of oxidative stress, and creatine kinase as a measure of muscle degradation. Additionally, we tested muscle function using a vertical ascent test, a technique that tests performance capability of pectoral muscles in birds. We found that creatine kinase levels were significantly higher in high dose of dietary carotenoids birds, indicating the presence of muscular degradation. Additionally, high dose birds also significantly reached lower elevation in the jump trials (p=0.009, 2005; p=0.03, 2006) indicating that there was a direct effect between increased carotenoid intake, increased creatine kinase levels and outward physical ability.

5.2 HUIZINGA, M.*; GHALAMBOR, C.K.; Colorado State University; *Meribeth.Huizinga@colostate.edu*

Moving away from the mean: does trophic divergence in sympatric populations of the Gold-breast Splitfin, (Ilyodon furcidens) increase fitness?

A central focus of evolutionary ecology is to understand how historic and current processes interact to generate and maintain patterns of diversity within and between species. Examining the role of natural selection in driving local adaptation and population divergence provides a framework from which to understand the processes that constrain adaptive evolution. Both theoretical and empirical work are recognizing that natural selection can lead to adaptive divergence within populations (i.e. in sympatry) and that individual specialization, speciation events, and whole adaptive radiations may commonly occur in sympatry. For example, the use of the mouth for pacifying and handling prey items has resulted in a variety of resource polymorphisms among vertebrates, altering morphology, life history traits and behavior. While several studies have demonstrated the presence of coexisting ecological morphs, few have established a link between this intraspecific morphological variation and fitness. I compared geographically isolated populations of the livebearing fish, *Ilyodon furcidens* and described the morphological differences within and between the sample populations. I found that I. furcidens exhibits morphological variation in a suite of trophic characteristics, and that populations show either a unimodal or bimodal frequency distribution of relative mouth width. Morphological variation was related to fitness estimates, and are discussed in the context of maintenance of morphological variation through selection, with implications for disruptive and frequency dependent selection.

18.6 HULSEY, CD*; ROBERTS, R; STREELMAN, JT; Georgia Tech; *dh251@mail.gatech.edu*

Cichlid Pectoral Fins: Is there a Link Between Locomotion and Feeding?

Although the unparalleled feeding diversity of cichlid fishes in the African Great Lakes is widely recognized, the locomotory diversity of these rapidly radiating groups remains underappreciated. We quantified pectoral fin musculature and shape in 30 cichlid species from Lake Malawi and examined the relationship of these variables to feeding modes. When accounting for newly reconstructed phylogenetic relationships, surprising correlations between locomotory morphology and trophic variation were uncovered.

S1-5.3 HUMPHRIES, Stuart; University of Sheffield, UK; *s.humphries@sheffield.ac.uk*

The allometry of suspension feeding

Suspension feeders exhibit convergence in feeding morphology due to limits imposed by hydrosol collection mechanisms. Previous cross-group scaling studies have been limited in extent, but here I present results from an investigation based on a dataset of 403 species across 24 broad taxonomic groupings. I relate body size to the size of feeding appendages and to food sizes to explore the scaling relationships within broad groupings such as passive and active feeders, and uni- and multicellular species. Filter morphology shows clear patterning related to feeding methods and fluid flow, while filter area relationships are different across groups. In general, scaling patterns differ between functional groupings, but not always in the way one might previously have expected.

28.2 HUNTER, Rebecca L.*; HALANYCH, Kenneth M.; Auburn University, Auburn, AL; *belchrl@auburn.edu*

Phylogeography of Astrotoma agassizii from South American and Antarctic waters using mtDNA

The isolation of the Antarctic continent has been a driving evolutionary force for Antarctic fauna for ~40 million years. Separation of Antarctica and South America, followed by the onset of the Antarctic Circumpolar Current (ACC), is presumed to be one of the primary forces driving speciation in the Southern Ocean. Despite this geographic and thermal isolation, some benthic marine taxa exhibit surprising levels of non-endemism. We therefore wanted to examine evolutionary relationships between Antarctic/subantarctic and South American benthic marine invertebrates due to the variety of potential isolating factors existing between these geographic localities. In this study, we looked at relationships among populations of the ophiuroid *Astrotoma agassizii* from both South America and Antarctica. Two mitochondrial genes were used to address questions regarding levels of divergence and gene flow among populations spanning the ACC. According to preliminary data for the 16S rDNA gene, low levels of sequence divergence (A. agassizii, which likely includes a planktonic larval stage, larval dispersal is the likely mechanism by which gene flow occurred.

55.4 HUSAK, J. F.*; IRSCHICK, D. J.; MEYERS, J. J.; MOORE, I. T.; Virginia Tech, Univ. of Massachusetts; *husak@vt.edu*

Hormones, sexual signals, and performance of green anole lizards (Anolis carolinensis)

The functional capacities of structures used as weapons during male contests for access to females have been shown to be important determinants of male fitness. However, male territorial interactions do not always involve physical aggression involving the weapon. Instead, sexual signals may advertise weapon quality and capacity. Despite the empirical evidence to support the link between signal size and weapon quality, we know surprisingly little about the mechanisms that underlie this link. We studied weapon performance (bite-force performance), signal size (dewlap size), and steroid hormone levels in a population of the green anole lizard (*Anolis carolinensis*), a species that exhibits strong sexual dimorphism and intense male competition for access to females. We explore whether testosterone mediates the connection between bite-force capacity and dewlap size in different size-classes of sexually mature males. We also investigate the influence of the stress hormone corticosterone on bite-force performance and dewlap size in males.

70.4 HUSKEY, Steve*; QUINTERO, Reyes; Western Kentucky University; *steve.huskey@wku.edu*

Why the long face? Prey capture in trumpetfishes

Feeding in fishes has received a tremendous amount of attention to better understand the evolution of vertebrate feeding mechanisms. Application of technologies such as high-speed video, sonomicrometry, and DPIV have assisted in helping researchers gain a thorough understanding of the complexities of the interaction between a fish and its environment, especially during feeding. However, we lack detailed knowledge of what happens to pressure within the buccal cavity of a feeding fish. Likely the result of no way to visualize flows within the buccal cavity and the morphological limitations imposed by most fishes, our limited understanding can be expanded through the use of long-snouted fishes able to accommodate multiple pressure sensors within the mouth. Trumpetfish were implanted with two sensors positioned at the caudal and rostral ends of the buccal cavity to better understand pressure changes during feeding. Peak pressures occurred at 0.026ms and 0.030ms, respectively, with pressure dropping first within the rear of the buccal cavity (mean -22.73kPa) and being translated through the elongate skull and jaws to the tip of the mouth 4ms later (mean -18.00kPa). Pressures in the caudal portion of the buccal cavity were, on average, 4.73kPa greater than at the oral jaws, indicating a precipitous loss of pressure within the elongate buccal cavity. Subambient pressure was accomplished via tremendous cranial elevation produced through contraction of epaxial muscles and translation through large sesamoid tendons down a long portion of the fish's body. While the overall body shape of trumpetfishes certainly yields ecological success, the long moment arm of the skull and the precipitous decrease of buccal pressure within the mouth suggest a trade-off between body shape and subambient pressure translation.

S8-1.4 HUYGHE, Katleen*; VANHOOYDONCK, Bieke; HERREL, Anthony; VAN DAMME, Raoul; Univ. of Antwerp, Belgium; *katleen.huyghe@ua.ac.be*

Colour polymorphism without ecological niche divergence in the lacertid lizard Podarcis melisellensis

Different hypotheses have been proposed to explain the origin of phenotypic polymorphisms. Non-adaptive mechanisms (gene flow, stochastic effects) are difficult to investigate and can be the original cause of such polymorphisms in a population, but they cannot explain their maintenance. Adaptive mechanisms on the other hand can explain the origin and the continued existence of polymorphisms, and can mainly be classified into three types depending on the selective pressures operating on the system: 1) trade-off in natural vs. sexual selection 2) frequency-dependent selection and 3) natural selection s.s.. Here we investigate the role of natural selection s.s. in the co-existence of three colour morphs in the lacertid lizard *Podarcis melisellensis*. In this species, males and females occur in 3 different colour morphs that differ in their abundance. We quantified a number of ecological and behavioral parameters that are expected to differ between morphs. First, the spatial distribution of individuals was mapped to look at the level of aggregation between morphs. Preliminary results suggest no differences here. Niche divergence may possibly also manifest itself in differential microhabitat use or thermal ecological parameters, but no obvious differences were found between the colour morphs. These results seem to suggest that niche divergence through natural selection is not the cause of the striking phenotypic polymorphism in these lizards.

8.4 HYDE, Martha L.; West Texas A&M Univ, Canyon; *mhyde@mail.wtamu.edu*

Maneuvering Obstacles on a Treadmill by Hopping Kangaroo Rats, Dipodomys ordii

The unpredictability of kangaroo rat locomotion is remarkably adapted to predator avoidance. Neural control mechanisms may allow for these rodents to effectively elude predators and still maneuver in a habitat that can be seasonally littered with annual and perennial plants of various sizes. Four kangaroo rats, *Dipodomys ordii*, were videotaped on a custom-designed Columbus Instruments treadmill bed 97x45 cm with a plexiglass box (111x31x30 cm). The box was modified to accommodate polyurethane foam obstacles attached with Velcro to the treadmill belt. The obstacles traveled the full length of the treadmill bed while animals hopped. The box was further modified to maintain a minimum distance of 40 cm between rodent and first appearance of an obstacle on the belt. The rodents were videotaped at 30 fps with three cameras for a dorsal view, a side view with closeup, and a side view with full view of the treadmill. All kangaroo rats responded to the first introduction of one 26x3.5x4 cm obstacle at 1.30 mps belt speed in the same way: they paused, the belt carrying them to the rear of the box. Responses thereafter varied from jumping to climbing to moving to the side of the obstacle. All continued to hop afterward in that first run but stayed in the back of the box. Subsequent introduction of obstacles either one at a time at 1.30 mps or multiple obstacles on the belt when it started at 1.00 mps produced varied responses. All animals adapted very quickly to the obstacles within three-four turns of the belt, as seen in more predictable angles of projection, timing of jump, jump height and stride lengths. These animals probably know the placement of all obstacles within their territory pretty soon after dispersal, maintaining unpredictability to predators and avoiding crashing into these obstacles.

53.3 HYNDMAN, Kelly A*; EVANS, David H; University of Florida, Gainesville, Mount Desert Biological Laboratory, Salisbury Cove ME; *khyndman@zoo.ufl.edu*

Endothelin from the killifish, Fundulus heteroclitus

Endothelin-1 (ET-1) is a vasoactive, paracrine peptide found in all vertebrates. It is produced in a variety of cells including endothelial, vascular smooth muscle, and transporting epithelial cells such as kidney tubules. In mammals, ET-1 is translated as a 203 amino acid (AA) preprohormone, termed preproendotheiln (PPET), and it undergoes two cleavage events to produce the active 21 AA ET. Endothelin's functions are mediated via two G-protein coupled receptors (GPCR) in mammals, ET_A and ET_{B1}, and by a third GPCR in non-mammalian vertebrates, ET_{B2}. Although ET-1 is traditionally viewed as a cardiovascular paracrine, recent studies suggest that ET plays a role in ion regulation in mammals and fishes. Electrophysiological studies from our lab have suggested that ET-1 inhibits net chloride transport in the opercular epithelium (a model for the sea water teleost gill) of the euryhaline killifish (*Fundulus heteroclitus*). Thus, we hypothesize that ET-1 may be a modulator of ion balance in euryhaline fishes. To explore this, we have cloned the cDNA encoding ET-1 from the killifish. We have found two ET-1 transcripts, and have designated them kET-1a and kET-1b. kET-1a contains 940 bp with a predicted open reading frame (ORF) of 483 bp, translating into a 161 AA PPET. kET-1b contains 935 bp with a predicted ORF of 429 bp, translating into a PPET of only 143 AA. The predicted active form (21 AA) of the killifish ET-1 is 100% identical between kET-1a and kET-1b, and they share 81% identity with human ET-1. In addition, tissue distribution and effects of environmental salinity on the mRNA expression of the two kET-1 transcripts were determined. These studies provide a better understanding of how the ET signaling axis plays a role in ion balance in euryhaline fishes.

36.5 IDE, C.*; DE PUYSSELEIR, J.; HUYSENTRUYT, F.; GEERINCKX, T.; ADRIAENS, D.; Ghent University; *celine.ide@ugent.be*

Non-algae scraping vs algae scraping, comparison between Synodontis and Atopochilus (Siluriformes: Mochokidae)

Until recently specializations related to algae-scraping have been studied in cichlids and loricariid catfishes, but very little has been done on the algae-scraping species of the African mochokid catfishes. In this study we examined the head morphology (osteology and myology) of both a non-algae scraper (*Synodontis schall* en *S. ocellifer*) and an algae scraper with a suckermouth (*Atopochilus savorgnani*). *Synodontis* is the largest genus of the family Mochokidae. We compared the morphological features of *Synodontis* with those of *Atopochilus savorgnani*, in order to gain some insight on possible relationships between musculoskeletal specializations and algae-scraping. The osteological research was done by means of cleared and stained specimens, for the myological study dissections were performed. It could be concluded that *Synodontis* shows the general head morphology of Siluriformes, and thus can be considered to represent the plesiomorphic condition in mochokids. After comparison we were able to relate some differences between the two taxa to algae scraping in *A. savorgnani*. In the latter, the dentary is rotated about 180° and is bigger, providing ample space for the ventrally pointed teeth, an adaptation to algae scraping also seen in loricariids. *A. savorgnani* also has smaller eyes and shorter barbels. Given their benthic feeding behaviour these fishes probably rely more on the sensory lip surface than on large eyes and long barbels. In contrast, *Synodontis* feeds in the water column, where light conditions are better and barbels are more efficient for probing the surrounding water during swimming.

37.2 INFANTE, C.R.; Harvard University; *los@oeb.harvard.edu*

Metamorphic remodeling and the evolution of larval morphology in the carnivorous tadpole Lepidobatrachus laevis

Members of the frog subfamily Ceratophryinae (Anura: Leptodatylidae) are known for the enlarged heads, massive jaws, and aggressive predatory natures of their adult forms. As tadpoles, however, each of the three genera that comprise the group exhibits very distinct larval feeding ecologies and accompanying morphologies. Most striking among these are the tadpoles of the genus *Lepidobatrachus* which feature laterally expanded jaws used to consume other tadpole prey whole. In terms of both behavior and morphology, *Lepidobatrachus* tadpoles appear to be expressing adult characteristics at the larval stage. I am interested in how the regulation of the metamorphic remodeling program has changed to accommodate the unique larval jaw morphology of these tadpoles. Metamorphosis in anurans is characterized by extensive remodeling of larval tissues via growth or resorption and the *de novo* formation of many adult structures. This process is dependent on thyroid hormone (TH), which initiates - via nuclear receptors - a cascade of gene expression in responding tissues. It has been hypothesized that changes in the TH-regulated metamorphic program mediate the evolutionary diversification of larval and adult morphology. This could be accomplished via temporal changes in tissue sensitivity to TH, or TH concentration on a tissue or organ-specific level via the local activity of deiodinases. To investigate these hypotheses in regard to the unique jaws of *Lepidobatrachus* tadpoles, I have used studies of receptor expression and enzyme activity during natural metamorphosis and in tissue culture. These studies demonstrate that deiodinase inactivation of TH protects the lower jaw during metamorphosis and the delayed morphological remodeling and ossification of the lower jaw correlates with deiodinase activation of TH.

39.3 IRIARTE-DIAZ, J.; Brown University; *jose_iriarte@brown.edu*
The effect of artificial loads on the straight flight performance of fruit bats
Most bats experience significant fluctuations in their body mass. These fluctuations can be both daily, mostly due to feeding, or seasonal due to fat storage and/or reproduction. Based on predictions derived from classic aerodynamic theory, increments in body mass, such as those in observed in natural populations of bats, should severely affect their flight performance. But because bat flight is spatially and temporally complex, and bat wings continuously change shape during a wingbeat, the utility of such theoretical models is limited. For example, some bats species are able to increase their body mass up to 40% and remain capable of maneuvering in complex three-dimensional environments. How increased lift is produced when weight is increased is well understood. Thus, the purpose of this study is to evaluate the effect of added mass on the kinematics of forward, steady flight in a fruit bat. Three lesser short-nosed fruit bats (*Cynopterus brachyotis*) were trained to fly in a flight corridor with and without carrying a load of about 20% of their original body mass. Ultra-light reflective markers were placed on the body and wings and flights were recorded with three synchronized, high-speed digital video cameras in low light conditions. Data from the three cameras were combined to reconstruct the 3D motion of each marker. From these recordings, flight speed and body and wing kinematic parameters were obtained for each treatment. Experimental bats showed a 27% increase in speed with a 20% increase in body mass. Wingbeat frequency and amplitude, however, did not change with load, suggesting that more subtle changes in wing configuration (e.g., angle of attack, camber) must be used to generate enough lift to compensate for the increased weight.

38.6 IRWIN, J.T.*; DIDRICKSEN, D.J.; REILLY, B.W.; ABRAHAMSON, W.G.; Central Washington University, Ellensburg, WA, Bucknell University, Lewisburg, PA; *irwinj@cwu.edu*
A climate-based model of winter energy consumption to examine the southern range limit of the goldenrod gall fly (Eurosta solidaginis) on late goldenrod (Solidago gigantea)
The goldenrod gall fly, *Eurosta solidaginis*, is a gall-inducing insect that has diverged into two reproductively isolated and genetically differentiated host races on its host plants *Solidago gigantea* and *S. altissima*. Both host plants range from Ontario to Florida in eastern North America. Flies of the *altissima* host race are found virtually everywhere that its host plant is present, but *gigantea* flies are only present in the northern tier of its host's range. We performed a series of experiments to identify factors restricting the *gigantea* host race to northern locales. Correlation analysis suggests that the southern limit of *gigantea* flies is constrained by warm winters, likely because warmth increases energy consumption. *Gigantea* flies are smaller and less fecund because *S. gigantea* senesces earlier (thus ceasing feeding earlier in the autumn) than does *S. altissima*. Being smaller, the *gigantea* host race has less energy to support metabolism during winter and egg production the following spring. We will present our ongoing efforts to produce a model of winter energy use for goldenrod gall flies across their range, and consequent range limitations. Our work provides a model for predicting shifts in geographic distributions with global climate change.

64.4 IRSCHICK, Duncan*; MEYERS, Jay; University of Massachusetts at Amherst; *irschick@bio.umass.edu*
A comparative analysis of natural and sexual selection in lizards
The disparate forces of natural and sexual selection are often examined individually, and typically on single species. The downfall of this approach is that one cannot determine whether the direction and magnitude of both kinds of selection is the same for ecologically different species that co-occur within the same community. Recent syntheses of adaptive radiation have argued that sexual and natural selection, often working in concert, may be key players for shaping adaptive radiations, but this idea necessarily requires information on selection on multiple species. We examined both natural and sexual selection on morphology and two kinds of performance (bite force and sprint speed) on four different species of lizards across an entire year (2005-2006). These four species (*Anolis distichus, A. sagrei, A. smargdinus*, and *Urosaurus ornatus*) differ markedly in morphology, habitat use, and behavior, but are similar in body size and overall lifestyle (e.g., arboreal, insect-eating). We found strong evidence for a mosaic of selection pressures on morphology and performance, and there was marked divergence in how selection operated among these different species. Further, there was some evidence that selection was often strong on morphology, but not concomitantly on performance, indicating a disconnect between the two kinds of traits. Our findings point towards a new way of quantifying selection on morphology and performance, namely expanding to a phylogenetic and community-based framework.

24.4 JACKSON, Jennifer L*; DICKMAN, Brian D; WEISSBURG, Marc J; WEBSTER, Donald R; Georgia Institute of Technology; *jennifer.jackson@gatech.edu*
Three-Dimensional Concentration Measurements Around Actively Tracking Blue Crabs
The fluctuating properties of odor signals in turbulent boundary layer flows are used by large marine invertebrate predators (e.g., blue crabs) to navigate towards, and locate, food and mates. A firm understanding of mechanisms underlying navigation in fluid borne plumes has been limited due to our inability to precisely define the relationship between stimulus patterns and behavioral output. To link these two phenomena, we have developed an integrated measurement system to simultaneously quantify the instantaneous odor concentration surrounding a freely tracking blue crab (*Callinectes sapidus*) using three-dimensional laser-induced fluorescence (3DLIF). *C. sapidus* receives chemical stimulus at several locations, including the antennules and the distal tips of the legs. Due to this spatial arrangement of chemosensors, 3D measurements of the concentration field are required to link behavior to plume structure. The concentration field is measured via 3DLIF by compiling horizontal laser scans separated by a small vertical distance and walking kinematics of tracking crabs were simultaneously recorded. During trials, crabs began their search 150 cm downstream of a source and were reversibly blindfolded to prevent aversive reactions to the intense laser light. The concentration field data around a tracking animal is used to determine how hypothesized navigational cues, such as concentration bursts at the antennules and spatial asymmetry in concentration at the distributed chemosensory organs on the legs, results in particular decisions during navigation. In addition, we can examine the roles of stimulation history and comparison between information across various vertical regions as navigational cues.

39.2 JACKSON, B.E.*; DIAL, K.P.; Univ. of Montana; *brandon.jackson@mso.umt.edu*

Scaling theory and locomotor performance: the most speciose clade of birds fails to conform

Allometric predictions of locomotor performance are often based on the scaling of a few morphological or physiological variables and rarely validated by actual measurements of performance. The prominent hypothesis for the negative scaling of avian burst-flight performance (e.g. peak acceleration) suggests that a single variable (wing length) explains size-dependent performance (mechanical power output) via decreasing wingbeat frequency (*wbf*). We provide the initial test of this hypothesis on the most speciose clade of birds (Passeriformes, containing >50% of all avian species) performing burst flight (vertical takeoff and acceleration). We measured the maximal escape-flight of a wide-range of passerines (N=29 species, 14 families, mass range 5.7-278 g) in a vertical chamber using four synchronized, high-speed cameras. During liftoff, the contribution from the legs was quantified using a force plate, and the aerodynamic power from the wings was estimated using 3-D kinematics in an aerodynamic model for accelerating flight. Mean peak jump force (6.04 +/- 1.26 x body weight; mean +/- s.d.) was independent of body mass (m). Contrary to the popular hypothesis, maximum mass-specific power (53.3 +/- 15.5 W kg^{-1}) was independent of m. Aerodynamic power is the product of *wbf* and aerodynamic work. The negative scaling of *wbf* ($m^{-0.24+/-0.05}$) was offset by positive scaling of mass-specific work ($m^{0.31+/-0.07}$). Work is dependent on numerous morphological and physiological variables. For example, work should vary inversely with wing loading, which scaled lower ($m^{0.20+/-0.05}$) than predicted for geometric similarity ($m^{1/3}$). Predicting performance in the most diverse clade of birds from traditional scaling appears inappropriate. As such, alternative multivariate approaches to predicting locomotor performance will be addressed.

1.8 JAMNICZKY, Heather A.; University of Calgary; *hajamnic@ucalgary.ca*

Turtle Carotid Circulation: Ontogeny, Phylogeny, and Evolution

The bony canals of the turtle skull associated with the cranial circulation have long been considered integral to our understanding of turtle systematics, both extinct and extant. Recent phylogenetic analyses employing a variety of data sets indicate alternatives to the traditional arrangement of crown turtles, and may have implications for extinct members of the clade. An integrative character analysis was therefore undertaken in order to re-examine the phylogenetic signal contained in this character complex. Quantitative reassessment of the osteological correlates of the turtle cranial circulation revealed that the initial, qualitative description of these characters is in need of revision. Further, the constraints of nominalism and a focus on size alone may have been confounding systematic analyses. Subsequent high-resolution x-ray computed tomography of extant specimens resulted a re-interpretation of primary homology among internal carotid branches in crown turtles, and re-evaluation and re-description of characters drawn from these features. Comparative embryology was employed to explore the origins of circulatory novelty and pattern divergence within the clade, resulting in the hypothesis that heterochrony has produced a circulatory morphology, exhibited in Trionychidae, that differs from the widely distributed and putatively primitive circulatory pattern. Character analysis such as this, employing information gleaned from multiple investigatory techniques applied to extinct and extant organisms, is necessary for effective homology determination and the generation of robust phylogenies for use in higher-level evolutionary inference.

S5.3 JACOBS, David K.*; NICHOLS , Scott; HARTENSTEIN, Volker; NAKANISHI, Nagayasu; YUAN, David; UCLA, UC, Berkeley; *djacobs@ucla.edu*

Origins of Sensory and Neural Organization in Basal Metazoa

The roots of the word animal imply muliticellular motility with inherent requirements for sensation and locomotory response. Cnidarians are traditionally viewed as the most basal animals with formal sense organs, yet sponges have an array of neural specific structural and regulatory genes. In summary: 1) Cnidarians employ a suite of canonical bilaterian sense-organ regulatory genes e.g. *sine oculus*, Brain 3, and *eyes absent* which are expressed in the statocyst and eye of the rhopalia in *Aurelia* medusae supporting a common evolutionary origin of cnidarian and bilaterian sense organs. 2) In the planula larvae sensory cells develop laterally and extend axons that integrate in the locomotory anterior. These larval structures are lost folowing settlement as the nerve nets, that constitute the neural organization of the polyp and medusa, develop. Thus, only the planula appears to integrate the output of multiple sensory cells in a single brain-like anterior plexus, a condition supportive of the acoel-planuloid theory of bilaterian origin. 3) Sponges, despite limited "animal-like" motility, possess a number of genes closely associated with sensory and neural organization. These include canonical sensory genes such as *sine oculus* and Brain 3. In addition, recent EST work documents the presence of genes such as slit and spondin that function in bilaterian axon guidance, as well as genes know to function in synaptic vessical formation and fusion. These genes may have distinctive functions in sponges, and the sensory and motor repertoire of sponges is likely more sophisticated than has been assumed in some zoological traditions. Understanding the range of roles of "sensory" genes in basal metazoans will help clarify the evolution of the multiple sensory modalities across the Metazoa as well as the functional evolution of these gene families.

5.5 JANG, Yikweon*; CHOE, Jae C; Ewha Womans University, Seoul, Republic of Korea; *jangy@ewha.ac.kr*

Reproductive character displacement in a wood cricket Gryllus fultoni (Gryllidae: Orthoptera)

Two wood cricket species, *Gryllus fultoni* (Orthoptera: Gryllidae) and *G. vernalis*, occur together in the eastern US and have a similar calling song structure. A previous study revealed that chirp and pulse rates in *G. fultoni* was highest (greatest difference vis-à-vis chirp rate in *G. vernalis*) in sympatric populations, intermediate in near allopatric populations that were located close to the sympatric zone, and lowest in allopatric populations. Here we investigated the song discrimination of females from sympatric and allopatric populations of *G. fultoni*. Stimuli presented were representative of calling songs in three classes of *G. fultoni* populations (sympatric, near allopatric, and far allopatric), a calling song of *G. vernalis*, and three calling songs with parameter values that were intermediate between the songs of far allopatric *G. fultoni* and *G. vernalis*. In the single-stimulus playbacks, females of all *G. fultoni* populations responded poorly if at all to the heterospecific stimulus. Females of sympatric and near allopatric populations responded poorly to all intermediate stimuli, but females of far allopatric populations frequently responded to these sounds. In the two-stimulus playbacks, females of sympatric and near allopatric populations generally discriminated against intermediate and heterospecific stimuli. However, females of far allopatric populations often did not discriminate against intermediate stimuli whose characteristics resembled the calling songs of *G. vernalis*. The divergent pattern of song discrimination between sympatric and far allopatric populations was thus generally congruent with the pattern of divergence in chirp and pulse rates and was consistent with a pattern predicted by reproductive character displacement.

4.4 JANZEN, F.J.*; GIBBONS, J.W.; GREENE, J.L.; IVERSON, J.B.; TUCKER, J.K.; Iowa State University, Savannah River Ecology Laboratory, Earlham College, Illinois Natural History Survey; *fjanzen@iastate.edu*

Climate change and temporal variation in nesting biology of North American turtles

Altered phenology of reproductive events has been noted as a particularly key indicator of biotic response to contemporary climate change. However, most research has focused on a single population of a given taxon (oftentimes at the edge of its geographic range), yet meta-analyses use such data as a proxy for the entire species. Moreover, few sufficiently long-term studies of phenology in reptilian taxa have been published. We address the possibility of climate-altered reproductive phenology with long-term (greater than 10 years) data on nesting behavior in multiple populations of each of four genera of North American turtles (*Kinosternon*, *Chelydra*, *Chrysemys*, and *Trachemys*). We find that initiation of the nesting season has advanced significantly only in populations at the northern edge of the geographic range of a species. Populations located farther south within the geographic range of a species exhibited less marked temporal changes in nesting behavior. Although more thorough analyses remain to be performed, our preliminary assessments reveal that variation in annual heating degree days and mean annual temperatures covary with the nesting patterns we observe in these turtles. Moreover, we are now testing whether the significant temporal shifts in phenology in populations at the northern edge of the range reflect phenotypic plasticity or adaptive evolutionary changes.

46.4 JAWOR, Jodie*; MACDOUGALL-SHACKLETON, Scott, A.; University of Southern Mississippi, Hattiesburg, MS, USA, University of Western Ontario, London, Ontario, Canada; *jodie.jawor@usm.edu*

Volume of song control nuclei in a songbird with near monomorphic song: Influences of sex and season

Song production and learning is controlled in songbirds by a series of brain nuclei called the song control system (SCS). Many songbirds are strikingly sexually dimorphic in song production and SCS morphology; females typically possess smaller repertoires and SCS nuclei than males. Additionally, SCS nuclei volume can vary seasonally with larger volume in the breeding season; this has been linked to seasonally varying testosterone (T) levels. Here we report on sexual and seasonal differences in the SCS of northern cardinals (*Cardinalis cardinalis*) a species with nearly monomorphic song production. We also compared SCS volumes with levels of T in both sexes. Brains from 10 females and 10 males were collected prior to breeding (5 of each sex, no song in population) and early in the breeding season (5 of each sex, frequent song in population). SCS volume was determined from Nissl stained sections; T at the time of capture was determined via EIA. We found a significant sex by season effect on the volume of the song nucleus HVC; female HVC was smaller than male HVC and HVC in both sexes was smaller in the non-breeding season. There was no co-variation between T and HVC volume regardless of season. Our results suggest that even in species with near monomorphic song production female HVC is smaller. This may be linked to overall sexual differences in T levels in adults, or to hormone levels during development. Interestingly, even though male HVC volume differed with season, the level of change is not as large as that observed in other species. This may potentially allow male cardinals to have a prolonged period of song production, or produce song outside of the breeding season.

S8-2.1 JOHN-ALDER, H.B.*; COX, R.M.; TAYLOR, E.N.; Rutgers Univ., Ohio State Univ., California Polytechnic State Univ., San Luis Obispo; *henry@aesop.rutgers.edu*

Proximate Developmental Mediators of Sexual Size Dimorphism: Case Studies from Squamate Reptiles

Sexual size dimorphism (SSD) is nearly ubiquitous in squamate reptiles, but we know very little about the relative importance of sex differences in proximate genetic and environmental mediators of the development of body size. Recent studies from our laboratories suggest that males and females share similar genetic growth potentials but express different growth phenotypes and adult body size in the wild because of inherent ecological differences and potential epigenetic effects of sex-specific growth regulators. In several species of free-living *Sceloporus* lizards and in the rattlesnake *Crotalus atrox*, both male-and female-larger SSD develop because of sex differences in age-specific growth. Growth is responsive to food availability in both sexes, but sex differences in growth and body size are nearly absent in the laboratory in both *Sceloporus* and *Crotalus*, indicating a sex difference in sensitivity to environmental conditions. In field-active *Sceloporus*, sex differences in growth rate are associated with sexual divergence in plasma testosterone (T). Experiments confirm that T inhibits growth in female-larger species (*S. undulatus* and *S. virgatus*) but stimulates growth in male-larger *S. jarrovii*. However, both surgical castration and T replacement are without effect in captive *S. jarrovii*, possibly because growth effects of T are superseded by an *ad libitum* diet. Our results indicate that resource limits on growth differ between sexes in free-living squamates and that T can serve as a sex-specific, bipotential growth regulator, leading to SSD. Discrepancies between field and laboratory experiments suggest that epigenetic effects of T interact with energy balance to influence growth.

S3-1.1 JOHNSEN, S; Duke University, Durham, NC; *sjohnsen@duke.edu*

Visual Ecology on the high seas

Oceanographic research has primarily focused on supra-organismal questions, particularly those involving abundance, distribution and trophic relationships. This approach has been extraordinarily productive and has presently culminated in remote sensing techniques that can map the chlorophyll distribution in the entire planet's surface waters on a daily basis. In contrast, our understanding of the physiology of the species eating this chlorophyll is in its infancy, particularly compared to what is known about coastal and terrestrial species. This is unfortunate, because understanding the physiologies of pelagic species is essential for understanding their distributions, abundance, energy budgets and overall ecology. For example, the respiratory physiologies of crustaceans affect their ability to colonize the oxygen minimum layer, and the different strategies for buoyancy in molluscs have significant effects on energy expenditure. Recently, however, interest in the relationship between the physiology and ecology of pelagic species has increased. A large fraction of this work has centered on sensory physiology, a subfield of which attempts to relate the visual and optical properties of pelagic species to their behavior, distribution, and diversity. This talk discusses three recent advances in the visual ecology of oceanic organisms and identifies several important, but as yet poorly understood issues. A common theme throughout is the highly variable nature of the underwater visual environment compared to most terrestrial environments. Illumination and turbidity levels can change dramatically due to both natural and anthropogenic factors, which has important consequences for predation, mating and other activities. How these changes interact with other physical and biological variables to influence pelagic ecology will continue to be a fruitful area of research.

33.5 JOHNSON, M. A.; Washington University, St. Louis, MO; *mjohnson@biology2.wustl.edu*

Does territory defense confer a fitness advantage to males? A paternity study in the Caribbean lizard, Anolis cristatellus

One important benefit of territoriality in many species is exclusive access to resources, including potential mates, within a defended area. A logical extension of this is that individuals who successfully defend exclusive mating rights within an area should then also retain parentage of the offspring from the area. To determine whether individuals who appear to be successful in defending their territories are also successful in securing mating opportunities with those potential mates within their territories, I examined a population of the Puerto Rican lizard, *Anolis cristatellus*. This lizard is a highly territorial, polygynous species whose males defend territories predominantly using visual displays. After performing 75 hours of focal observations and determining the territory boundaries of 54 male and female *A. cristatellus* in their natural habitat, I collected eggs from 27 females from among those I observed. I determined the paternity of those eggs using six highly polymorphic microsatellite markers. Preliminary results show that most females produce eggs sired by more than one male, extra-territorial paternity is extensive, and those males who perform more territorial displays are not more successful at siring the offspring resulting from the territories they maintain. Quantifying the fitness consequences of territorial behavior is an important step in understanding the evolution of this common behavioral strategy.

63.5 JOHNSON, S.L.*; YUND, P.O.; University of Maine, University of New England; *sherij@maine.edu*

The effect of fertilization distance on the relationship between sperm production and male reproductive success in a colonial marine invertebrate

The shape of the function that describes the relationship between resources allocated to sperm production and resulting male fertilization success (the male gain curve) plays a central role in models of sex allocation in hermaphrodites. A variety of ecological factors are expected to affect the shape of this function. In some free-spawning taxa, high levels of sperm production may be the result of selective pressures to maximize male fertilization success in competitive situations. When male gain curves saturate at fairly low sperm production levels in the absence of competitors, higher levels of sperm production may only be adaptive in competitive situations. Alternatively, high levels of sperm production might instead be adaptive if they enhance the ability of a male to fertilize distant eggs. Thus, even if the male gain curve saturates for fertilization of nearby eggs, it may remain linear through higher allocation levels if distant fertilizations are considered. We have explored the effect of distance on male gain curves in the colonial ascidian, *Botryllus schlosseri*. The performance of focal males was assayed at 10, 60 and 160 cm. Microsatellite markers were utilized for paternity assignment in experimental populations. Fertilization decreased with distance from focal males and microsatellite data confirmed short-distance gain curves previously reported from allozyme data. Results suggest that high levels of sperm production may enhance male fitness, both in competitive situations, and with fertilization distance. These results highlight the need to consider distance effects when evaluating gain curves in free-spawners.

S1-4.9 JOHNSON, A.S.*; ELLERS, O.; BUTLER, M.; Bowdoin College, Maine; *ajohnson@bowdoin.edu*

Barbs of a Feather Bend (and Twist) Together

We propose the following design principle for feather barbs. By being thicker-walled dorso-ventrally, their flexural stiffness is increased during flight; but by allowing for twisting when loaded with dangerously high forces they firstly avoid failure by bending and secondly avoid complete failure by buckling rather than rupturing. Dorsal-ventral thickening of feather barbs is required to achieve sufficient flexural stiffness to support normal wing loads. However, if this high flexural stiffness were accompanied by high torsional stiffness, there would be a greater risk of catastrophic failure by rupture. Low torsional stiffness permits twisting and, because barbs are usually tall, narrow, thin-walled beams, a twisted barb can bend in a way that effectively sheds high forces. Furthermore, because it is laterally thin-walled, forces that are sufficiently large to lead to failure would cause failure by buckling rather than by rupture. Buckling is likely to be less catastrophic to barb function as it usually leaves an intact but weakened barb and, therefore, a barb that still functions almost as well as before buckling. This interpretation is supported by analysis of breaking and bending patterns of Osprey feather barbs.

2.10 JOHNSTON, G.I.H.**; FRENCH, S.S.; MOORE, M.C.; Arizona State University; *gjohnston@asu.edu*

Phenotypic Effects of Increased Yolk Corticosterone in Tree Lizards (Urosaurus ornatus)

Maternal influences on offspring phenotype via non-genetic mechanisms is an area of recent interest, especially in egg-laying species. Hormones are a common yolk constituent in many vertebrates, and they can profoundly alter offspring development, survival, growth, and behavior. Maternal corticosterone, the primary hormone involved in the vertebrate stress response, can be increased due to many environmental conditions such as drought, increased predation, or food scarcity. Previous research with tree lizards (*Urosaurus ornatus*) demonstrated that increased maternal corticosterone can be deposited into developing follicles and eggs. Here we examined the phenotypic effects of increased yolk corticosterone concentrations on developing tree lizards. We found that maternal corticosterone treatment significantly decreased both hatching success and offspring survival. Additionally, offspring from treated mothers had a longer incubation period, were smaller upon hatching, had a decreased growth rate, and many also exhibited developmental abnormalities. As sub-adults, the effects this treatment were still evident. The sub-adults from corticosterone treated mothers had an initially slower wound healing rate than offspring from control mothers. These data demonstrate that maternal stress during egg formation has the potential to profoundly influence offspring development and phenotype.

48.4 JONES, S.J.*; MIESZKOWSKA, N.; WETHEY, D.S.; Univ. of S. Carolina, Columbia; *sierra@biol.sc.edu*

Who's hot and who's not? Species-specific thermal histories may determine the biogeographies of Mytilid mussels in the US.

Most organisms have latitudinally discreet biogeographical distributions. While various factors may affect species' distributions, the range limits are believed to be set primarily by environmental temperature. Thus, with changing climatic conditions, the biogeographic ranges of organisms are predicted to shift polewards in response to shifting seasonal isotherms. Intertidal ecosystems are likely to be strongly affected due to the large variations in temperature these habitats experience in response to the diurnal cycle of emersion and immersion. In the Northern Hemisphere, the southern limit of a species should be a sensitive indicator in response to climate warming, where species are often living very close to their thermal tolerance limits. Laboratory experiments were performed to determine the lethal limits of four Mytilid species from locations in the USA. Differences in response to elevated air and water temperatures were examined, as well as the potential for seasonal acclamatory effects. Short-term thermal history has been found to be important in determining lethality, and thus poses serious consequences for these species in relation to a warming climate, where heatwave events are predicted to increase in frequency and duration in the coming decades.

28.6 JONES, CB; San Diego State University; *jonesc@rohan.sdsu.edu*

Systematic Revision and Biogeography of North American Tortoises (Testudinidae:Gopherus)

Gopherus is one member of a clade of tortoises that are endemic to North America. *Gopherus* arose sometime in the late Eocene or early Oligocene. During the Cenozoic, three other named genera of tortoises existed in North America: *Hadrianus*, *Stylemys*, and *Hesperotestudo*. The earliest confirmed gopher tortoise, *G. laticunea*, is known from the White River Formation of the central U.S. However, gopher tortoises have also been reported from Eocene and Oligocene sediments of San Diego County, California.

Until this project most systematic analyses of North American tortoises have not coded for individual species of tortoises of all fossil genera. This study hopes to clarify relationships between later diverging *Hadrianus* and very early diverging *Gopherus*, such as *G. utahensis*. Also including individual species from *Stylemys* and *Hesperotestudo* will aid in resolving relationships between them as well as with *Gopherus*.

Fossils from Southwest North America have been analyzed and have added much to the zoogeographical and systematic understanding of gopher tortoises. Correct identification and careful analysis of these specimens have expanded the temporal and spatial distribution of *G. laticunea*, as well as the extant *G.berlandeiri,* which has been confirmed in Pleistocene sediments from the Sonoran Desert of Mexico. Futher examination of the undescribed Eocene *Gopherus* from San Diego will either expand the known range of *G. utahensis* or confirm the existence of another early diverging *Gopherus* in the region. This study builds on previous work on North American tortoises with the addition of numerous postcranial characters. This aids in resolving the placement of fossil specimens from which only postcranial elements are known.

68.7 JOST, JA*; HELMUTH, B; University of South Carolina; *jostj@biol.sc.edu*

THE EFFECT OF BODY TEMPERATURE ON THE GROWTH AND MORTALITY OF GEUKENSIA DEMISSA

The ability to predict the effects of climate change on intertidal communities requires the ability to measure both the physiological limits of organisms in the laboratory and the actual body temperatures of these organisms in the field. Recent technology has allowed for great advances in the ability to measure body temperatures of organisms under field conditions, and using a physical model, I have documented spatial and temporal patterns in the body temperature of the Atlantic ribbed mussel, *Geukensia demissa* in a South Carolina estuary for a period of three years. Based on previous laboratory data, I suggested a lethal temperature for this species between 45 and 50°C. In order to examine the upper lethal temperature limit more closely, I exposed this species to temperatures of either 44, 46, 48, or 50°C in an incubator for 6 hours, followed by a 24 hour recovery period in a seawater holding tank. Preliminary results suggest the lethal temperature for 50% of the population is 47°C. In addition, I conducted a laboratory study to examine the potential effects of sublethal temperatures on mussel growth. Preliminary results suggest that an increase in daily maximum temperature results in a decrease in growth rate. These data imply that *Geukensia demissa* is negatively affected by temperatures that are currently occurring at a site within in its geographical range. Therefore, with the current predictions in climate change, there is the potential for mussel populations to experience an increase in mortality over time, ultimately leading to changes in salt marsh community structure.

S1-3.1 JUSUFI, A.**; GOLDMAN, D.I.; FULL, R.J.; Univ. of California, Berkeley; *ardianj@berkeley.edu*

Active Tail Stabilizes Rapid Vertical Running in Geckos

Animals running vertically must respond rapidly to gaps, obstacles and slippery surfaces to negotiate complex scansorial terrains. We challenged geckos (*Cosymbotus platyurus*; n=7) with three vertical surfaces that produced different degrees of foot slippage. Vertically running geckos held their tails off the wall when footholds on the high traction surface were secure. We induced foot slippage by placing a low traction horizontal patch in the vertical track. Foot slippage initiated a tail reflex that prevented catastrophic pitch-back. *C. platyurus*, running on a vertical high traction surface, began to move their tail tip towards the wall approximately 28±6 ms after fore foot contact with the low traction patch. Tail tip wall impact occurred within 47±11 ms after slip initiation. Geckos running up a bead-covered force platform that continuously resulted in moderate foot slippage always kept their tails in contact with the wall. Tail tip force on the beaded substrate of intermediate traction increased further 17±5 ms after the fore foot contacted the low traction patch. The tail reflex induced a stabilizing impulse moment (0.007±0.004 mN-m-s) that counterbalanced the natural pitch-back moment (0.012±0.007 mN-m-s). Geckos confronted with large, repeated slips tolerated pitch-back by placing their tail in a posture where the last 2/3 of the tail pressed against the wall similar to that of a bicycle's kickstand. Even during these extreme perturbations tailed animals never fell off the wall. In contrast, catastrophic pitch-back resulting in falling was observed in nearly 20% of animals that had naturally lost their tails. In over 60% of the trials, tailless animals failed to cross the slippery patch, whereas less than 15% of the tailed animal trials were unsuccessful.

65.3 KAISER, A.*; QUINLAN, M. C.; Midwestern University, Glendale, AZ; *akaise@midwestern.edu*

Gas exchange patterns in beetles from Southwestern USA

The unique CO_2 release pattern of discontinuous gas exchange (DGE) in insects is often assumed to have evolved to conserve body water. Recently, several alternative hypotheses have been presented to explain the adaptive significance of the gas exchange pattern (reviewed in Chown *et al.* 2006, Physiol. Biochem. Zool. 79, 333-343). Testing these hypotheses has proven difficult and far too few species have been investigated to obtain agreement about which hypothesis is correct. We address this issue by examining three families of beetles in the Southwestern US, occupying a wide range of habitats. So far, we have examined a total of 50 species: 22 Scarabaeidae, 18 Tenebrionidae and 10 Carabidae. We detected three patterns of gas exchange (DGE, cyclic, and continuous). We classified the respiratory patterns in every beetle and correlated them with phylogeny, habitat, wing status and "cryptic" lifestyle, where beetles are - at least occasionally - hidden under dung, soil, rocks, bark or in burrows. Most of the Carabidae and Scarabaeidae exhibited cyclic or discontinuous gas exchange (Carabidae: 20.0% DGE, 70.0% cyclic; Scarabaeidae: 18.2% DGE, 72.7% cyclic). Tenebrionidae were more likely to show continuous gas exchange (55.6%). There was no association between xeric habitat and the occurrence of cyclic gas exchange or DGE. The occurrence of DGE was weakly correlated with a cryptic life style. We found strong associations between the occurrence of DGE or cyclic CO_2 release and the possession of wings. The adaptations of winged beetles to high metabolic demands during flight might be associated with the evolution of discontinuous gas exchange patterns during resting periods. Supported by NSF grant IBN 0344963 to M.C.Q.

47.10 KALMAN, J.E.**; REYES, J.A.; ARMSTRONG, J.L.; SAK, K.; KELLEY, K.M.; California State University, Long Beach, Orange County Sanitation District, Fountain Valley, CA; *jkalman@csulb.edu*

Ectoparastic Infestation and Impaired Endocrine Stress Responsiveness in Marine Fishes in the Southern California Bight

The southern California marine environment is subjected to numerous inputs of pollution, but little is known about pollution effects on infestation of parasites on fishes. Poor water quality and pollution exposure can be chronic stressors, potentially decreasing a fish's defense systems and increasing its susceptibility to diseases and parasites, while disease and/or parasitic infestation will further exacerbate the stressed condition. Pollutants may also have direct effects upon several targets along the neuroendocrine hypothalamo-pituitary-interrenal (HPI) axis, affecting production of the stress hormone, cortisol. We evaluated marine fish and parasite species as potential bioindicators of environmental stress, and also assessed the ability of the HPI axis to normally respond to delivered stressors. Selected marine fish species were collected by trawling from stations adjacent to and away from the four largest wastewater treatment plant (WWTP) outfalls in southern California, and were inspected for ectoparasitic infestation. Many parasites exhibited high host specificity, while the rates of infestation varied according to host fish species suggesting that some fish species may be more resistant to parasitization or have evolutionarily lost their parasites. Interestingly, several fish species, when sampled from locations in the vicinity of WWTP outfalls, exhibited relatively higher parasite prevalence coincidentally with significantly impaired function of their HPI axis, as they could not produce normal surges in cortisol in response to catching stress.

33.4 KAR GUPTA, K*; KATTI, M; Arizona State University, California State University; *kaberi@asu.edu*

Size Matters: Male mating tactics in a prosimian primate, slender loris Loris tardigradus

Nocturnal prosimian primates have been used as models to understand early evolution of primate social systems, but their social and mating systems are poorly understood. While simian primates exhibit diverse and complex mating systems with distinct male tactics, viz., mate guarding, territoriality, and sperm competition, prosimians are often viewed as having simple polygynous mating systems. We challenge this view by showing that male slender lorises *Loris tardigradus*, a small little known prosimian, employ a complex conditional mating strategy incorporating the alternative tactics of roaming and sneaking or territory and mate guarding. We studied the slender loris, a little known nocturnal prosimian, in Kalakad-Mundanthurai Tiger Reserve (KMTR), the southernmost protected area in peninsular India, during June December 1998 and July 2002 June 2003. We captured, marked with radio-transmitters and focal followed 40 individuals in 10 square km area. We demonstrate that these tactics are mediated through body condition and testis size, resulting in three male types roamers, settled bachelors, and settled paired. Settlers are in better body condition than roamers. Among settlers, paired males have larger testes than bachelors, suggesting a role for both sperm competition and mate guarding. This study, like other recent work, refines our understanding of prosimian mating systems. Instead of polygyny, lorises show a complex mating system that combines pair living, elements of polygyny, and sperm competition an unusual combination among primates and a conditional male mating strategy with alternative tactics.

7.7 KARLEN, David J.*; CAMPBELL, Terry G.; GAREY, James R.; University of South Florida; *garey@cas.usf.edu*

A Molecular Analysis of Marine Meiofaunal Diversity Along a Natural Environmental Gradient in the Vicinity of a Shallow-Water Hydrothermal Vent.

The meiofaunal diversity was characterized along an environmental gradient from a shallow water hydrothermal vent at Tutum Bay, Ambitle Island, Papua New Guinea. The meiofaunal community was characterized by sequencing 18S rDNA clones from libraries derived from sediment samples. Samples were collected at nine sites located at 30-50m intervals along a 300 m transect from the vent area and an additional tenth reference site located approximately 1.5 km away from vent. Five samples from each site were combined and sieved through a 500 µm sieve onto a 53µm mesh sieve. A portion of the 18S rDNA gene was amplified and cloned into libraries and approximately 300 clones were sequenced from each site. The sequences were aligned in CLUSTAL and phylogenetic trees made using MEGA. Individual and clustered groups of sequences were identified by using the BLAST search function in GENBANK. Unique sequences were used as a proxy for species and the number of sequences within a cluster served as a proxy for abundance in calculating traditional diversity indices. We report a preliminary analysis of this data and correlate it with physicochemical properties along the transect including gradients in temperature, pH and arsenic concentration. We also compare these meiofaunal results to a previous macrofauna diversity study at the same site.

S6-1.1 KARR, T*; DORUS, S; GERIKE, U; University of Bath; *T.L.Karr@bath.ac.uk*

A sperm's eye view of evolution

A very limited amount of knowledge exists concerning the genetic and molecular basis underlying the diversity of sperm form and function. We have identified 381 proteins of the *Drosophila melanogaster* sperm proteome using whole-sperm mass spectrometry. This direct empirical approach has increased the number of characterized *D. melanogaster* sperm proteins by at least 60-fold. The major functional categories, including mitochondrial, metabolic and cytoskeletal proteins in addition to several unexpected categories suggestive of novel functional capacities are discussed. Evolutionary analyses identified global functional conservation and nonrandom gene clustering and underrepresentation on the X chromosome indicating that sexual selection has played a limited role in sperm evolution and function in this taxa. This suggests that a large number of proteins in the DmSP may serve critical, yet in many cases unknown, functions in reproduction including male-infertility factors. A substantial number of sperm genes have recent evolutionary origins including a recently expanded and functionally diversified family of leucyl aminopeptidases that are testis specific in expression and encode predominant sperm proteins by mass. Finally, significant homology between the DmSP and mouse sperm flagellum proteins highlights the power of comparative evolutionary proteomics in determining fundamental and conserved properties of sperm. Also discussed will be the effect of the paternal-effect gene *ms(3)K81* on proteins of the DmSP.

56.6 KAVANAGH, KD*; EVANS, A; JERNVALL, J; University of Helsinki, Finland; *kathryn.kavanagh@helsinki.fi*

Evolution of murine dentitions along the path of least developmental resistance

We report discovery of a developmental rule governing relative molar sizes in the mouse *Mus musculus*, and, by a macroevolutionary test, we demonstrate its success in predicting the range of dentition patterns found among murine rodent species varying in diet, thereby providing an example of ecologically-driven evolution along the path of least developmental resistance.This study first examined relationships between sequentially developing molars in the mouse by simple experimental surgery to separate tooth germs.We cultured tooth germs from a mutant mouse that expressed Green Fluorescent Protein off a Sonic Hedgehog promoter, which marked the enamel knots and pinpointed the future positions of the molars and cusps *in vitro*, thereby allowing us to follow sequential organogenesis of molars in individual teeth. The results suggested an inhibitory patterning cascade guiding development such that the size of each subsequent tooth was related to the relative size of the preceding tooth. To test the role of the inhibitory patterning cascade in evolution, we measured crown areas of individual molars from 3D scans of dentitions from 25 species of murine rodents. We found that the developmental rule predicted the macroevolutionary pattern shown among rodent species, and that the dietary pattern of the species appeared to drive the evolutionary shift in relative molar sizes.

20.5 KAVANAUGH, S.I.*; SOWER, S.A.; Univ. of New Hampshire, Durham; *sik@unh.edu*

Isolation of a cDNA encoding a third form of Gonadotropin-Releasing Hormone from the Sea Lamprey Petromyzon marinus

As a member of the class Agnatha, sea lampreys, *Petromyzon marinus*, represent one of the two oldest lineages of vertebrates. Previously, two isoforms of GnRH have been isolated and cloned from the sea lamprey. Therefore, the objective of this study was to search the lamprey genome for evidence of a novel form of GnRH and then to determine the expression and its evolutionary relationship with current forms of GnRH. The mapping of the sea lamprey genome started in 2005 and has not yet been completed or annotated. However, 10,000,000 sequences have been released since 2005. Trace files were downloaded from: ftp.ncbi.nlm.gov/pub/TraceDB/petromyzon_marinus in FASTA format. These files were uncompressed and then chopped into smaller files to allow the BLASTing to be done locally against a complete NCBI non-redundant database using software provided by NCBI at: http://www.ncbi. nlm.nih.gov/Tools. Search parameters were blastall p blastx a 2 d GnRH e0.1 v10 b10. The results of this search indicated the presence of a third form of GnRH named lamprey GnRH-II. Similar to the other vertebrate GnRHs, lamprey GnRH-II is highly conserved with 10 amino acids and conserved C- and N-terminal ends. Lamprey GnRH-II has a novel amino acid, phenylalanine, in position 8, the most variable position of the GnRH family. Initial reverse transcriptase-polymerase chain reactions indicate lamprey GnRH-II is expressed in the brain and may be another neurohormone. Future anatomical, phylogenetic, and developmental studies will be required to determine if lamprey GnRH-II is a member of the GnRH-IV family proposed by Silver et al., 2004.

52.3 KELLY, SA*; GOMES, FR; KOLB, EM; MALISCH, JL; GARLAND, T, JR.; Univ. of California, Riverside; *skell005@student.ucr.edu*

Effects of Voluntary Activity and Genetic Selection on Muscle Metabolic Capacities and Organ Masses in House Mice

Studies of rodents have generally found that chronic voluntary exercise causes elevations in total daily energy expenditure (DEE) that also entail increases in food consumption, which may result in compensation by internal organs that support nutrient extraction and utilization. In addition, species that naturally have higher DEE often have larger relevant processing organs, which could represent innate differences and/or phenotypic plasticity. We tested for changes in organ masses of 4 replicate lines of house mice that had been selectively bred for high voluntary wheel running (S lines) for 37 generations as compared with 4 non-selected control (C) lines. Females were housed either with or without wheel access for 13-14 weeks beginning at 53-60 days of age. We also measured hematocrit, citrate synthase activity, and myoglobin concentration. As in previous studies, both selection for high activity and chronic wheel access reduced body mass, with additive effects (no statistical interaction). Body mass was a significant predictor of all traits except citrate synthase and myoglobin, so all results reported are from ANCOVAs. Several traits were significantly affected by selection history and/or wheel access, but interactions between these two main effects were never significant (all $P > 0.05$). With body mass as a covariate, mice from S lines had significantly larger ventricles, with more myoglobin. Wheel access increased ventricle and kidney size, and skeletal muscle citrate synthase activity and myoglobin concentration. S-line individuals with the mini-muscle phenotype (homozygous for a Mendelian recessive allele that halves hindlimb muscle mass) had larger ventricles, spleens, livers, kidneys, lungs, and stomachs. Surprisingly, stomach, intestine, and caecum masses were not significantly affected by any factor. Supported by NSF IOB-0543429 to T.G.

40.3 KERNEY, Ryan; Harvard University, Cambridge, MA; *kerney@fas.harvard.edu*

Detecting the early skeletal anlagen of the direct-developing frog Eleutherodacylus coqui through gene expression

Anurans exhibit a wide range of life history variation that often coincides with developmental diversity. The most dramatic departure from the typical biphasic lifestyle is direct development, where the free-living tadpole stage has been removed entirely. Concomitant with the evolution of direct development is the loss of several tadpole-specific features, which are not found in the direct developing embryo. Former work on this loss of features has focused on the head skeleton of the direct-developing frog *Eleutherodactylus coqui* using histology, immunohistochemistry and whole mount clear-and-stained analyses. These analyses have revealed the loss of the tadpole-specific jaw cartilages in the E. coqui embryo. Through *in situ* hybridizations with several early skeletal markers, this project extends our knowledge of early skeletal patterning in *E. coqui*, and reveals the presence of several pre-cartilaginous anlagen that may be homologous with the tadpole-specific mouthparts formerly thought to be absent in *E. coqui*.

32.6 KHODABANDEH, Saber*; SHAHRIARI MOGHADDAM, Mohsen; ABTAHI, Behroz; Univ. of Tarbiat Modarres, Tehran, IRAN; *surp78@gmail.com*

Na+,K+-ATPase immunolocalization, activity and gene expression in Mugil auratus fry gills: after acclimated to artificial salinities

The immunolocalization, activity, quantitative analysis of intensity and gene expression of the Na+,K+-ATPase in the gills of the golden grey mullet fry, Mugil auratus, investigated after acclimated in different salinity (<2‰, 12‰, 36‰ and 46‰). Na+,K+-ATPase enzyme detected in the gills of samples from all salinities. In <2‰, the fluorescent cells (ionocyts) were observed on the filaments, lamellae and in the epithelium of the gill chamber. The number and size of fluorescent cells decreased in the gills and in the epithelium of the gill chamber of samples from 12‰ salinity. Samples from the 36‰ and 46‰ were showed a high density of ionocyts on the gills and also on the epithelium of gill chamber. Na+,K+-ATPase intensity does not change significantly with salinity from 36‰ to 46‰ and it is significantly higher in the <2‰ salinity compared to 12‰. In compared to 12‰, the expression of Na+,K+-ATPase □□ gene increased 2, 2.5, and 3 fold in the gills of individuals transferred to <2, 36 and 46 ‰, respectively.

7.11 KHODABANDEH, Saber; TAGHIZADEH, Zahra; ABTAHI, Behroz*; CHARMANTIER, Guy; CHARMANTIER-DAURES, Mireille; Univ. of Tarbiat Modarres, Tehran, IRAN, Univ. of Montpellier II, France; *surp78@gmail.com*

Ultrastructure and osmoregulatory function of the kidney in the Acipenser persicus at larval stage

In freshwater fishes, the maintenance of blood osmolality and ion concentrations different from those of the external medium is based on active ion uptake (mainly Na+ and Cl-) by a Na+,K+ exchange pump. This pump is immunopositive for Na+,K+-ATPase. Ultrastructure of the cells and the localization of mitochondria rich cells were examined in the kidney of Iranian sturgeon, *Acipenser persicus*. Investigations were conducted through light and electron microscopy and through immunofluorescence for the Na+,K+-ATPase enzyme detection. Ultrastructuraly, the glomerular cells (podocytes) possess distinctive pedicels that extend to the basal membrane. Tight junctions are not observed, but desmosome-like junctions and large lateral channels are visible between the cells. The proximal tubule cells possess apical microvilli and basolateral membrane infoldings associated with mitochondria. The arrangement of apical microvilli is usually disturbed by the formation of cytoplasmic extrusions and globular vesicles which become detached and pass into the lumen. No immunofluorescence of Na+,K+-ATPase was detected in the glomerular cells. A week immunostaining was observed in the proximal tubule cells. A storage immunostaining of Na+,K+-ATPase was observed in the epithelial cells of the distal tubule and in the some cells of the bladder. In all immunostained cells, the basolateral region showed a much higher fluorescence. In conclusion, the tubule epithelial cells of kidney present morphological and enzymatic features of the osmoregulatory cells, particularly distal tubule cells. The kidney of the *A. persicus* , thus possesses active ion exchange capabilities and beside of their implication in excretion high participate in osmoregulation at larval stage.

64.3 KIM, T. W.*; CHRISTY, J. H.; CHOE, J. C. ; Ewha Womans University, Smithsonian Tropical Research Institute; *ocean74@snu.ac.kr*

The attractiveness of courtship signals increases with predation risk

Although the sensory trap model for sexually selected signals has been suggested over 2 decades, there has not yet been direct evidence how the sensory-trap response functions in the context of mate choice. In some species of fiddler crabs (genus *Uca*), courting males build ornamental structures at their burrows using mud or sand. There has been considerable suggestion that structures attract females because they elicit landmark orientation, a behavior that has evolved for predator escape not for mate choice. Here we tested if mate-searching female *Uca beebei* and *U. terpsichores* change their preference on structure building wavers depending on predation risk, by manipulating the predator visit frequency. We found that mate-searching females of both species more often oriented to the male building ornament when predation risk increased. Our finding suggests that, by orienting to the structures, females reduce their risk when searching for mates and then the relative attractiveness of males with structures should increase with an increase in the level of disturbance by predators. This study provided the first evidence that a female preference based on a sensory-trap response benefits the female when made in the mate-choice context.

54.4 KINSEY, S.T.; Univ. of North Carolina Wilmington; *kinseys@uncw.edu*

Scaling of aerobic metabolic processes in muscle: the effect of fiber size and diffusion

Studies of the scaling of metabolism with body mass typically focus on rates of oxygen consumption. We have investigated the scaling of an aerobic metabolic process, the rate of post-contractile phosphagen resynthesis in muscle, to determine whether aerobic capacity and aerobic metabolic function scale in parallel. We are particularly interested in the influence of intracellular metabolite diffusion on the rate of aerobic processes, and so we have examined muscle tissues from organisms that have a large developmental range in fiber size. Some crustaceans and fishes have muscle fibers that grow hypertrophically during development, leading to very large fiber diameters in adult animals, and this growth is accompanied by a shift in mitochondria toward the periphery of the fiber. Thus, the intracellular diffusion distances between mitochondrial clusters in adult animals are much greater than in juvenile animals. Using both *in vivo* and *ex vivo* muscle stimulation protocols, we have monitored phosphagen resynthesis as a function of body mass (and fiber size) and analyzed these data using reaction-diffusion mathematical models. The models allow us to examine the extent to which diffusion limits the observed rate of phosphagen resynthesis. Despite the large range in fiber size, diffusion limitation appears to be minimal in large, burst contraction fibers, and the measured aerobic process scales in parallel with aerobic capacity. However, in fibers with high rates of ATP turnover, diffusion limitation may be substantial even when diffusion distances are short, perhaps leading to divergence in the scaling of aerobic processes and aerobic capacity.

S9-1.7 KLEY, N.J.*; MEHTA, R.S.; Stony Brook Univ., Univ. of California, Davis; *nathan.kley@stonybrook.edu*

Feeding mechanisms in snakes

Most previous studies of snake feeding mechanisms have focused predominantly on details of the anatomy of the jaw apparatus and/or various qualitative aspects of feeding behavior. In contrast, relatively few studies have attempted to quantify feeding performance in living snakes, and none have done so within a broad, phylogenetic context; most such studies have focused on single species. In this study, we examined feeding performance across a relatively wide range of prey sizes in a phylogenetically, morphologically, and ecologically diverse sample of nearly twenty species of terrestrial and fossorial snakes. Prey transport performance was evaluated for all species studied, and prey capture/subjugation performance was evaluated for several constricting species. Interspecific differences in prey transport performance were then correlated with differences in the relative sizes of various elements of the feeding apparatus, such as the supratemporal, quadrate, palatine, pterygoid, dentary, and compound bone. The relationships between feeding performance and morphology that were obtained from these analyses will be discussed in the context of several hypotheses that have emerged from recent molecular phylogenetic studies, which have called into question the traditional, gradualistic view of the evolution of macrophagy in alethinophidian snakes.

21.3 KLOK, C.J.*; KAISER, A.; LEE, W.H.; SOCHA, J.J.; HARRISON, J.F.; Arizona State University, Midwestern University, Argonne National Laboratory, Argonne National Laboratory; *cjklok@asu.edu*

Single- and multi-generational effects of atmospheric oxygen level on body size and tracheal dimensions in Drosophila melanogaster

Comparison of the historical records for maximal insect size and atmospheric oxygen level suggest that oxygen has influenced insect size through time. An increasing body of evidence using extant insects also suggests that atmospheric oxygen level affects many aspects of insect growth and development, especially size and tracheal investment. Many but not all insects tested show strong developmental plasticity of body size in response to atmospheric oxygen, with higher oxygen levels correlated with larger size and decreased tracheal dimensions or branching. Multi-generational exposure to variation in atmospheric oxygen level has the potential to amplify the effects of oxygen on size through natural selection. We tested this possibility by rearing *Drosophila melanogaster* at 10, 21, 40 and 60% oxygen for single and multiple generations, weighing the founding adults for every generation. Tracheal dimensions were determined using in vivo phase-contrast x-ray synchrotron image capturing and MATLAB M-file image analyses. Body sizes and leg tracheal dimensions did indeed respond to rearing oxygen. Normoxic flies maintained constant body sizes across multiple generations while 10% oxygen, size decreased by 7 to 10% and at higher oxygen levels male and female sizes increased by 10 and 15%, respectively. Leg tracheal diameters increased in hypoxia and decreased in hyperoxia, resulting in compensatory changes in tracheal oxygen diffusing capacity of 143% in 10% and 57% in 60% oxygen. Multi-general exposure increases the responses of insects to atmospheric oxygen level, supporting the hypothesis that oxygen has influenced insect size through the earth's history. This research was funded by NSF grant IBN-0419704 awarded to JFH.

20.1 KNAPP, R.*; NEFF, B.D.; LEARY, C.J.; Univ. of Oklahoma, Norman, Univ. of Western Ontario, London; *rknapp@ou.edu*

Patterns of spermatogenesis and steroid hormone levels differ among reproductive phenotypes in bluegill sunfish

In some species, males achieve reproductive success via one of several alternative reproductive tactics. In bluegill sunfish (*Lepomis macrochirus*), large parental males attract females to the nest to spawn and then provide sole parental care. Small sneaker males and intermediate-sized satellite males reproduce by cuckolding parental males. Previous studies have documented morph differences in sperm characteristics and sperm competition (Leach and Montgomerie 2000; Neff et al. 2003; Burness et al. 2004, 2005; Stolz and Neff 2006). In the present study, we characterized spermatogenesis and circulating steroid hormone levels on the day of spawning. Parental males' testes had proportionally more cysts containing spermatozoa, and proportionally fewer cysts containing spermatocytes, than did cuckolders' testes. Parental males also exhibited a relatively high degree of individual variation in overall patterns of spermatogenesis, a finding that may be related to whether or not the parental male will nest again later in the breeding season (Magee et al. 2006). There was a positive relationship between the percent of cysts containing spermatozoa and plasma cortisol levels in parental males. There was no such correlation for cuckolders. Across morphs, the percent of cysts containing spermatozoa and plasma 11-ketotestosterone levels were also positively correlated. We are using these morph differences in patterns of spermatogenesis and associated hormone levels as a starting point for understanding the proximate mechanisms underlying the documented morph differences in sperm characteristics and the likely morph differences in spawning frequency. Supported by NSF and NSERC.

PLE.1 KOEHL, M. A. R. ; University of California, Berkeley; *cnidaria@socrates.berkeley.edu*

Putting the Organism in its Environment: Ecological Biomechanics

Organisms function in environments where they interact with the fluids, objects, and other organisms around them. We can gain insights about how organisms work if we couple knowledge of their physical and biotic environments, ecological roles, and life history strategies with our laboratory analyses of their function. For example, measurements of the spatial and temporal distribution of loads on an organism in nature reveal the magnitudes and rates at which biologically-relevant biomechanical tests should be performed in the laboratory. Furthermore, the size, shape, and material properties of an individual change during ontogeny, as can its habitat, activities, and ecological role. Therefore, knowledge of the population biology and ecological interactions of organisms being studied is crucial to determine when during the life of an individual particular aspects of mechanical performance should be measured. The environment can also affect which aspects of an organism's morphology determine performance, as well as which aspects of performance are biologically important (i.e. affect survivorship or reproductive success). I will discuss each of these points using examples from my research in order to illustrate how ecological studies can enhance or change our understanding of biomechanical function.

59.1 KOHN, A.J.*; MEYER, C.P.; Univ. of Washington, Seattle, Univ. of California, Berkeley; *kohn@u.washington.edu*

Are radular tooth characters of the gastropod Conus informative for taxonomy and phylogeny?

Conus radular teeth are independently operating, hypodermic needle-like structures that inject paralytic neuropeptides to overcome prey. We tested the hypotheses that 1) they are sufficiently complex to provide discrete and quantitative characters useful in evaluating the range of intraspecific variation within and interspecific differences among closely related species, and 2) phylogenies constructed from radular tooth character matrices are congruent with those based on mitochondrial gene sequence data. For both hypotheses we selected three functional species groups from our current gene sequence database of more than 200 congeners. Radular characters evaluated included the number, size, shape, and configuration of barbs, blades, and serrated edges, and presence or absence of a waist, spur, or cusp. In an earlier study Nishi and Kohn showed that nine quantitative characters were sufficient, either singly or in combination, to distinguish a set of 11 molluscivorous *Conus* species, concluded to be distinct but closely related on the basis of shell characters, from one another. Species-level molecular phylogeny suggests that all extant molluscivorous Conus species arose from a single common ancestor. Phylogenetic analysis of radular tooth characters in this clade also indicates a high degree of congruence with the molecular phylogeny. In the second functional group, that of piscivorous species, molecular genetic evidence suggests multiple origins within the genus. Taxonomies based on gene sequence and shell characters agree. Molecular and radular tooth morphology-based phylogenetic hypotheses are somewhat less congruent than in the molluscivorous species group. Data on the third group, vermivorous species of the Western Atlantic region, are currently being analyzed.

65.9 KOLB, EM*; KELLY, SA; MIDDLETON, KM; SERMSAKDI, LS; GARLAND, JR., T; Univ. of California, Riverside; *zookolb@yahoo.com*

Effects of Experimental Erythropoietin Elevation on Voluntary Exercise and Maximal Aerobic Capacity in House Mice

Voluntary exercise is a complex trait involving numerous subordinate characters, both behavioral and physiological. We have used artificial selection for voluntary exercise to explore evolutionary correlates of a high-activity phenotype. The model is comprised of four replicate lines of house mice selected for high-voluntary wheel running (HR lines) and four replicate lines of non-selected control mice (C lines). Previous work has shown that HR lines run voluntarily on wheels closer to their estimated maximum aerobic capacity (VO_2max) than C lines, and that plasma hemoglobin (Hb) concentration is positively correlated with VO_2max in forced-exercise trials in HR lines, but negatively correlated in C lines. Given that oxygen availability may be limiting exercise capacity, we tested whether voluntary exercise and VO_2max changed in response to an experimental elevation of Hb concentration. The long-acting, recombinant human erythropoietin (EPO) darbepoetin alfa (Amgen Inc.) was administered by intraperitoneal injection to female mice (N = 96) from both HR and C lines at doses of 0 (vehicle control), 100, and 300 ug/kg. Resulting Hb levels were increased by approximately 40 % in both groups HR and C lines. Changes in voluntary exercise and maximal aerobic capacity will be reported. Supported by Amgen Inc. and NSF IOB-0543429 to T.G.

45.1 KOLODZIEJSKI, Johanna A.*; SMITH, G.T.; Indiana Univ; *hkolodzi@indiana.edu*

Evolution and function of communication signals in Apteronotus

Within the electric fish genus *Apteronotus*, communication signals known as chirps are produced by modulating the frequency and amplitude of an otherwise constant-frequency electric organ discharge (EOD). The number and structure of chirps vary across species and sex. Chirping is highly sexually dimorphic in the brown ghost knifefish, *Apteronotus leptorhynchus*. When stimulated with an electric signal simulating a conspecific, males chirp far more than females. Males also produce high frequency chirps that are rarely produced by females. These high frequency chirps are produced by males most often in response to female-like electric signals. They have therefore been hypothesized to be courtship chirps. The more common lower frequency chirps, produced by both males and females in response to same-sex signals, are hypothesized to be aggressive chirps. To test the validity of these hypothesized functions across species, we examined the chirp response of a closely related species, the black ghost knifefish (*Apteronotus albifrons*). This species produces fewer chirps than *A. leptorhynchus* and shows no sex difference in the number of chirps produced. In this study, both male and female *A. albifrons* produced low frequency chirps most often to same-sex signals, a pattern similar to that seen in *A. leptorhynchus*. *A. albifrons* also produced more high frequency chirps to same-sex stimuli than to opposite-sex stimuli. Therefore, although male *A. leptorhynchus* direct their high frequency chirps preferentially at female EODs, *A. albifrons* direct their high frequency chirps preferentially to same-sex EODs. This suggests that high frequency chirps in *A. albifrons*, unlike those in *A. leptorhynchus*, may not function as courtship signals. This behavioral evidence indicates that the use of high frequency chirps during courtship may be a derived feature in the lineage leading to *A. leptorhynchus*.

30.1 KONOW, N*; BELLWOOD, DR; WAINWRIGHT, PC; KERR, AM; Hofstra University, James Cook University, University of California, Davis, University of Guam; *nicolai.konow@hofstra.edu*

Intramandibular joints help coral reef fishes have a bite

Coral reef fishes are more than any other fish fauna characterised by a prevalence of taxa that feed using biting strategies. We investigate the functional morphology of biting in the squamipinnes, a putatively monophyletic assemblage containing nine of the most successful and distinctive coral reef fish families. Using a supertree hypothesis, we demonstrate independent evolution of an intramandibular joint at least five times in this group and discuss the role of this joint in facilitating biting. Character mapping reveals up to seven gains or losses of intramandibular flexion, all associated with trophic transitions between free-living and attached prey. Generalized squamipinnids are commonly suction feeders that lack intramandibular flexion, while atavistic planktivores typically exhibit secondarily derived mandible stiffening. In angelfishes, f. Pomacanthdiae, an intramandibular joint is a basal trait permitting over 35$^{\&deg}$ of mandible flexion, which causes peak-protruded jaw closure. Intramandibular joints in all other squamipinnid taxa function to augment vertical gape expansion during biting behaviours to remove small invertebrates and algae from the reef. In butterflyfishes, f. Chaetodontidae, the origin of intramandibular flexion coincides with a transition from mid-water suction feeding to benthic biting, with flexion magnitude reaching a peak in coral-feeding *Chaetodon* taxa of the subgenera *Corallochaetodon* (16±6.6$^{\&deg}$) and *Citharoedus* (49±2.7$^{\&deg}$). A complex evolutionary history appears to have led to the widespread occurrence of intramandibular joints in extant biters, indicating that intramandibular flexion is a major functional innovation that comprise a functional prerequisite to biting in many reef fishes.

18.2 KONOW, N*; SANFORD, CPJ; Hofstra University; *nicolai.konow@hofstra.edu*

Congruent patterns of muscle activity and kinematics in modulation of a novel feeding mechanism in fishes

Concurrent analyses of motor activity patterns and kinematics in a functional system, although rarely tested, can convey a detailed understanding of how changes in muscle activity can directly influence functional differences. We investigated the role of each of these components of function in facilitating modulation of a novel prey processing behavior (raking) found in two phylogenetically distinct teleost lineages. We fed an elusive, tenacious prey (goldfish) and a non-elusive, mallable prey (earthworm) to brook trout, *Salvelinus* and clown knifefish, *Chitala*. For each taxon, kinematic and muscle activity data were treated separately to establish whether congruent patterns exist between these components when feeding on different prey. Raking in *Salvelinus* was primarily driven by neurocranial elevation but is not modulated. In *Chitala*, however, raking is characterized by extensive pectoral girdle retraction which significantly increases during raking on elusive goldfish. This tendency was directly reflected in muscle activity patterns with prey-type differences in *Chitala* primarily being driven by duration variability in two of the three serially organized ventral muscles bracing the tongue-bite apparatus and connecting it with the pectoral girdle. We discuss these results in the context of a potential decoupling of function in this ventral subsystem of the tongue-bite apparatus. Supported by NSF IOB 0444891 and DBI 0420440.

63.4 KORDONOWY, LL*; MAUCK, RA; MAYS JR., HL; HEITHAUS, ER; Simon Fraser Univ., Kenyon College, Georgia Southern University; *lkordono@sfu.ca*

Eastern Bluebird Sialia sialis Nestling Condition and Facultative Adjustment of Brood Sex Ratios

One hypothesis to explain facultative adjustment among avian populations is that it is an evolutionary response to variable food resources in a promiscuous mating system. Unlike previous studies, our study focuses on chick condition to evaluate factors potentially associated with sex ratio manipulation in an Eastern Bluebird (*Sialia sialis*) population. We explored extra pair paternity (EPP) and food provisioning as possible contributors to facultative manipulation favoring a male biased brood sex ratio. Sex ratio data were collected for four years in a Knox County, Ohio nest box population. We observed a cohort level male biased sex ratio among nestlings in the summer of 2003, and even ratios from 2004-2006. The ratios of mass to wing length (Mass Wing Index) were correlated with male production in nests not parasitized by blowflies (*Protocalliphora sialis*), indicating a maternal facultative shift of sex ratios favoring males when parents provide more food for their clutch. The Trivers-Willard Hypothesis predicts facultative manipulation toward male chicks in a population with high rates of EPP. Previous studies of populations of Eastern Bluebirds have shown moderate rates of EPP; however, this population did not display EPP in 2005. We attribute male biased sex ratios in nestlings within heavy broods to maternal facultative manipulation to produce offspring with optimal reproductive success. We believe this manipulation has adaptively evolved in Eastern Bluebirds spanning wide geographic areas, but EPP is a relatively plastic behavior that need not occur at high rates yearly for populations to manipulate sex ratios in response to resource availability.

S1-3.7 KORFF, Wyatt L.*; GOLDMAN, Daniel I.; California Institute of Technology, Univ. of California, Berkeley; *korff@caltech.edu*

Studies of surface drag in a fluidized bed to discover principles of locomotion on sand.

Terrestrial animals that live in or on sandy habitats contend with a dynamic environment that can deform and flow in response to movement. Inspired by recent field and laboratory studies of lizard locomotion that have documented substrate deformation and drag-based propulsion, we studied the drag on a half-submerged 2cm disk using a large aspect ratio (1200X800 particle diameters) air-fluidized bed filled 200 particle diameters deep with 250 μm glass beads. The use of a fluidized bed allowed for the precise control and manipulation of the material properties of the substrate. We varied the air-flow rate (Q) to the bed and the drag velocity (V_d) (0-40 cm/s) of the disk. Below fluidization, the drag force (F_d) increased linearly with V_d, but unlike Newtonian fluids, had a nonzero intercept. As the onset of fluidization was approached, the intercept decreased yet the slope of the F_d / V_d relationship remained constant. Above fluidization, F_d was no longer linear with velocity but instead had a positive curvature. Above a critical velocity V_c, F_d increased sharply after subtracting the viscous drag. The average slope of F_d / V_d relationship above V_c was the same as the slope below the onset of fluidization. The sharp increase in drag was correlated with the formation of a wake behind the disk similar to studies of wave drag in a viscous Newtonian fluid [T. Burghelea and V. Steinberg, Phys. Rev. Lett. 86, 2557, (2001)]. The formation of surface waves above a critical velocity in Newtonian fluids is a result of a competition between gravitational and capillary restoring forces; in the fluidized bed, the mechanism that produces the sharp onset to wave drag is unknown.

9.8 KOT, B.W.; Univ. of California, Los Angeles; *bkot@ucla.edu*
The Ventral Pouches of Lunge-Feeding Great Whales Play Central Dynamic Roles in Prey Capture and Filtration
Among the largest and most visible anatomical features of the great whales (rorquals; Mammalia: Balaenoptera) are their antero-ventral pleated pouches. These pouches are major components of the filter feeding apparatus of the whales and extend from the tips of the lower jaw posterior to nearly the umbilicus. The understanding of how they function during feeding remains mostly qualitative and speculative. Most rorquals capture prey by lunging into masses of prey organisms such as schooling krill or fishes. Due to the impossibility of directly investigating internal flows in the buccal cavities of feeding wild rorquals, I have used external observations and measurements to study aspects of these flows. Visual observations and digital video recordings were made of three species of rorquals feeding at the sea surface in the Gulf of St. Lawrence, Canada. Blue whales (*Balaenoptera musculus*; the largest species), finback whales (*Balaenoptera physalus*; intermediate in size), and minke whales (*Balaenoptera acutorostrata*; the smallest species) were observed while actively feeding on prey at the surface. As lunging rorquals opened their mouths and partially emerged from the water three things happened: they turned on their sides or backs, exposing their ventral pouches; their forward motions rapidly slowed; and the engulfed volumes of water generated conspicuous waves (moving bulges) in the outer walls of the pouches. Two-dimensional kinematics of the waves were estimated from video recordings of the three species. Results show that these rorquals use their ventral pouches in a functionally similar manner despite their large differences in body size and mass. The evident elasticity of the pouch may also help maintain elevated internal water pressures necessary for the completion of filtration.

56.3 KREGTING, L.T*; YUND, P.O; THOMAS, F.I.M; GRABOWSKI, R.C; University of New England, University of Hawaii, University of South Florida; *lkregting@une.edu*
Position, distance and hydrodynamic effects on fertilization success of the green sea urchin Strongylocentrotus droebachiensis.
The distance and location between free spawning invertebrates such as sea urchins can have important implications on fertilization success and where fertilization occurs (on the substratum or aboral surface, or in the water column). The high viscosity of male spawn may reduce the rate of diffusion from a sperm mass, thus increasing the longevity of sperm and providing a steady supply of viable sperm up to several meters downstream of the male. Fertilization is generally assumed to be unlikely if a female is upstream of a male, but negatively buoyant eggs can become entrained and fertilized in the eddy downstream of a male. In this study, we quantified the percentage of eggs fertilized on or near sea urchins and in the water column as a function of water velocity, distance, and position of the male relative to the female for the green urchin, *Strongylocentrotus droebachiensis*. Fertilization decreased with velocity, and eggs were fertilized in different locations under different conditions; the substratum was an important site for fertilization under a broad range of conditions. In contrast to previous studies, we found that fertilization in some locations did not decrease rapidly with distance, and that fertilization in substratum samples was still fairly high even when the female released eggs upstream of the male.

67.4 KRISTAN, Deborah M.*; CHEEKS, Chrystal; MANIBUSAN, Pierre T.; California State University, San Marcos; *dkristan@csusm.edu*
Changes in antioxidant production during chronic caloric restriction may affect susceptibility to intestinal parasites.
Chronic caloric restriction (CR) produces many physiological benefits, including enhanced immune function. However, recent work indicates that, despite adequate immune function, CR can increase susceptibility to pathogen infection. We tested the effects of long-term CR on susceptibility of male and female laboratory mice (*Mus musculus*, C57BL/6J) to the intestinal nematode *Heligmosomoides bakeri*. CR mice were fed 40% fewer calories than ad libitum (AL) mice, but had no micro- or macronutrient deficiencies. After six months of CR, mice were infected with *H. bakeri*. Both AL and CR mice showed similar amount of eosinophilia above levels of uninfected mice and CR mice had greater IgG1 than AL mice indicating adequate immune function of CR mice for the variables we examined. However, CR mice had more worms than AL mice and worms that resided in CR mice had greater egg output both in vivo and in vitro compared to worms from AL mice. A possible explanation for our data relates to the reactive oxygen species (ROS)/antioxidant pathway. Caloric restriction often decreases ROS production and has variable effects on antioxidants. This is important to our study because ROS are used by the mouse host against the parasite. Our preliminary data show decreased production of the superoxide dismutase antioxidant by the small intestine for CR compared to AL mice. A better understanding of the relationship between caloric restriction and the reactive oxygen species (ROS)/antioxidant pathway during parasite infection may have important implications for human health of persons living with low food availability but with high parasite prevalence.

22.5 KSIAZEK, A.*; KONARZEWSKI, M.; CZERNIECKI, J.; University of Bialystok, Bialystok, Poland; *anetak@uwb.edu.pl*
Reserve capacities of internal organs in laboratory mice divergently selected for basal metabolic rate (BMR)
BMR is considered to reflect energetic costs of maintenance of metabolically active internal organs. We examined whether BMR also reflects the costs of maintenance of reserve capacity of these organs to withstand sudden metabolic stress, using as a animal model laboratory mice from two lines divergently selected for high and low BMR. We suddenly transferred mice of both lines from an ambient temperature of 23°C to 5°C. Cold stress elicited an increase in food intake, which was significantly higher in high (H-BMR) than in low (L-BMR) line and simultaneous similar reduction of food digestibility in both lines. Cold-exposure also elicited a considerable increase in masses of internal organs (small intestine, heart and kidneys), however smaller in L-BMR than in H-BMR mice. It did not affect the mass of liver. The metabolic load on small intestine (quantified as the ratio of food consumption to organ mass) was significantly higher in L-BMR line. In contrast, the metabolic load on liver, kidneys and heart (quantified as the ratio of energy assimilation to organ mass) was significantly higher in H-BMR line. However, the latter was associated with an increase of activity of citrate synthase in these organs, which was higher in H-BMR line. We conclude that L-BMR mice subject to sudden cold stress were close to exhaustion of their reserve capacities, whereas H-BMR mice were able to quickly restore them. Thus, high BMR may be adaptive under unpredictable environmental conditions.

61.2 KUHN, Carey E.*; COSTA, Daniel P.; University of California, Santa Cruz; *Kuhn@biology.ucsc.edu*

Interannual variability in the foraging behavior of California sea lions: behavioral responses to environmental variation

The California sea lion (*Zalophus californianus*) is an abundant predator along the west coast of the United States and populations continue to grow at a rate of over 6% per year. Previous research has shown that El Niño events significantly impact California sea lions, causing changes in foraging trip durations, dive behavior, and pup survival rates. These studies have demonstrated the impact of extensive environmental change; however, little is known about how these animals respond to more typical environmental variation. This study examined the winter foraging behavior of 30 adult female California sea lions over 3 years (2003, 2004, and 2005), using satellite transmitters and dive recorders. As females are constrained to return to the rookery to nurse young pups, we hypothesized trip durations would be maintained and females would alter foraging locations and dive behavior in response to environmental variation. Among years, there were significant differences in movement parameters (transit rate: p

S1-3.8 KUKILLAYA, R.P.*; HOLMES, P.J.; Princeton University, New Jersey; *rkukilla@princeton.edu*

Towards a realistic model of insect locomotion

We develop a hexapedal model to describe insect locomotion in the horizontal (ground) plane. The head-thorax-body is modeled as a single rigid body, and leg masses and inertias and joint dissipation are ignored. As in earlier work by Seipel, Holmes and Full (2004), we employ six actuated legs, but the legs, with `hip' and `knee' joints, better represent insect morphology. As an initial simple model, the muscles are represented as joint torsional springs. Actuation is provided via nominal angle inputs at each joint, corresponding to zero torques in the hip and knee springs. The inputs are determined from estimates of foot forces in the cockroach *Blaberus discoidalis* via an inverse problem. The resulting three degree-of-freedom dynamical system, subject to feedforward joint inputs, exhibits stable periodic gaits that compare well with observations over the insect's typical speed range. The model's response to impulsive perturbations also matches that of freely-running cockroaches (Jindrich and Full, 2002), and stability is maintained in the face of random foot touchdowns representative of running on rough terrain. Further, working towards our goal to develop a neuromechanical model, we introduce more realistic Hill-type muscles which actuate each joint in an agonist-antagonist pair. We study the stability properties of periodic gaits of this model driven by spike-train inputs, obtained from experimental data. Incorporation of a central pattern generator in such a model would provide an integrated description of locomotion, and ultimately permit the study of proprioceptive feedback pathways involving leg force and joint angle sensing.

S2-1.1 KURATANI, Shigeru; Center for Developmental Biology, RIKEN, Kobe, Japan; *saizo@cdb.riken.jp*

Craniofacial evolution from a developmental perspective

In the craniofacial development of vertebrates, some developmental stages are conserved across species, representing particular developmental constraints such as the Hox code clearly expressed in pharyngula. By this stage, primarily unsegmented cephalic mesoderm is subdivided by embryonic structures like otocysts and pharyngeal pouches into several domains. This mesodermal regionalization is shared by all the vertebrate species. The oral developmental program is also constrained to some extent, as both its morphology and the the Hox-code-default state of this region are well conserved among vertebrate embryos. These features do not by themselves explain the evolution of jaws, but should be regarded as a prerequisite for evolutionary diversification of the mandibular arch. By comparing the morphology of pharyngula between the lamprey and gnathostomes, it has become clear that the oral pattern is not entirely identical, in particular the differentiation of the rostral ectomesenchyme is shifted between these animals. Therefore, the jaw seems to have arisen as an evolutionary novelty, by overriding ancestral constraints, a process in which morphological homologies are partially lost. This change involves the heterotopic shift of tissue interaction, which appears to have been preceded by the transition from monorhiny to diplorhiny, as well as separation of the hypophysis. When gene expression patterns are compared between the lamprey and gnathostomes, cell-autonomously functioning genes tend to be associated with identical cell types or equivalent anatomical domains, whereas growth factor-encoding genes have changed their expression domains during evolution. Thus the heterotopic evolution may be based on changes in the regulation of signalling molecule-encoding genes.

S8-1.2 LAILVAUX, S; University of Antwerp; *slailvau@ua.ac.be*

Sex differences in locomotor performance and thermoregulation in reptiles: behavioral and ecological implications

Males and females from several animal taxa differ in locomotor performance abilities such as sprinting and jumping. These performance dimorphisms may be explained at least partially by sex differences in physiology. In ectotherms such as reptiles, however, thermal ecology places an additional constraint on realized locomotor performance capacities. I review recent studies on reptiles examining sex differences in locomotor capacity and thermoregulatory behaviour, and discuss the potential importance of such differences for several aspects of male and female ecology; for example, the interaction between sex, performance and temperature in *Platysaurus intermedius* lizards results in males and females using different behavioral strategies to evade predators. I also consider the evidence for divergence in male and female optimal performance temperatures. Finally, I point to several potentially important areas for future research.

17.5 LAMMERS, A.R.; Cleveland State Univ., Ohio;
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Effects of limb placement on the mechanics of quadrupedal arboreal locomotion

Quadrupedal animals which frequently move on arboreal substrates face unique challenges to maintaining stability. One such challenge to overcome is the tendency to topple over the sides of the branch. Any limb contact will generate a torque (twisting moment) about the long axis of the branch (unless limb force is directed toward the center of the branch). If the reaction torque is not balanced over a stride, the animal may throw itself off one side of the branch. Previous data show that the manus and pes of many animals contact arboreal substrates on different parts of the branch cross-section. This study measures the relationship between limb placement on a simulated branch and the torque generated about the long axis of the branch. Gray short-tailed opossums and laboratory rats ran across an artificial tree branch. While these animals can readily move on branch-like surfaces, the arboreal trackway was too wide in diameter for either species' manus or pes to grip the branch. The trackways was instrumented to measure torque about the long axis of the branch and vertical, fore-aft, and mediolateral forces. High-speed video was used to determine where the manus and pes contacted the branch. Preliminary data indicate that the magnitude of the peak torque is about 1.5 times greater in forelimbs than in hindlimbs. Plots of torque vs time appeared similar to vertical force vs time in both limb pairs, even though forelimbs contacted the branch on its dorsal aspect while hindlimbs contacted the branch laterally. Thus it appears that body weight is the most important factor contributing to torque generated about the long axis of the branch. Mediolateral force, an order of magnitude less than vertical force, contributes little to this torque. Placement of the limbs on the branch may have little effect on the torque generated.

2.9 LANCASTER, LT*; MCADAM, AG; WINGFIELD, JC; SINERVO, BR; Univ. of California, Santa Cruz, Michigan State Univ., Univ. of Washington; *lesley@biology.ucsc.edu*

Yolk steroids regulate crypic back patterns in a lizard

We investigated the role of maternally derived yolk steroids in modulating back pattern elements in side-blotched lizards (*Uta stansburiana*). These lizards exhibit alternative social strategies associated with alternative throat colors (Orange, Blue or Yellow coded by the OBY locus). Previously unreported, the species also exhibits a polymorphism for back pattern, which serves a cryptic, anti-predator function. Here we show that back pattern variants are induced by prenatal exposure to yolk steroids. Yolk steroid levels varied as a function of the dam's social environment (local OBY allele frequencies). Effects of yolk steroids on dorsal markings in progeny in turn depended on progeny OBY genotype. Progeny with steroid-modulated back patterns experienced fitness benefits compared to non-induced progeny. Our results reveal a novel effect of yolk steroid exposure (effects on crypsis are, to our knowledge, previously undescribed in the endocrine maternal effect literature). The effects on progeny of similar yolk steroid concentrations varied as a function of the dam's inducing cue and progeny genotype, suggesting that effects of maternal hormones may be more versatile than previously thought. Because we describe epigenetic inheritance mechanisms contributing to the reliable, context-dependent formation of adaptive trait complexes (throat color and back pattern), our results also support the broader hypothesis that increasing complexity in biological systems corresponds to increasing complexity in inheritance mechanisms.

34.6 LANDRY, S.O.; State University of New York, Binghamton;
slandry@binghamton.edu

Mechanical and Bird Flight.

The fathers of heavier than air flight from Leonardo Da Vinci down to the Wright Brothers gained many of their insights from observing the flight of birds. Is it possible that students of the evolution of flight, in return, might gain some valuable insights from the history of the development of aircraft? Air pioneers can be divided into two types: those primarily interested in perfection of airfoils, and those interested in means of powering flight, usually trying more powerful engines on the same airfoil. It turns out that airfoil is the key to flight. In airplanes it explains the action of the propeller as well as that of the wing. In bird flight, thrust is obtained, not by rowing through the air but by adjusting the angle of action of the airfoil of the outer wing. There is a correspondence bewteen the two types of aviation pioneers and the two approaches to the development of bird flight. The airfoil development aviators correspond to the tree-down theorists of flight development (both concerned with airfoils) while the aviation theorists concerned with motors, correspond with ground up bird flight supporters (both concerned with power.)

S1-2.2 LANGERHANS, R.B.; Harvard University;
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Morphology to Performance to Fitness: Biomechanics and Ecology Predict Evolutionary Divergence in a Livebearing Fish

To examine whether evolutionary outcomes can be predicted from first principles, I test predictions of phenotypic evolution based on biomechanical and ecological knowledge regarding the relationships between body morphology, swimming performance, and fitness in a livebearing fish. Resource competition is expected to generate selection favoring enhanced prolonged swimming performance in low-predation environments (important for foraging, acquiring mates, reserving energy for reproduction), whereas predation is expected to create selection favoring enhanced fast-start swimming performance in high-predation environments (important for evading predator strikes). *Gambusia* (mosquitofishes) use body-caudal fin steady and unsteady propulsion for prolonged and fast-start swimming respectively. Because this locomotor system is mechanically coupled, optimizing one swimming mode necessarily compromises the other (i.e. performance tradeoff). Specifically, prolonged swimming is optimized with a relatively shallow caudal peduncle and a deep anterior body/head region (fusiform body shape), while fast-start swimming is optimized with the opposite trait values (deep caudal peduncle, shallow anterior body/head). This scenario creates specific predictions regarding phenotypic divergence between predator regimes. I test these biomechanical (morphology = performance) and ecological (performance = fitness) assumptions, as well as their resulting predictions for divergent evolutionary trajectories in different predatory environments for a post-Pleistocene radiation of Bahamas mosquitofish (*G. hubbsi*) inhabiting blue holes (vertical solution caves). All predictions are upheld, resulting in strong morphological divergence between predator regimes matching *a priori* predictions.

S2-1.8 LARK, K/G*; CHASE, K; CARRIER, D/R; University of Utah; *lark@bioscience.utah.edu*

Links between the genetic architecture and functional morphology of the canid skeleton

Complex phenotypes, such as the size and shape of the mammalian skeleton, are composed of many individual polygenic components, Quantitative Traits. Purebred dog breeds are a valuable resource for the genetic analysis of complex traits. More than 200 such populations exist. Here we review the use of one such population, the Portuguese Water Dog, to analyze the genetic architecture that informs the canine skeleton. The analysis has provided insights to three interesting phenotypes: Size sexual dimorphism (males are on average larger than females); bilateral asymmetry QTLs that affect one side of the animal (right or left) to a far greater extent than the other side; and functional morphology single loci that affect multiple parts of the anatomy (e.g. skull and limbs) to change shape along axes of variation that represent trade-offs between speed and power. The sequence of the canine genome now provides an additional resource that, when coupled with the use of purebred populations, will allow the further dissection of individual QTLs into the relevant genes that comprise each locus.

7.6 LASKER, HR*; JAMISON, JL; University at Buffalo; *hlasker@buffalo.edu*

Relationships Between Recruitment and Adult Distribution Among Pseudopterogorgia spp.on the Little Bahama Bank

Recruitment of the octocoral *Pseudopterogorgia elisabethae* was monitored twice a year from May 2004 through June 2006 at 6 sites spanning 60 km along the southern edge of the Little Bahama Bank. In 2005 recruits of all *Pseudopterogorgia* spp. were collected from three depths at one of the sites, Cross Harbour, Great Abaco Is. Microsatellite loci were used to identify recruits of the six species found in the adult populations. At all sites and depths recruits were collected from twenty 1 m^2 areas. More recruits were collected during May than November, which is consistent with the spawning information known for four of the species. There was a positive relationship between adult density and recruitment of *P. elisabethae* across the 8 sites, but temporal changes in adult density at the sites did not correlate with changes in recruitment. At Cross Harbour, Great Abaco Island, densities of adults varied between 9, 18 and 27 m for all six *Pseudopterogorgia* spp. Recruitment varied between depths and there was a positive relationship across depths between recruitment and adult density for *P. bipinnata* and *P. elisabethae*, which are known to surface brood. Among the known broadcast spawning species (*P. acerosa* and *P. americana*) there were differences in adult distribution over depth, but no relationship between recruitment and adult density across the depths. The data are generally consistent with the hypothesis that brooding species have more restrictive larval dispersal resulting in populations where recruitment is correlated with local adult density whereas broadcast spawning species disperse widely and have populations in which recruitment is independent of adult population size.

11.1 LAUFER, Hans*; DEMIR, Neslihan; BAGSHAW, Joseph; Univ. of Connecticut, CT, Worcester Polytech Inst., MA; *laufer@uconn.edu*

Identification of CHH-b functions of the lobster Homarus americanus

Crustacean hyperglycemic hormones (CHHs) are members of a family of neuropeptides that inhibit other hormones. The main function of CHHs is to regulate hemolymph glucose, but they also inhibit reproduction by gonad-inhibiting hormones (GIHs) or vitellogenesis-inhibiting hormones (VIHs); mandibular organ-inhibiting hormones (MOIHs) control methyl farnesoate (MF) synthesis which regulate morphogenesis, and metamorphosis; molting is inhibited by molt inhibiting hormones (MIHs). Other CHH functions include androgenic gland inhibition, stress responses, osmoregulation, hydromineral regulation, and secretion of digestive enzymes. Lobsters have two CHH isoforms (CHH-A and CHH-B) which may have different targets and functions. Our goal was to determine the function of pure eyestalk recombinant hyperglycemic hormone-B (CHH-B). The gene encoding *H.americanus* CHH-B was constructed and expressed in *Pichia pastoris* yeast cells. The supernatants from cultures expressing CHH-B were tested for biological activity and compared to sinus gland extracts (0.4-1 SG equivalents). Recombinant CHH-B resulted in decreased methyl farnesoate (MF) synthesis, demonstrating MOIH activity; increased CHH activity; decreased vitellogenin synthesis, VIH activity or GIH activity, and androgenic gland-inhibiting activity; decreased ecdysone production, MIH activity was also found. Our results show that CHH-B is one multifunctional member of the CHH neuropeptide family, with a minimum of 5 different endocrinological functions. (Supported in part by the Sea Grant College Program, NOAA, and the CT Department of Environmental Protection's Long Island Sound Research Fund).

10.1 LAVROV, DV*; HAEN, KM; WANG, X; Iowa State University; *dlavrov@iastate.edu*

Mitochondrial genomics of sponges Implications for animal phylogeny and evolution

Mitochondrial DNA of bilaterian animals is typically a small, circular-mapping molecule that encodes 37 tightly packed genes. MtDNA of choanoflagellate Monosiga brevicollis, the closest unicellular out-group of animals, is four times larger and contains 1.5 times as many genes. We are investigating this remarkable transition in mtDNA evolution, by studying mitochondrial genomes from representatives of all three classes of sponges and other groups of lower animals. Several intriguing funding have been made. First, we were able to show that sponge mitochondrial DNA represents an intermediate stage in the evolution of typical animal mtDNA. Poriferan mtDNA resembles those of other animals in its compact organization, lack of introns, and a well-conserved animal-like gene order. Yet, it contains several extra genes, encodes bacterial-like rRNA and tRNAs, and uses a minimally derived genetic code. Second, we found that the tempo and mode of mitochondrial DNA evolution are quite dissimilar among the tree major lineages of sponges. In particular, mitochondrial genomes of calcareous sponges have several unusual features that clearly set this group apart from other sponges. The diverse patterns of mitochondrial evolution in three groups of sponges suggest that different genetic architectures are hidden behind the superficially similar morphology of sponges. Third, we tested some existing hypotheses of demosponge relationships by using several different datasets derived from mitochondrial genomes: supermatrices of concatenated rRNA, tRNA and protein-coding gene sequences and gene arrangements. Our results indicate that both mitochondrial gene sequences and mitochondrial gene arrangements are informative for the study of poriferan relationships and may represent the datasets of choice for phylogenetic studies in sponges.

S6-1.3 LAWNICZAK, Mara*; BEGUN, David; UCL/UCDavis, UCDavis; *marakat@gmail.com*

Postcopulatory male-female interactions in Drosophila melanogaster: dissecting the female side.

In Drosophila, what we know about the proteins involved in post-mating interactions is heavily biased towards the male side. Genes important in female-mediation of seminal fluid and sperm (including female effects on the outcome of sperm competition) remain largely undiscovered in spite of the obvious fitness-related phenotypes affected in females by seminal fluid transfer. We used quantitative trait locus (QTL) mapping to identify regions of the genome contributing to female propensity to use first or second male sperm (P2), female refractoriness to re-mating, and early-life fertility. We found several regions of the genome influencing P2, refractoriness, and fertility. We also used Affymetrix whole genome expression microarrays to identify genes differentially expressed between virgin and recently mated females. Genes showing the greatest induction upon mating included several serine proteases. We used molecular population genetic approaches to investigate the history of selection experienced by these mating-induced serine proteases. Evolutionary genetic analyses indicate extremely rapid evolution in several of genes, and interesting patterns of gene duplication and gene loss just within the melanogaster subgroup. Directional selection has been important in the evolutionary history of these genes, similar to several seminal fluid genes, documenting evidence for rapid evolution of female reproduction-related genes in Drosophila.

41.2 LEE, DN; University of Missouri - St. Louis; *dnl62e@umsl.edu*

Using animal behavior to teach the scientific process in a high school environment

Far too many students enter and leave science classes memorizing the products of scientific endeavors without knowing what science is. They fail to understand that science involves the observation of natural phenomena, formulating hypotheses, and testing hypotheses; and this is especially true for many high school and college freshman students. As a GK-12 Fellow, I serve as a resource scientist in Life Science classes at a local urban high school, Normandy Senior High School. I work with life science teachers to enrich the existing curriculum. Together, we develop and implement inquiry-based lessons including laboratory exercises and independent research projects (science fair). I help high school faculty increase their content knowledge in life science as well as help students discern what science is. As a scientist and an educator, my objective is to engage students to become active learners -- to ask questions, design experiments and test hypotheses. I use animal behavior to introduce students to science because I believe Animal Behavior is gateway to other scientific disciplines including ecology, chemistry, and physics. I will share how authentic science experiences can help foster lessons related to scientific processes among high school students.

8.8 LEE, David V.; Harvard University; *dvlee1@gmail.com*

Quadrupedal walking, trotting, and galloping reveal different collisional patterns as assessed by center of mass velocity and whole-body ground reaction force vectors

The collisional perspective of Ruina, Bertram, and Srinivasan (2005) demonstrates that energetic losses can be reduced by employing several, sequenced collisions, instead of just one, to redirect the center of mass during legged locomotion. As they discuss, this fundamental mechanical observation holds important implications for quadrupedal gait. Here, collisional patterns of different gaits were tested experimentally in both dogs and goats. A series of four force platforms measured all of the foot forces during a stride of walking, trotting, or galloping. These individual forces were summed to determine the total ground reaction force (GRF) vector. Hence, multiple, overlapping footfalls were considered a single collision. Motion capture was used to measure the animal's velocity immediately preceding the first footfall of the stride and this initial velocity, along with CoM acceleration measured from the force platforms, was used to determine the center of mass (CoM) velocity vector. A perpendicular relationship between the CoM velocity vector and the total GRF vector would minimize collisional loss, so the deviation of these two vectors from perpendicular, termed collision angle', was used to characterize differences between gaits. Collision angle was least in walking, intermediate in galloping and greatest in trotting. Velocity angles were greatest in walking and trotting, whereas, GRF angles were greatest in trotting and galloping. During walking and galloping, collision angle was significantly less than the sum of velocity and GRF angles but collision angle was similar to this sum during trotting. Together, these results suggest a collision reduction strategy in walking and galloping, where footfalls tend to be out of phase, but greater, unmitigated collisions in trotting.

S1-5.7 LEIDERMAN, K.M.*; MILLER, L.A.; FOGELSON, A.L.; University of Utah; *karin@math.utah.edu*

Endothelial Mechanotransduction: Let's Sugarcoat It!

Endothelial cells line blood vessels in the body and are continuously exposed to blood flow, and thus, fluid mechanical forces such as shear stress. Variations in shear stress magnitude and distribution are known to affect many processes needed for proper vasoregulation. Such processes include, but are not limited to, permeability and hydraulic conductivity across vessel walls, gene and cell surface adhesion molecule expression, cytoskeletal rearrangement, and the release of vasodilators. The mechanism responsible for these changes is known as mechanotransduction and has three basic stages: stimulation of a mechanical sensor, transmission of stress through that sensor, and stress transduction which ultimately creates biochemical signals. The endothelial glycocalyx, a dense matrix of membrane-bound macromolecules, is thought to be an important mechanical sensor for endothelial cells. We would like to find the shear stress patterns in and around the glycocalyx to gain a better understanding of the mechanotransduction process. In order to do this, we must be able to calculate the flow through it. Since the exact structure of this layer is not well understood, we use mathematical models to explore the effect of different matrix permeabilities and Reynolds number regimes on flow through a porous matrix to find the resulting exerted fluid stresses. We built a low Reynolds number flow tank and physical models of possible glycocalyx structures to compare our computational results with flow measurements over a range of Reynolds numbers.

44.2 LEMA, S.C.*; DICKEY, J.T.; SCHULTZ, I.R.; SWANSON, P.; Northwest Fisheries Science Center, Univ. of Washington, Battelle Marine Sciences Laboratory; *sean.lema@noaa.gov*

Disruption of the Fish Thyroid Axis by Polybrominated Diphenyl Ether (PBDE) Flame Retardants

Polybrominated diphenyl ethers (PBDEs) are a class of brominated hydrocarbons used as flame retardant additives in plastics, polyurethane foam, and textiles. While PBDEs have helped reduce the loss of human life from fires, concern about the ecological and health risks of PBDEs has been heightened by recent evidence that levels of these chemicals are increasing in wildlife and humans. Little is known, however, about potential impacts of PBDEs to fish health. PBDEs share a structural similarity with polychlorinated biphenyls (PCBs), and there is evidence that PBDEs may disrupt the thyroid system. The goal of this study was to evaluate the effects of the PBDE congener 2,2',4,4'-tetrabromodiphenyl ether (PBDE-47) on the thyroid axis of one model fish species, the fathead minnow (*Pimephales promelas*). Breeding pairs of adult fathead minnows were given oral doses of PBDE-47 bioencapsulated in brine shrimp for 21 days. Effects of PBDE-47 exposure on plasma thyroid hormone levels and on gene expression for thyroid-stimulating hormone &beta subunit (TSH&beta) and thyroid hormone receptors &alpha and &beta were assessed by radioimmunoassay and quantitative real-time RT PCR, respectively. Minnows treated with PBDE-47 had depressed plasma levels of thyroxine (T_4) but no change in levels of triiodothyronine (T_3). PBDE-47 exposure also altered gene expression for TSH&beta in the pituitary and for thyroid hormone receptors &alpha and &beta in the brain. Together, our results show that PBDE-47 can disrupt the thyroid axis in teleost fish. Since thyroid hormones regulate metabolism and have permissive roles in growth, neural development, and reproduction in fish, future work will examine how PBDE exposure may impact these processes. (Funded by NOAA Oceans and Human Health Initiative)

44.3 LERNER, D.T.*; DAVIS, L.K.; MCCORMICK, S.D.; HIRANO, T.; GRAU, E.G.; Hawaii Inst. of Marine Biol., Univ. of Hawaii, Kaneohe, Hawaii Inst. of Marine Biol., Univ. of Hawaii, Kaneohe, USGS, Conte Anadromous Fish Res. Cntr, Turners Falls, MA, Hawaii Inst. of Marine Biol., Univ. of Hawaii, Kaneohe, Hawaii Inst. of Marine Biol., Univ. of Hawaii Kaneohe; *dlerner@forwild.umass.edu*

Effects of environmental estrogens on osmoregulatory homeostasis and endocrine responses of euryhaline teleosts

Mozambique tilapia and Atlantic salmon are euryhaline fishes widely used as models for examining hormonal control of ion regulation in fish. We examined the effects of nonylphenol (NP), a xenoestrogen, and estradiol (E2) on the maintenance of osmoregulatory homeostasis and endocrine responses in FW- and SW-adapted fishes. Tilapia received two intraperitoneal (ip) injections with either E2 (5 mg/kg), NP (150 mg/kg), or vehicle (vegetable oil). Atlantic salmon in FW received three ip injections with either E2 (2 mg/kg), NP (150 mg/kg), or vehicle. SW-acclimated salmon received a slow release implant of E2 (30 mg/kg in 1:1 solution of Crisco and vegetable oil). In tilapia, plasma GH, IGF-I and chloride, and gill Na^+,K^+-ATPase (NKA) were not affected at either salinity. E2 and NP reduced liver GH receptor (GHR) mRNA 50% in FW; only E2 had this effect in SW. In gill tissue, NP and E2 increased GHR mRNA in FW and SW, respectively. E2 and NP reduced liver IGF-I mRNA 25-50% in FW; only E2 had this effect in SW. In gill tissue, NP and E2 increased IGF-I mRNA 50-100% in FW and had no effect in SW. In Atlantic salmon, E2 and NP decreased plasma GH 3-6 fold in FW and E2 increased GH 4-fold in SW. Plasma IGF-I was decreased more than 50% in FW and SW. E2 reduced NKA in SW and ion regulatory ability in FW and SW; there was no affect of NP. E2 and NP decreased liver and gill GHR binding activity 2-3 fold in FW and SW. These data suggest that estrogenic compounds alter the GH/IGF-I axis and in some teleosts, this may compromise ion regulatory capacity.

69.4 LENTINK, D.*; MÜLLER, U.K. ; STAMHUIS, E.J. ; DE KAT, R.; VAN GESTEL, W. ; HENNINGSSON, A.; HEDENSTRÖM, A.; VAN LEEUWEN, J.L.; Wageningen University, Wageningen, The Netherlands, Groningen University, Groningen, The Netherlands, Delft University of Technology, Delft, The Netherlands, Lund University, Lund, Sweden; *david.lentink@wur.nl*

How swifts control their glide performance with morphing wings

During gliding flight, birds continually change the shape and size of their wings. Wing geometry has a profound effect on aerodynamic performance. Here we show how morphing enlarges the performance envelope of swift wings, affording swifts effective control of their gliding flight. To quantify the effect of morphing, we measured lift and drag forces using a wind tunnel for a range of wing geometries and glide speeds that extend well beyond the birds behavioural envelope. We formulated six figures of merit related to flight costs and agility to evaluate variable wing geometry. We show that sweeping the wings back by up to 50 degrees can alter flight cost related figures of merit by 30 to 265%, and agility by 125 to 320%. Straight gliding favours extended wings at low glide speeds and swept wings at high speeds, whereas turning favours extended wings at all speeds. However, all fast gliding flight generates excessive wing loads that can only be accommodated by high sweep. Our semi empirical glide model predicts the most cost effective glides at speeds between 8-10 m/s whereas agility peaks at 15 and 25 m/s. Swifts in fact roost at 8-10 m/s, thus our model accurately predicts minimal energy loss during resting behaviour. We conclude that morphing wings show special promise for innovative agile and efficient bird sized air vehicles.

S1-1.10 LEYS, S.P.*; YAHEL, G.; Univ. of Alberta, Univ. of Victoria; *sleys@ualberta.ca*

In situ measurements of glass sponge pumping: testing the current-induced flow hypothesis

Flow through sponges (Porifera) is thought to be enhanced by ambient current due to Bernoulli's principal, pressure differential, viscosity entrainments, or a combination of the three mechanisms. Vogel's test of this phenomenon suggested that current augmented by fanning live and inactivated (by killing in freshwater) sponges increased flow through the sponge. Glass sponges are an ideal subject with which to re-examine the hypothesis. Individuals are large (up to 1m tall), chalice-shaped animals, with a cavernous atrial cavity and a body wall less than 1cm thick that houses the flagellated chambers. We used Accoustic Doppler Velocimeters (ADVs) to measure flow velocities from 3 sponges and ambient water at 165m depth on a glass sponge reef near Vancouver, British Columbia. Week-long ADV records illustrated that exhalent flow corresponded to local tidal rhythms (measured with a nearby current profiler). However, at times the sponge pumping pattern deviated from the ambient flow suggesting that glass sponges do control excurrent flow velocities independently of ambient flow, and at the same time can take advantage of Vogel's principal of current-induced flow. However, glass sponges are syncytial and can arrest pumping following mechanical stimulation, regardless of ambient flow, as was shown in both lab and field experiments. Furthermore, fluorescent dye applied to dead sponges was not drawn through the inert skeleton, as would be implied by Vogel's hypothesis. Evidence from other sponge classes (Calcarea and Demospongiae) suggests that cellular sponges can also control flow through the animal by constriction of incurrent openings (ostia) and canals. Our experiments imply that while sponges can take advantage of current-induced flow, flow through these animals is largely controlled by their complex physiology.

71.5 LEYSEN, Heleen*; JOUK, Philippe; ADRIAENS, Dominique; Ghent University, Antwerp Zoo; *heleen.leysen@ugent.be*

Patterns of cranial skeleton ontogeny in Syngnathidae: a comparison between Syngnathus rostellatus and Hippocampus capensis

The special reproductive strategies of Syngnathidae, their elongated snout without teeth, the fastest food intake among teleosts and the vertical position in the water column with the accompanying tilted head of seahorses, makes pipefishes and seahorses very remarkable. Despite their exceptional appearance little is known about their morphology and ontogeny. The aim of this research is to compare the ontogeny of the head skeleton in *Syngnathus rostellatus* and *Hippocampus capensis*. A detailed morphological study was performed using cleared and stained specimens, as well as serial histological sections for graphical 3D-reconstructions. The obtained results were compared with those of *Gasterosteus aculeatus*, which has a basal position within the same order. Based on the results of this study and data from literature it could be concluded that the elongation of the snout appears very early in the development. Already at the moment of being expelled from the brooding pouch, the juveniles are provided with a specialized feeding-apparatus, comparable to the adult situation. It could also be shown that there is a close resemblance between *S. rostellatus* and *H. capensis*, with the most important dissimilarities being related to the different levels of snout elongation. However, a distinct neurocranial dissimilarity was observed during early ontogeny, with the seahorse braincase being tilted with respect to the ethmoid region. The differences with *G. aculeatus* involve a series of structural specializations in *S. rostellatus* and *H. capensis* that can be related to powerful and fast suction feeding, such as the reduced maxillary bones without protrusion, the elongation of the ethmoid region to form the tubular snout and the well developed hyoid arch.

23.3 LIAO, James C.; Cornell University; *jl10@cornell.edu*

In vivo activity of zebrafish inhibitory spinal interneurons across behaviours

Inhibitory commissural spinal interneurons play a key role in shaping the rhythmicity underlying undulatory locomotion. Here we present data on the morphology, activity, and possible interconnectivity of these cell types in 2-5 day post-fertilization zebrafish larvae obtained by targeted patch clamping in a stable transgenic line of zebrafish expressing green fluorescent protein in glycinergic cells. Commissural bifurcating longitudinal interneurons (CoBLs) are active during swimming frequencies of 30-60 hz and have motor neurons and other CoBLs as likely postsynaptic targets (as indicated by confocal imaging). Some CoBLs have a relatively long descending axon (> 4 myotomes) compared to the ascending axon while others have short ascending and descending axons (< 2 myotomes). Long-axon CoBLs are active at swimming frequencies of 30-60 Hz, as well as during struggling, when the body wave passes caudal to rostral. Short-axon CoBLs are active at 30-40 Hz and not during struggling. Commissural longitudinal ascending interneurons (CoLAs) are not active during swimming at any frequency, but rather are only recruited during struggling. Their likely post-synaptic targets include motor neurons. Commissural local interneurons (CoLOs) have a high threshold for firing and possess a short, robust descending axon that is excited by the descending reticulospinal Mauthner axon. These cells are not active during swimming or struggling, but are active during the escape response, as has been found in goldfish. Commissural secondary ascending interneurons (CoSAs) are active during swimming at 30-40 Hz as well as during struggling. Our data suggest that some cell types are dedicated to particular behaviors, whereas others are shared among behaviors. The challenge now is to understand better their ability to serve either more generalized or specific behavioral roles.

S1-3.9 LIBBY, T.*; FULL, R.J.; Univ of California, Berkeley; *tlibby@berkeley.edu*

Passive Muscle Facilitates Rapid Perturbation Recovery in an Insect Leg

Isolated and intact legs of cockroaches begin to recover from vertically directed impulse perturbations within 5 ms and return to within 99% of their original position within the swing phase duration. This response is due to the leg's passive exoskeletal properties because of their vertically oriented joint axes. To examine recovery from horizontal plane leg perturbations involving passive muscle, we used a small servomotor and material testing techniques including sinusoidal oscillations and impulses to classify the passive dynamic system of the metathoracic leg of *Blaberus discoidalis*. We focused on motion of the coxa-femur joint that is responsible for fore-aft motion of the foot. Passive viscoelastic forces from muscle and exoskeleton were nonlinear and history dependent. For low speed ramp perturbations, recovery was slow and highly overdamped. For rapid perturbations, legs returned quickly and recovery was slightly underdamped. Applying sinusoidal forces to legs elicited periodic displacement as in running. Adding ramps and impulses confirmed that the passive system alone rejected perturbations to a periodic trajectory in less than 40 ms. Using this system as a model for the swing phase of running, we conclude that passive forces from the exoskeleton and inactive muscle allow the leg to completely recover from large impulse perturbations before footfall at stride frequencies over 8 Hz. Further, the swing phase can act as a stabilizer for leg position, rejecting perturbations to leg displacement that occur during stance phase. Stance phase perturbations that create an error in leg position at the onset of swing do not affect footfall position.

17.3 LIEBERMAN, DE*; BRAMBLE, DM; RAICHLEN, DA; Harvard University, University of Utah, Uinversity of Arizona; *danlieb@fas.harvard.edu*

Humans use a unique mechanism to stabilize the head during running

Mammals must stabilize the head during running to keep angular accelerations of head within the operating range of the vestibulo-ocular (VOR) reflexes. However, several unique aspects of the human body plan and locomotor kinematics make head stabilization more challenging than in other cursors. Most bipedal and quadrupedal cursors have cantilevered heads and necks that act to attenuate forces and counter sagittal head pitching through controlled flexion and extension movements. In contrast, humans have short vertical necks that emerge from near center of head, combined with relatively extended, stiff legs at heel strike (HS), resulting in a strong tendency for the head to pitch forward at the beginning of stance. Using EMG, kinematic, and kinetic measurements of human arm and head movements during running and walking we show that humans stabilize the head following HS using a unique tuned-mass damper system. This mechanism, which links the head with inertial forces in the stance side (ipsilateral) arm, is facilitated by a number of derived aspects of human anatomy and running kinematics. Notably, humans have lost all muscular connections between shoulder girdle and head except for the cleidocranial portion of the trapezius (CCT), which reaches the occiput via a tendon-like nuchal ligament. Additionally, coordinated movements of the arm and thorax position the ipsilateral arm behind the head-neck joint prior to HS, when the ipsilateral CCT fires. Out of phase accelerations of the arm and head then link the counterbalancing mass of the arm and the flexed forearm via a compliant connection to the head, controlling the head's rate of pitch. Because the nuchal ligament, a key component of the system, leaves a trace on the skull, it is possible to show that this novel mechanism for head stabilization originated within the genus *Homo* approximately 2 million years ago.

48.2 LIGHTON, J.R.B.; UNLV and Sable Systems International; *lighton@sablesys.com*

Hot Flies: The Effects of Hypoxia on Thermal Tolerance in Drosophila melanogaster.

This study addresses the effects of acute hypoxia on thermal resistance in *Drosophila*. The upper critical thermal maximum (CT_{max}) of metazoans varies over a wide range, and its determinative factors, such as oxygen limitation, remain controversial. Induction of thermoprotective mechanisms after challenge by sublethal heat stress has been well documented in many organisms, including the model fly *Drosophila melanogaster*. Interestingly, however, other challenges notably a period of anoxia induce post-exposure thermoprotective effects in some organisms such as locusts. Here I show, using thermolimit respirometry, that acute hypoxia during thermal stress significantly reduces the CT_{max} of *D. melanogaster*, but only below an oxygen partial pressure of 10 kPa. Likewise, the scope for voluntary motor activity declines sharply below 10 kPa and is essentially eliminated at 2.5 kPa. Respiratory water loss increases highly significantly below 10 kPa. The post-mortal release of a large quantity of CO_2 is shown to be independent of loss of spiracular control, but dependent in part on oxygen availability. The results of this study are broadly in accord with the oxygen limitation hypothesis, but suggest that oxygen limitation only becomes an important factor during significant hypoxia.

1.1 LINDGREN, AR*; DALY, M; The Ohio State University; *lindgren.11@osu.edu*

Issues in DNA sequence alignment and its affect on topology: the evolution of Decapodiformes (Mollusca: Cephalopoda)

In molecular phylogenetics, mode of analysis is typically the primary reason for obtaining different topologies. However, sequence alignment is likely to be as important in determining topology as analytical method or optimality criterion. The impact of alignment method or parameter parameters is most significant for length-variable sequences. We investigate the effect of alignment strategy and parameters an analysis of length-variable 18S rDNA sequences from 41 oceanic squids (Decapodiformes), focusing particularly on the impact of including hypervariable regions on the resulting topology. Decapodiforms are an enigmatic group of mollusc whose evolutionary relationships remain unclear because standard molecular analyses have continued to produce poorly-supported or resolved trees, due potentially to elevated levels of molecular evolution. We find that alignment strategy (ClustalX versus POY) has a greater affect on topology than does parameter choice. However, some groups are highly robust to shifts in methodology, including cuttlefishes (Sepiidae), bobtail squids (Sepiolidae) and pygmy squids (Idiosepiidae). No alignment strategy supported the monophyly of Oegopsida, although the Myopsida did consistently form a monophyletic group. The hypervariable regions consistently provided more well-supported and well-resolved trees than the conserved regions alone, indicating the importance of including hypervariable data.

6.4 LILLYWHITE, H.B.*; BABONIS, L.S.; SHEEHY III, C.M.; TU, M.C.; Univ. of Florida, Gainesville, National Taiwan Normal University, Taipei, Taiwan; *hbl@zoo.ufl.edu*

Sea Snakes Dehydrate in Sea Water

Sea snakes are generally thought to remain in water balance without consuming fresh water owing to salt excretion by extrarenal salt glands. We studied dehydration and drinking behavior in three species of laticaudine sea snakes inhabiting Lanyu (Orchid Island), Taiwan. These species differ with respect to degree of terrestrial tendency and permeability of skin to water: *Laticauda colubrina* is semi-terrestrial and its mean cutaneous evaporation rate (CEWL) is 0.118 ± 0.11 mg/cm^2 h^1; *L. laticaudata* is relatively more aquatic and CEWL = 0.37 ± 0.20 mg/cm^2 h^1; *L. semifasciata* is the most fully aquatic and CEWL = 0.54 ± 0.31 mg/cm^2 h^1 ($P<0.0001$, ANOVA for CEWL differences measured at 23-24 °C). We report direct evidence that sea snakes do not drink sea water and require fresh water to replenish water stores that are depleted by dehydration in air or water. Moreover, a conservative input/output analysis of water balance indicates that snakes in sea water will dehydrate with or without food. We further show that populations of these species are most abundant at coastal sites where sources of fresh water such as springs are present ($P=0.004$). Elsewhere these snakes presumably acquire fresh water from brackish surface lenses that form on the ocean during rainstorms. The threshold salinity for drinking is 25% SW < 50% SW. Globally, species diversity of sea snakes correlates positively with mean annual precipitation. The stochastic nature of rainfall patterns, both in time and space, appears likely to limit the distribution of marine snakes, which is characteristically patchy. This work was supported by the National Geographic Society and Delfin Technologies Ltd.

S5.2 LIU, Yu; STEENKAMP, Emma; DARMON, Daniel; BURGER, Gertraud; LANG, B. Franz*; 1, 2 Department of Microbiology and Plant Pathology, University of Pretoria, South Africa, 1 Robert Cedergren Centre for Bioinformatics and Genomics, Canadian Institute for Advanced Research, Departement de biochimie, Universite de Montreal, Quebec, Canada; *Franz.Lang@Umontreal.ca*

The evolutionary transition from protists to Metazoa: mitochondrial genome organization and phylogenomic analyses based on nuclear and mitochondrial genes.

Key events in eukaryotic evolution such as the divergence of major lineages such as animals, Fungi and plants occurred a billion or more years ago. Hence, their phylogenetic inference is difficult, and analyses based on a single or few genes are usually insufficient to provide statistically significant results. Therefore, we perform phylogenomic analyses either based on complete sets of mtDNA-encoded proteins, or on large collections of nucleus-encoded proteins derived from ESTs. We are interested in the phylogenetic position of protists that are suspected to branch close to the animal-fungus divergence including *Monosiga, Capsaspora, Nuclearia, Amoebidium* and members of the Apusozoa (*Amastigomonas* and *Ancyromonas*). The analysis of complete mtDNA sequences reveals that all of these species have extra genes (several for ribosomal proteins) compared to the animal set (now including *atp9* and 25 standard tRNAs in sponges). Phylogenomic analyses with mt and nuclear data show that *Amoebidium, Capsaspora* and *Monosiga* branch at the base of animals and *Nuclearia* at the base of Fungi. However, we have difficulties to place Apusozoa. Contrary to results by others who position them close to the animal-fungus divergence, our mt data tend to group them with malawimonads (jakobid-related bacterivorous flagellates), yet without significant support. Nuclear data so far do not resolve this question.

3.1 LOHMANN, K. J.*; HORNER, A. J.; AKINS, L.; LOHMANN, C. M. F.; Univ. of North Carolina at Chapel Hill; *KLohmann@email.unc.edu*

Detection of Coastal Magnetic Fields by Sea Turtles: a Possible Mechanism Underlying Natal Homing

Loggerhead sea turtles (*Caretta caretta*) from eastern Florida undertake a transoceanic migration in which they gradually circle the north Atlantic Ocean before returning to the North American coast. Later, as adults, the turtles exhibit natal homing on a regional scale, returning to nest in the same general geographic area where they themselves hatched. Young sea turtles are known to use the magnetic fields that exist in different oceanic regions as a system of open-sea navigational markers. In principle, such fields might also function in helping turtles return to nest in the coastal areas where they themselves hatched. As a first step toward investigating this possibility, hatchling turtles were exposed to two different magnetic fields that mark coastal areas in north and south Florida. Hatchlings responded to the field from the northern site by swimming approximately southeast, a response that might serve to help turtles move farther into the Gulf Stream and reduce the chances of being swept into fatally cold water that lies to the north. In contrast, hatchlings exposed to the field from the southern site, where there is no danger of displacement from the migratory route, were not significantly oriented. The orientation elicited by the two fields was significantly different. Thus, by the time they enter the ocean, hatchling turtles already possess the ability to distinguish among magnetic fields that exist in different nesting areas along the Florida coast. The precision with which turtles can resolve differences among fields is, in principle, sufficient to account for the known resolution of natal homing in Florida loggerheads.

S4-2.3 LOLADZE, I.*; ZEA, E.; CASSMAN, K.; MCFADDEN, C.; University of Nebraska - Lincoln; *iloladze@math.unl.edu*

Elevated CO2 effects of plant stoichiometry and "hidden hunger" disorder

One of the most certain aspects of global change is the increase in the concentrations of atmospheric CO2 - the major nutrient for plants. Field experiments showed that elevated CO2 can alter micronutrient content in plants. Understanding and quantifying such change in plants is important, because chemical elements such as iron (Fe), iodine (I), and zinc (Zn) are already deficient in the diets of the half of human population, which derives 84% of its calories from plant products. Suboptimal concentrations of these and other essential elements in crops contribute to the most widespread nutritional disorder in the world hidden hunger . Apart from an overall decline in nitrogen (N) concentration, however, little is known about the effects of high CO2 on other chemical elements. One of the ways (and, perhaps, the least inexpensive way) to narrow this gap in our knowledge is to construct a mathematical model of an individual plant that reflects the effects of elevated CO2 on its stoichiometry. We present such a minimal, in our view, model consisting of the system of ordinary differential equations that tracks nutrient concentrations in soil, rhizosphere, and inside of a plant. In addition, we compiled the largest to date database of CO2 effects on plant stoichiometry. The preliminary analysis of the model and the database suggests that elevated CO2 leads to an overall decline in micronutrient content in plants. This can aggravate hidden hunger disorder.

36.3 LONGRICH, Nicholas; University of Calgary; *longrich@ucalgary.ca*

Structure and function of hind limb feathers in Archaeopteryx lithographica

A restudy of the Berlin *Archaeopteryx* was undertaken to understand the morphology and function of the hind limb feathers. Feathers cover the legs of the Berlin specimen, extending from the cranial margin of the tibia and the caudal margins of the tibia and femur. These feathers exhibit features of flight feathers rather than contour feathers, including asymmetrical vanes, curved shafts, and a self-stabilizing overlap pattern. These features are thought to facilitate lift generation in the wings and tails of extant birds, suggesting that the hindlimbs acted as airfoils. A new reconstruction of *Archaeopteryx* is presented, in which the hindlimbs form approximately 12% of the total airfoil area. Depending upon their orientation, the hindlimbs could have reduced stall speed by up to 6% and turning radius by 12%. Presence of a "four-winged" planform in both *Archaeopteryx* and Dromaeosauridae suggests that their common ancestor used both the fore- and hindlimbs to generate lift. This finding in turn suggests that arboreal parachuting and gliding may have preceded the evolution of avian flight.

68.6 LOTTERHOS, K. E.*; LEVITAN, D. R.; Florida State University; *klotterhos@bio.fsu.edu*

Broadcast spawners that poof: a model of turbulent diffusion from a point source applied to coral spawning in the field

Broadcast spawners are organisms that emit both male and female gametes into the water column, and depend on water motion to bring sperm and eggs together. Diffusion models of gamete mixing can give insight into the behavioral adaptations of broadcast spawners and have implications for biological processes such as fertilization success. Some taxa, such as sea urchins, emit their gametes over a period of time in a plume, a process that has been modeled theoretically and tested experimentally in marine systems. These plume models are time independent as a plume will establish a concentration gradient of gametes. Here we present a model of turbulent diffusion from an instantaneous point source, which is time dependent as the sperm rapidly diffuses from a point source. This model may be applied to organisms that emit gametes in bundles or bursts, such as in some corals and fish. Parameterization of the model was accomplished by measuring diffusion coefficients of dye blobs in the field. The model was tested by examining sperm concentration and fertilization as a function of time and distance from a bursting coral gamete bundle in the Caribbean.

S1-2.10 LOUDON, C.*; MILLER, G. L.; FREED, S.; University of California, Irvine; *cloudon@uci.edu*

Position Around a Tree: Consequences for Pheromone Detection

The usual flow pattern expected around a cylindrical object such as a tree in slow wind is predicted from fluid mechanics to have areas of faster flow (upwind) and slower recirculating flow with eddies (downwind). An organism located on the surface of a tree would therefore experience different flow depending on its circumferential position. If that organism was searching for a chemical signal, such as a pheromone plume, it might maximize its probability of chemodetection by placing itself in areas of greatest flow speed (the upwind surface of the cylinder, i.e. in front of the separation points). We tested whether wood roaches in the genus *Parcoblatta* exhibit such upwind positioning; they live in forests, and males actively fly from tree to tree while searching for females releasing sex pheromone. In contrast to an expectation of upwind preference, male cockroaches were evenly distributed around trees relative to upwind (measured with a novel feather boa flow visualization technique), even when the wind direction was relatively steady. We investigated whether sex pheromone could be detected at any location around a cylindrical surface in a laboratory flow chamber using *Bombyx mori* wing fanning as a bioassay. Although upwind moths arrayed on the surface detected pheromone more rapidly, pheromone detection occurred at least a third of the time at any position, which could explain the even distribution of *Parcoblatta* males around trees.

63.3 LOVE, Oliver/P*; WILLIAMS, Tony/D; Simon Fraser University, Canada; *olovea@sfu.ca*

Exposing the embryo to maternal stress: an adaptive predictive mechanism or an unavoidable developmental cost?

How and why maternal stress affects offspring phenotype has become a subject of considerable interest in studies spanning numerous vertebrate taxa. In birds, embryonic exposure to elevated maternal stress hormones can reduce multiple measures of nestling quality, which could be interpreted as a proximate cost to the offspring and an ultimate cost to the mother. However, we recently suggested that the transfer of the maternal stress hormone corticosterone to eggs may represent an adaptive mechanistic link between maternal quality and sex-biased maternal investment in offspring. Here we present results from a recent field experiment in the European starling (*Sturnus vulgaris*) combining both a manipulation of yolk corticosterone (egg hormone injections) and maternal quality (feather-clipping of mothers). Low quality (feather-clipped) mothers raising corticosterone-exposed offspring fledged more young of higher quality than low quality mothers raising control young. Furthermore, low-quality females that raised corticosterone-exposed young in the first brood also appear to fledge higher quality young in their second brood attempts than low quality females originally raising control young. Finally, return rates (survival) of low-quality females that raised hormone-exposed young the previous year were higher than those of low quality females that raised control young. These preliminary results indicate that the transfer of corticosterone to eggs is adaptive in that it matches the quality of a mother to the offspring she will rear. Moreover, this adaptive mechanism increases fitness in future reproductive attempts and maximizes survival of mothers.

59.4 LUDTKE, JA; San Diego State University; *joshualudtke@gmail.com*

A Systematic Revision of the Agriochoeridae (Cetartiodactyla: Oreodontoidea)

Oreodonts, despite being a common component of Tertiary North American terrestrial faunas, lack a firm phylogenetic placement within Cetartiodactyla. Most workers agree that they are an early diverging`group, but disagreement exists as to whether oreodonts are more closely related to ruminant, suid, or tylopod artiodactyls. The earliest appearing branch of Oreodontoidea is the clade Agriochoeridae, which is defined by the retention of several ancestral character states, such as an incomplete postorbital bar and a lack of lacrimal fossae. Some members of this clade are unique among Cetartiodactyla in developing clawed ungual phalanges. As currently defined, Agriochoeridae is paraphyletic, as it contains basal oreodonts, true agriochoerid oreodonts, and basal members of the highly successful oreodontid oreodonts. In addition, the named genera within Agriochoeridae, *Protoreodon*, *Diplobunops*, and *Agriochoerus*, are in need of taxonomic revision. *Protoreodon* contains several independent evolutionary lineages, *Diplobunops* might simply be early species of *Agriochoerus*, and several other species are known but lack a published diagnosis, definition, or name.

Reorganization of the species and supra-species level systematics of the Agriochoeridae is necessary to allow the proper placement of Oreodontoidea in cetartiodactylan systematics. This investigation uses measurements and observations of dental, cranial, and postcranial morphology to diagnose and describe members of Agriochoeridae at the species level. At least fifteen species in this clade can be distinguished, mostly by a combination of dental row size and the cusp development of the upper and lower fourth premolar. These characters are used to place the agriochoerid species into a phylogenetic taxonomy. This information will be used to further refine the placement of Agriochoeridae and Oreodontoidea within Cetartiodactyla.

12.5 MACEDONIA, J.M.*; LAPPIN, A.K.; LOEW, E.R.; MCGUIRE, J.A.; HAMILTON, P.S.; PLASMAN, M.; BRANDT, Y.; LEMOS-ESPINAL, J.A.; Arizona State University, Tempe, Northern Arizona University, Flagstaff, Cornell University, Ithaca, NY, University of California, Berkeley, Utrecht University, The Netherlands, University of Toronto, Ontario, Canada, University Nacional Autonoma de Mexico, Tlalnepantla; *Joseph.Macedonia@asu.edu*

Between the Devil and the Deep Blue Sea: Conspicuousness of Dickerson's Collared Lizard (Crotaphytus dickersonae) Through the Eyes of Conspecifics and Predators

Collared lizards (*Crotaphytus*) are rock-dwelling reptiles endemic to the western USA and Mexico. Most *Crotaphytus* species exhibit dull coloration to avoid detection by predators and by potential lizard prey, but adult male Dickerson's collared lizards (*Crotaphytus dickersonae*) a species restricted to Isla Tiburon in the Sea of Cortez and adjacent coastal mountains in Sonora, Mexico are bright blue (females are largely brown). We used visual modeling to investigate the differential conspicuousness of *C. dickersonae* to conspecifics and to snake and bird predators. Predation pressure and saurophagy (lizard eating) also were assessed. Disparity analysis of contrast between lizard color patterns and their visual backgrounds revealed that *C. dickersonae* males were more conspicuous in coloration than females in all visual models, and with one exception both sexes were more conspicuous to their own visual system than to snake or avian visual systems. Although males were highly conspicuous against rocks, they were relatively inconspicuous against the background of the sea, especially to avian predators. Comparisons with males from two blue' *Crotaphytus collaris* populations suggested that natural selection may have fine-tuned blue body coloration in *C. dickersonae* males to reduce detection by predators (the devil') when viewed against the prominent visual background of the sea.

69.10 MACESIC, L.J.*; HOLMES, A.; KAJIURA, S.M.; Florida Atlantic University, Boca Raton; *lmacesic@fau.edu*

Pelvic fin locomotion in batoids

Studies of locomotion in batoids have largely focused on pectoral fin movements. However, pelvic fin punting,' has been described as an important locomotive mechanism in skates. Other benthic batoids have been observed to perform similar punting movements despite lacking the skate's specialized pelvic fin structure. In this study, we compared the use of pelvic fins in locomotion between two benthic batoid species with disparate pectoral and pelvic fin morphologies: Bancroft's numbfish, *Narcine bancroftii* and the Atlantic stingray, *Dasyatis sabina*. The large, paired electric organs of *N. bancroftii* compromise its ability to undulate its pectoral fins and it thus swims by axial undulation. In contrast, *D. sabina*, although sharing a similar benthic lifestyle, swims by pectoral fin undulation. To determine structural and locomotory differences between the pelvic fins of these species, we compared the pelvic fin to pectoral fin surface area ratios, skeletal morphology, and swimming kinematics, including punting distance (body length (BL)), speed ($BLsec^{-1}$), glide duration (sec), and thrust duration (sec). *Narcine bancroftii* punts significantly faster and covers a significantly greater distance (0.16±0.014 $BLsec^{-1}$; 0.85±0.055 BL; n = 4) than *D. sabina* (0.06±0.005 $BLsec^{-1}$; 0.34±0.041 BL; n = 4), and does so with no significant difference in duty factor. Moreover, punts by *D. sabina* were always accompanied by a brief undulation of the pectoral fins; *N. bancroftii* displayed only pelvic fin movement during punting. The relative size of the pelvic fins may indicate their importance in locomotion as the pelvic fin surface area of *N. bancroftii* (n = 10) is more than twice (2.202 times) that of *D. sabina* (n = 10). This study demonstrates that despite lacking specialized structures, benthic batoids can efficiently utilize punting in locomotion.

S3-2.3 MADIN, Larry; Woods Hole Oceanographic Institution; *lmadin@whoi.edu*

Pelagic Tunicates Pack and Ship the Carbon

The biological carbon cycle in the ocean begins in the surface waters with photosynthetic fixation of carbon dioxide into phytoplankton cells, which are consumed by a variety of grazers. Some respire and recycle the carbon near the surface, while others transport significant portions of ingested C to deeper ocean strata as rapidly sinking fecal pellets. An ideal grazer for this purpose would feed rapidly and indiscriminately on a wide range of particles, compact them into much larger and more rapidly sinking particles, and sometimes accelerate the vertical transport by diel migration to greater depths. In the midwater zone, an ideal particle-feeder would have an efficient mechanism to collect and ingest detrital particles, and would also produce large, sinking excreta. Pelagic tunicates appear to meet these specifications better than any other zooplankters. Epipelagic salps can occur in huge populations over large areas, consuming and sedimenting tons of C daily from the surface to deeper waters. In midwater, salps are rare, but doliolids and appendicularians are often abundant, collecting food with internal or external filters and producing both fecal pellets and discarded mucous houses. These species repackage small detrital material and accelerate its transport out of mesopelagic depths. The activity of pelagic tunicates has consequences both for the food supply to the deep sea and benthos, and for the removal of C from the ocean-atmosphere equilibrium. This natural sequestration of C has been occurring for millions of years. If currently rising carbon dioxide levels in the atmosphere and upper ocean lead to increased primary production, it is conceivable that pelagic tunicate populations will increase to remove larger fractions of organic carbon to the deep ocean, where it may be respired to carbon dioxide by deep-living biota, but will be isolated from the atmosphere.

1.2 MAHON, A.R.*; CARPENTER, K.E.; Old Dominion University, Norfolk, VA; *amahon@odu.edu*

A molecular phylogeny of the Perciformes using the nuclear RAG1 gene

The order Perciformes contains approximately 160 families and over 10,000 species. This accounts for more than one third of all fishes and is the single largest order of vertebrates. Although studies testing the limits and relationships its individual families and groups are commonplace, few serious attempts have been made to test the monophyly of the entire order or to investigate the evolutionary relationships between its 20 putative suborders. This study utilized approximately 1500 bases of the single copy nuclear recombination activating gene 1 (RAG1) to infer phylogenetic relationships between families suborders of the Perciformes in the context of its putative sister groups. Preliminary analyses provide support for some previously reported hypotheses and also offer some novel interpretations. Resulting cladograms resolve the Perciformes as polyphyletic. Although the RAG1 gene shows a lack of statistical support for some mid-level groupings in both maximum parsimony and maximum likelihood analyses, we resolve a well supported monophyletic percomorph group that includes the Atheriniformes, Beloniformes, Gasterosteiformes, Synbranchiformes, Mugiliformes, Scorpaeniformes, Perciformes (including all percoid families), Pleuronectiformes, and Tetraodontiformes. The Beryciformes resolve as the sister group of these orders. The results of this study provide a working hypothesis for the evolutionary relationships of the major groups of perciform fishes that could enable many comparative biological studies of this most speciose group of vertebrates.

9.0 MAHON, H. K. *; DAUER, D. M.; Old Dominion University; *hmahon@odu.edu*

Energy maximization strategies of two surface deposit-feeding gastropods.

Surface deposit-feeders rely on a poor food source; therefore, many have evolved strategies to increase sediment processing efficiency and to maximize net energy gain. Two strategies are patch selection and particle selection. This study looked at patch and particle selection of two common gastropods, *Littoraria irrorata* and *Ilyanassa obsolete*, which feed upon deposited sediments. For patch selection, time spent on each patch was recorded for a total time of 10 minutes. The results show both gastropods spent more time on organically-coated patches over uncoated patches and more time on large-particle patches over small-particle patches. For particle selection, gastropods were allowed to feed on a mixture of particles for 3 hours. Afterwards, their guts were dissected into four parts (i.e. esophagus, stomach, digestive gland, and intestine) and the ratio of beads was determined. The results demonstrate *L. irrorata* showed no difference in particle ratio between the esophagus, stomach, intestine, and ambient sediment. However, the digestive gland showed more coated particles and also more small particles, indicating internal particle selection. *Ilyanassa obsoleta* showed no difference in particle ratio between the gut and the ambient sediment. The differences seen may be attributed to both ecological and phylogenetic differences between the gastropods.

39.6 MAIE, Takashi*; PRUETTE, M. E.; SCHOENFUSS, H. L.; BLOB, R. W.; Clemson University, Saint Clout State University; *tmaie@clemson.edu*

Feeding kinematics and performance of Hawaiian Stream Gobies, Awaous guamensis and Lentipes concolor: implications for habitat distribution

Distributions of Hawaiian stream fishes are typically interrupted by waterfalls that divide streams into lower and upper segments. Hatched larvae are flushed into the ocean, and must climb the waterfalls to reach adult habitats when returning back to freshwater streams as part of an amphidromous life cycle. Stream surveys and studies of climbing performance show that *Lentipes concolor* can reach fast-flowing upper stream segments, but that *Awaous guamensis* reaches only slower, lower stream segments. Gut content analyses indicate that diet differs between these species only by 10% or less dry weight for most major components (green algae and small invertebrates). This might suggest that feeding kinematics and performance of these two species would be similar. Alternatively, feeding kinematics and performance of these species might be expected to differ in relation to the different flow regimes where they live (faster feeding for *L. concolor*, slower feeding for *A. guamensis*). To test for such differences, we compared suction feeding kinematics and performance between *A. guamensis* and *L. concolor* through analysis of high-speed video footage. *L. concolor* showed significantly faster jaw opening performance than *A. guamensis*, which may facilitate suction feeding in the fast stream reaches *L. concolor* typically inhabits. Morphological differences between the feeding structures of these species appear to contribute to their differences in performance, which might also help to explain the absence of *L. concolor* from lower stream reaches inhabited by *A. guamensis*.

32.3 MALISCH, J.L.**; GOMES, F.; BREUNER, C.W.; GARLAND, JR., T.; Univ. of California, Riverside, Univ. of Montana; *jbunk001@ucr.edu*

Circadian Pattern of Plasma Corticosterone and Binding Globulins in Mice Selectively Bred for High Activity Levels

In vertebrates, baseline glucocorticoids vary predictably on a diel basis, typically peaking shortly before the onset of activity. Presumably, circadian patterns in glucocorticoid secretion have evolved to match predictable rises in energetic need. In mice from lines selectively bred for high voluntary wheel running (HR lines), total baseline levels of corticosterone (CORT) are significantly elevated (2-fold) above that of non-selected control (C) lines (Malisch et al., in press, Physiological and Biochemical Zoology). We propose that increased baseline CORT is a necessary adaptation to permit the high levels (nearly 3-fold higher than C mice) of wheel running exhibited by HR mice. Here we examine baseline CORT levels, corticosterone-binding globulin (CBG) capacity, and free CORT levels (CORT not bound to CBG and hence biologically active) at six points during the 24-hour cycle. Plasma samples were obtained from 4 individuals from each of the 4 HR lines and 4 C lines at 6 equally spaced timepoints. Preliminary analyses indicate that CORT is elevated at all timepoints, significantly so at three of the six. CBG binding capacity does not differ between HR and C lines; therefore, free CORT is also higher at all timepoints in the HR lines. Additionally, the circadian pattern does not appear to differ between HR and C mice. These findings support the hypothesis that elevated CORT is an adaptation to support increased activity levels in HR mice. Supported by NSF IOB-0543429 to T.G and IBN-0202676 to C.W.B.

62.5 MANGIAMELE, L.A.*; BURMEISTER, S.S.; University of North Carolina, Chapel Hill; *lisaman@email.unc.edu*

Acoustically-evoked immediate-early gene expression in the pallium of the túngara frog

The anuran auditory system is a good model for studying the neural mechanisms of sexual communication. Previous studies have focused on the role of the auditory midbrain and thalamus in the perception of biologically relevant sounds; however, few have investigated the role of the telencephalon in processing auditory stimuli. In frogs, the medial pallium (MP) and dorsal pallium (DP) are multimodal sensory integration areas that receive ascending auditory input from the thalamus. The MP is considered homologous to the mammalian hippocampus. Although controversial, some propose that DP is homologous to mammalian neocortex. To assess whether the pallium may play a part in processing sexual signals in frogs, we measured neural activity-dependent gene expression in the MP and DP of female túngara frogs listening to conspecific male calls. Females were housed in acoustically-isolated chambers for 6 hr followed by sacrifice (no sound group) or the presentation of a 30 min mating chorus followed by 30 minutes of silence before sacrifice. We quantified *egr-1* gene expression by *in situ* hybridization and found that acoustic stimulus presentation caused a 3-fold increase in *egr-1* expression in the dorsal MP ($p=.01$). We did not find an effect in the ventral part of the MP ($p=.07$). In the DP mating calls induced a 2-fold increase in *egr-1* expression in the anterior half of both the dorsal ($p=.03$) and ventral ($p=.001$) subdivisions, but we found no differences in the posterior half. These results show that acoustically-evoked neural activity varies spatially in the pallium and may suggest a role of the MP in auditory memory. This is the first report of auditory responses in the DP and may support homology with sensory cortex.

38.3 MARKLEY, J.S.*; CARRIER, D.R.; University of Utah; *markley@biology.utah.edu*

Ventilation is metabolically expensive in resting and running guinea fowl

Avian ventilation may be metabolically costly because the mechanical work required to overcome the inertial and gravitational resistance to movement of the mass of the sternum, associated flight muscles, and viscera is expected to be high. A novel method was used to measure the cost of ventilation (COV) in resting and running guinea fowl (*Numida meleagris*). Birds' caudal air sacs were cannulated and air was pumped through the lungs and out the nares and mouth (unidirectional artificial ventilation: UAV) until the flow rate was sufficient to decrease ventilatory drive and stop ventilatory movements. The difference in oxygen consumed with and without ventilation was assumed to be COV. The COV of guinea fowl was found to be considerably higher (23% of resting metabolism, 32% of running metabolism) than estimates in mammals and reptiles (1-6% of resting metabolism, up to 15% in running mammals). The high COV measured appears not to be due to UAV inducing metabolic suppression, because expired P_{CO_2} did not decrease drastically during UAV. Additionally, the COV per unit ventilated was the same in resting and running birds (20.3 ml O_2 l^{-1} ventilated), although higher volumes of air were moved in running than resting birds (at rest: minute ventilation 0.31 l min^{-1} kg^{-1}, tidal volume 16 ml kg^{-1}; during running: minute ventilation 1.5 l min^{-1} kg^{-1}, tidal volume 25 ml kg^{-1}). These data raise the question of why the ancestors of birds shifted from the primitive mechanism of breathing, which is very economical, to one that consumes more energy.

28.5 MARKO, P.B.*; MORAN, A.L.; Clemson University; *pmarko@clemson.edu*

Larval Mode and Species Accumulation in a Transisthmian Marine Bivalve

Evolutionary biologists have employed the formation of the Isthmus of Panama and the closure of the Central American Seaway approximately 3.1 million years ago as a model system for the study of allopatric speciation. The fossil record indicates that the closure of the Seaway was not an abrupt occurrence, but a complex macroevolutionary event involving massive species turnover (speciation and extinction) in response to environmental upheaval associated with the gradual separation of the Atlantic and Pacific oceans. Here, we use molecular phylogenies of the bivalve subgenus *Acar* to investigate the rate of accumulation of clades in tropical America over the course of Isthmus formation in the context of larval developmental mode. Molecular analyses suggest the existence of nearly an order of magnitude more species than currently recognized in this single subgenus. Lineages-Through-Time-Analysis (LTTA) shows that the accumulation of lineages has been constant throughout most of the history of the subgenus, including the period of Isthmus formation, suggesting no detectable macroevolutionary response to seaway closure in this group. Most lineage splitting events in the last seven million years, however, are concentrated in a single clade distinguished by brooded development. If brooded development tends to increase rates of both speciation and extinction, this clade may have experienced significant species turnover that cannot be detected with LTTA and which can probably only be characterized through analysis of morphologically distinct forms in the fossil record.

13.5 MARLOW, H.**; MATUS, D.Q.; MARTINDALE, M.Q.; Kewalo Marine Laboratory, University of Hawaii; *marlow@hawaii.edu*

Development of the nervous system in Nematostella vectensis, an anthozoan cnidarian

Due to their phylogenetic position as sister taxa to the bilateria, as well as their reportedly simple nervous system organization, cnidarians are an interesting model for the understanding of the evolution and development of the nervous system. The anthozoan cnidarian *Nematostella vectensis* (the starlet sea anemone) is an increasingly suitable model for many reasons: embryogenesis is easily observed and manipulated, the complete genome is now available, and many experimental tools have been developed. Utilizing degenerate PCR and genomic resources, we have identified many gene families and pathways involved in specificaion, determination, guidance and differentiation of the nervous system that are conserved between *N. vectensis* and bilaterian systems such as arthropod, nematode and vertebrate models. Through in situ hybridization and antibody labeling, we have characterized the structure of the *N. vectensis* nervous system during the course of development. *N. vectensis* neural cells originate in the ectoderm of early planula stages. In the adult polyp, we have identified neuralized regions such as mesenteries, the oral nerve ring, and pharyngeal ectoderm. In addition, we have characterized subsets of neurons based on their expression of specific neurotransmitters, such as GABA, FMRF-amide, and serotonin. We have also determined developmental genes such as the Notch/Delta and pro-neural specification pathways as well as the netrin and neogenin guidance systems share a conserved role in neurogenesis between cnidarians and bilaterian systems.

45.3 MARSHALL, Vincent T.*; GERHARDT, H. Carl; University of Illinois, University of Missouri; *marshallvt@life.uiuc.edu*

Signal timing by the gray treefrog, Hyla chrysoscelis: responses to conspecific and heterospecific advertisement calls

Breeding aggregations of acoustically signaling animals often comprise multiple species sharing a common communication channel. Whether and how an individual adjusts the timing of its signals relative to those of other signalers, an often important predictor of the responses of receivers, may therefore depend on the species identity of its neighbors. In this study, I examined how males of the gray treefrog, *Hyla chrysoscelis*, adjusted the timing of their advertisement calls relative to the calls of conspecifics and those of the closely related, syntopically breeding species, *H. versicolor*. During interactions between calling males, calls were timed such that there was little signal overlap regardless of whether the neighbor was conspecific or heterospecific. In response to playbacks of conspecific and heterospecific advertisement calls, males generally avoided producing calls during either stimulus type, and instead initiated them during the silent gaps between stimuli. There were, however, differences in the response to conspecific and heterospecific signals. Males produced calls with relatively short latencies after the heterospecific calls, which resulted in their often rapid placement within the silent intervals between stimuli. In contrast, calls produced after conspecific stimuli had significantly longer latencies, resulting in a distinct gap between the end of the stimulus and the male's call. This plasticity in signal-timing behavior is discussed in light of hypotheses for the function of adjustments in the timing of acoustic sexual signals.

48.10 MARTIN, T.L.; HUEY, R.B.*; Harvard Univ., Univ. Washington, Seattle; *hueyrb@u.washington.edu*

Why sub-optimal is optimal: a model of ectotherm thermal preferences

Body temperature profoundly affects the fitness of ectotherms, and many ectotherms use behavioral adjustments in an attempt to control body temperatures within narrow, species-specific levels. Biologists have long assumed that such preferred body temperatures are optimal and thus correspond with the body temperatures ($T_{r\text{-}max}$) that maximize Darwinian fitness (r). We develop a simple model of optimal behavioral thermoregulation and find that thermal preferences should in fact be centered not at $T_{r\text{-}max}$, but at a temperature lower than $T_{r\text{-}max}$. This finding may seem paradoxical, but is an inevitable consequence of two considerations. First, ectotherms aren't perfect thermoregulators and so experience a range of body temperatures. Second, thermal fitness curves of ectotherms are asymmetric ($T_{r\text{-}max}$ is much closer to the upper than to the lower lethal temperature), such that a body temperature higher than $T_{r\text{-}max}$ will depress fitness much more than will a body temperature displaced an equivalent amount below $T_{r\text{-}max}$. This model makes several predictions. Ectotherms should maximize total fitness by centering thermal preferences below $T_{r\text{-}max}$ and the magnitude of the optimal deviation below $T_{r\text{-}max}$ should increase with the degree of asymmetry of the thermal fitness curves as well as with the variance in body temperature. Moreover, deviation should be relatively large for thermal specialists, but should be insensitive to whether fitness increases with $T_{r\text{-}max}$ (warmer is better). We challenge some of these predictions primarily with a large comparative data set on the thermal dependence of sprint speed of lizards. Thermal preferences are indeed generally below the optimum temperature for sprinting. As predicted, the magnitude of the deviation increased with the degree of asymmetry of the thermal performance curve and with the degree of thermal specialization (standardized independent contrasts). Thus, suboptimal is optimal.

S5.7 MARTINDALE, Mark Q.; Univ. Hawaii; *mqmartin@hawaii.edu*
The developmental basis of body plan organization in the Eumetazoa
Recent work is beginning to provide more confidence in our ability to understand the true phylogenetic relationship between extant animal groups. This provides opportunities to hypothesize about how morphological transitions might have occurred during early animal evolution. Because adult animals arises via a process of embryogenesis it seems likely that an understanding of these morphological transitions should be approachable by studying changes in the development of phylogenetically relevant forms. Our lab has been studying the cellular and molecular origins of axial organization and germ layer formation during the development of representative cnidarians (sea anemones, corals and cubozoans), ctenophores, and acoel flatworms. I will attempt to summarize recent progress from our lab from experimental embryological analyses of egg organization to the conservation of gene regulatory networks, and the organization of nervous systems that may be relevant to discussions on the origins of animal complexity and the origin and diversification of bilaterally symmetrical, triploblastic animals.

38.2 MARTINEZ DEL RIO, C.*; SABAT, P.; Univ. of Wyoming, Univ. de Chile; *cmdelrio@uwyo.edu*
Neutrons, Niches, and Adaptive Radiation in Cinclodes Ovenbirds
Passerines are astoundingly speciose and ecologically diverse. However, remarkably few songbird species have evolved a marine habit. The genus *Cinclodes* (Furnariidae) is an exception. In addition to species that inhabit terrestrial/freshwater streams and species that shift between freshwater and marine habitats, it includes two strictly marine species. We present evidence that supports the idea that *Cinclodes* satisfies the criteria for an ecological radiation: 1) The clade is monophyletic, 2) it experienced recent speciation accompanied by phenotypic diversification, and 3) the osmoregulatory traits of five *Cinclodes* species satisfies the criterion of adaptive phenotype-environment correlation. The carbon isotopic composition of the birds' tissues diagnosed the degree of reliance on marine food sources and was positively correlated with renal traits responsible for urine concentration. We contend that radiation in *Cinclodes* was mediated by the rapid evolution of osmoregulatory traits. The capacity to withstand salty diets of *C. nigrofumosus*, one of the coastal species, exceeded that of most songbirds. Carbon and nitrogen stable isotope measurements of bird's tissues differentiated the seasonal dependence of *Cinclodes* species on intertidal, terrestrial, and freshwater food webs, and allowed assessing the contribution of intra- and inter-individual variation to each species' niche width. Stable isotopes measurements were useful as covariates in comparative analyses, and as tools to quantify ecological niches.

S1-1.7 MARTONE, P.T.; Hopkins Marine Station of Stanford University; *pmartone@stanford.edu*
Of kelps and corallines: histological insights into seaweed strength and strengthening
The survival of intertidal macroalgae depends upon the ability of algal thalli to resist the drag force applied to their fronds by breaking waves. Many studies of macroalgal biomechanics have explored the effects of thallus properties (e.g., flexibility, reconfiguration, size limitation) on drag force reduction, but few have investigated the opposite side of the equation: mechanisms for increasing thallus strength. Previous studies have revealed a trade-off in macroalgal growth strategies to resist breakage: increasing girth versus growing stronger tissues. Brown macroalgae, such as kelps, grow thick stipes but have weak tissues, while red macroalgae grow slender stipes but have much stronger tissues. For example, the joints (genicula) of the articulated coralline *Calliarthron cheilosporioides* have tissues that are much stronger than other algal tissues but rarely exceed 1 mm in diameter. Furthermore, genicular tissue gets stronger as fronds grow. Here I present a histological analysis exploring the cellular basis for mechanical strength of *Calliarthron* genicula. Genicula are composed of thousands of long, fiber-like cells whose cell walls thicken over time. Cell wall thickening likely explains increased tissue strength in older genicula: mature genicula may be more than 50% cell wall. However, the strength of genicular cell wall is similar to the strength of cell wall from a freshwater green alga, suggesting that the quantity, not the quality, of cell wall material gives genicular tissue its great strength. Observed differences in tissue strength across algal taxa may be a consequence of tissue construction rather than material composition.

S3-1.6 MATUS, D.Q.*; HEJNOL, A.; DUNN, C.W.; HALANYCH, K.M.; MARTINDALE, M.Q.; Kewalo Marine Laboratory, Univ. of Hawaii, Auburn Univ., Auburn; *matus@hawaii.edu*
New light on an old problem: Insights into the development and evolution of the chaetognaths
Chaetognaths, or arrow worms, are one of the most ubiquitous and abundant members of pelagic zooplankton communities. In spite of this, they have remained one of the most recalcitrant groups of organisms to place within the metaozoan tree. They possess a suite of morphological and developmental characters that ally themselves with the deuterostomes, including a posterior blastoporal fate, a holoblastic radial cleavage program, a tri-partite coelomic arrangement, enterocoely, and a post-anal tail. However, molecular phylogenetics fail to find any affinity between the chaetognaths and the deuterostomes, despite being ambivalent about their placement within the protostomes. We have attempted to resolve the group's phylogenetic position through a large-scale analysis of a conserved set of nuclear genes isolated from the pelagic chaetognath, *Flaccisagitta enflata*, via Expressed Sequence Tags (ESTs), since more traditional molecular phylogenetic approaches (*e.g.*, 18S/28S ribosomal DNA) have failed to resolve their position within the protostomes. Additionally, we have isolated key developmental regulatory genes involved in axial patterning and mesoderm formation and are examining their expression via *in situ* hybridization to investigate both conserved and novel patterns of expression throughout development.

36.6 MCBRAYER, LD*; CORBIN, CE; STAYTON, CT; Georgia Southern Univ., Bloomsburg Univ., Bucknell Univ.; *lancemcbrayer@georgiasouthern.edu*

Covariation between morphological and behavioral evolution in lizards

Lizards (non-ophidian squamates) are an ecologically diverse, species rich clade of terrestrial vertebrates. Morphologically, lizards are also very diverse; they range over an order of magnitude in body size and numerous groups possess unique skeletal modifications (e.g. casques, horns, cranial kinesis, etc.). Like most vertebrate groups key aspects of skull form are correlated with diet. However, despite their ecological, morphological, and taxonomic diversity, most lizards are thought to employ one of two broad foraging styles or modes (ambush foragers and active foragers). In this study, we perform phylogenetically informed analyses testing for the degree of coevolution between skull morphology and foraging mode. This study differs from previous studies in several important ways. First, we use the most recently published phylogenetic hypotheses for comparison to previous results. Second, we use a combination of geometric morphometrics and traditional linear distance measures to better understand changes in skull shape throughout the history of this diverse clade. Third, we use species-specific behavioral (moves per minute, percent time moving) and morphological data rather than assigning a foraging mode state to an entire family. Therefore, this study is a rigorous attempt to test the adaptive significance of changes in skull form as they pertain to prey capture and processing.

3.5 MCCALL, J. M.; MEAD, K. S.*; Univ. of California, San Diego, Denison University; *meadk@denison.edu*

What Happens To Crayfish Antennule Structure And Function During Regeneration?

Crayfish are capable of regenerating sensory structures such as their antennules. These olfactory appendages allow the organisms to receive stimuli from the environment such as information directing them toward food or mates. The ability to regenerate nerve systems is an advantage in an environment where damage from fights, infection, and distress is common. We collected and removed the antennules from 48 *Orconectes sanborni* (N=48), to initiate the regenerating process. We developed and used a new method of structural analysis, to avoid destructive sampling of antennules. We created progressive molds of the regenerating antennules using dental epoxy and then made positives using Spurr's epoxy resin, which we analyzed via a scanning electron microscope prior to and during the stages of regeneration. This nondestructive method allows several progressive samples of the same individual to be collected- a clear advantage in comparing continuously-regenerating tissues. Throughout the stages of regeneration, we tested intermolt crayfish in a Y-maze method to assess their ability and speed in tracking odors. We found several relationships will be between specific features of the structural regeneration of the antennules and the resulting changes in olfactory ability. Both the structural and the behavioral data indicate that the antennules have regained odor-tracking ability and possess many aspects of their original structure by the end of the second molt.

5.4 MCCARTNEY, Michael A.*; LIMA, Thiago G.; Univ of North Carolina, Wilmington; *mccartneym@uncw.edu*

Massive introgression of gamete recognition alleles in a blue mussel hybrid zone

Earlier work in our laboratory examined evidence for reproductive character displacement of gamete compatibility between the blue mussels *Mytilus edulis* and *M. trossulus* inside and outside of their hybrid zone in the Gulf of Maine. We found a contrary result *M. trossulus* males were actually more compatible with *M. edulis* females from within the hybrid zone that they were with *M. edulis* females from an allopatric population. We are now investigating evidence for introgression of alleles at *M7 lysin*, a gene coding for a sperm lysin that may control gamete compatibility in *Mytilus*. We have found that *M. edulis M7 lysin* alleles are unusually common in *M. trossulus* individuals that carry no *M. edulis* alleles at other marker loci. So far, this massive introgression of gamete recognition alleles seems to be confined to within the hybrid zone. Previous analyses of nucleotide substitutions in *M7 lysin* have shown evidence for positive, diversifying selection. The present result argues that balancing selection may also play a role in the evolution of *M7 lysin*.

34.5 MCCAULEY, D.W.; University of Oklahoma; *dwmccauley@ou.edu*

SoxE genes in development and evolution of the pharynx

The neural crest is a defining characteristic of vertebrates that gives rise to many characters specific to vertebrates and are considered a hallmark of vertebrate evolution. In gnathostome vertebrates, derivatives of the neural crest include the jaws and pharyngeal skeleton. Since jawed vertebrates arose from a jawless ancestor, jawless lampreys provide an important proxy for the study of evolution of the pharyngeal skeleton. Cartilage of the pharyngeal skeleton in jawed vertebrates is composed of type II collagen (Col2a1) whose expression is driven by Sox9, a member of the SoxE subfamily. We have found that three SoxE paralogs are expressed in the pharynx. Although adult lamprey cartilage is not composed of Col2a1, SoxE1 and SoxE2 are expressed in the cartilage cells of the developing pharyngeal skeleton Interestingly, SoxE3, the lamprey paralog most closely related to gnathostome Sox9, is expressed in the branchial arch mesenchyme but not in the cartilage cells. The velum derived from the 1st branchial arch shows expression of SoxE3, but SoxE1 and SoxE2 expression are absent. Morpholino knockdown of the SoxE1 protein affected expression of SoxE2 and development of the pharyngeal skeleton, but development of the 1st arch was not affected. Since the 1st branchial arch forms the jaws of gnathostomes, these results suggest the duplication of SoxE genes may have been important for the evolution of jaws. We are continuing to investigate the role of SoxE genes in the development of the pharyngeal skeleton. A recent description of lamprey SoxE3 and Col2a1 expression in the pharynx suggested an ancient origin for the role of Sox9 in driving Col2a1 expression. We show here that SoxE3 expression does not overlap with that of Col2a1, suggesting further steps were required for the acquisition of Sox9 regulation of type II collagen expression in the pharyngeal skeleton of early jawed vertebrates.

5.1 MCCLEARY, R.J.R.*; OSTROW, D.G.; CLARK, A.M.; University of Florida, Department of Zoology, University of Florida, ICBR Genetic Analysis Lab; *mccleary@zoo.ufl.edu*

Adapting Crotalus microsatellites for use in the Florida cottonmouth, Agkistrodon piscivorus conanti

Microsatellite loci are powerful tools for analyzing many parameters of population genetics. However, development of microsatellites can be very time consuming and frustrating. One alternative to species-specific development of microsatellite loci is to use those that have been developed for use in other, closely-related species. Although this technique has been espoused as a viable alternative, and although cross-reactivity (in terms of amplification) has previously been shown even in distantly-related species, few studies have examined fragment variability using microsatellites developed in different snake species. The Florida cottonmouth, *Agkistrodon piscivorus conanti*, is a well-studied, venomous snake that has been examined in a population context. However, microsatellite loci have not been specifically developed for use in this species. We assayed loci developed for four species of rattlesnakes (*Crotalus horridus*, *C. tigris*, *C. viridis concolor*, and *C. willardi obscurus*) in order to find polymorphic loci suitable for use in cottonmouths. Annealing temperature and $MgCl_2$ gradients were utilized to optimize reaction conditions in *A. p. conanti*. Of the 23 primer sets examined, 13 (56.5%) showed PCR products within the typical size ranges reported for the species of development. Of these 13 loci, 8 (34.8% of total) showed variability using a small sampling of cottonmouths (N = 11). These results support previous observations that microsatellites developed in one snake species may be useful for genetic analysis at the population level in other snake species.

44.6 MCCOY, K. A*; GUILLETTE, L. J; ST MARY, C.; Univ of Florida, Gainesville; *kristam@zoo.ufl.edu*

From chemical confusion to chemical castration: endocrine disruption leads to a range of reproductive abnormalities in Bufo marinus living in agricultural areas of South Florida

Endocrine disrupting chemicals (EDCs) cause reproductive abnormalities in a variety of wildlife species. For example, many studies (laboratory and field-based) have demonstrated that the herbicide atrazine induces ovary development or ovo-testes in male frogs at low ecologically relevant concentrations. Importantly, differential exposure to EDCs likely results in variation in these morphological abnormalities; however, few studies have quantified this variation in amphibians living in agricultural areas. In addition, the influence of these abnormalities on reproductive physiology and function remains unclear. Here, we 1) compare the prevalence and severity of various morphological abnormalities in populations of frogs from agricultural areas (where EDCs are used) and non-agricultural (reference) areas, 2) determine how sex hormone concentrations and spermatogenesis differ between frogs from both populations, and as a function of the severity of abnormality, and 3) determine the relationship between reproductive abnormalities and other traits important for sexual identity such as sexually dimorphic color patterns. This study was performed via field surveys at agricultural and reference sites in South Florida. Initial results show that as many as 60% of male Bufo marinus (giant toads) collected from agricultural sites were feminized (e.g. had female coloration), and up to 40% were also intersexed (i.e. had testes and ovaries). Conversely, 4% (on average) of the individuals collected from three reference sites were feminized. Differences in severity of these abnormalities and their relationship to spermatogenesis, hormone concentrations, and sexually dimorphic coloration will be discussed.

22.2 MCCOY, M. W.*; GILLOOLY, J. F.; ALLEN, A. P.; University of Florida, NCEAS; *mmccoy@zoo.ufl.edu*

Metabolic rate governs rates of genotypic and phenotypic evolution

Determining the relative importance of neutral versus adaptive processes in shaping rates of phenotypic evolution is a central aim of evolutionary biology. Many evolutionary biologists, while agreeing that most changes to the genotype are neutral, would argue that most changes to the phenotype are adaptive. However, the relative importance of neutral mutation versus natural selection in driving phenotypic change has been difficult to quantify. Here we apply the body size- temperature model of molecular evolution proposed by Gillooly et al. (2005) to address the importance of neutral processes in controlling rates of phenotypic evolution. Gillooly et al. (2005) showed that neutral rates of DNA evolution are proportional to mass-specific metabolic rate. In this study we show that for both mitochondrial and nuclear genes, non-neutral rates of DNA evolution, as well as rates of amino acid (i.e., phenotypic) evolution show the same size-and temperature dependence as neutral molecular evolution. This indicates that rates of phenotypic evolution, like neutral evolution, are directly proportional to mass-specific metabolic rate. More generally, these results suggest that the primary controls on individual metabolic rate (i.e., size and temperature) may also constrain the overall rate of evolution in organisms through their effects on mutation rate. Ultimately, our hope is that this work can be extended to better understand rates of speciation and patterns in biodiversity.

49.2 MCDONALD, K.A.*; VAUGHN, D.; University of Washington, Friday Harbor Labs; *kamcdon@u.washington.edu*

Impacts of food concentration and larval stage on incidence of cloning in Dendraster excentricus plutei

Asexual reproduction confers efficient use of limiting resources. Some freshwater plankters undergo a shift in reproductive mode in response to environmental cues, capitalizing on ephemeral increases in food density. Studies have indicated that asexuality may be widespread in echinoderm planktonic larvae, but the ecology of larval cloning is largely unexplored. In this study we examine the impact of feeding on occurance and timing of cloning in larvae of the sand dollar *Dendraster excentricus* by varying (1) algal density, (2) duration of food availability, and (3) timing of availability relative to developmental stage. Initial results show effects of algal density and timing of food delivery on incidence of cloning in cultures of *D. excentricus* plutei. Cultures reared on high-food diets or exposed transiently to a high-food environment begin generating clones as primary larvae develop the third (posterodorsal) pair of larval arms. High-food pulses, in particular, rapidly result in uniform cultures of earlier-staged plutei. Rather than constituting a developmental rarity, cloning may occur early and often in *D. excentricus* cohorts when environmental conditions favor rapid growth.

55.1 MCELROY, E*; MEYERS, J; IRSCHICK, D; Ohio U., U. Mass. Amherst; *em386403@ohiou.edu*

Linking badge morphology, performance, and field behavior in the ornate tree lizard, Urosaurus ornatus.

Sexual badges honestly signal performance and fighting ability. However, few studies have tested whether this relationship translates into field behavior, which is key to understanding how badge structure relates to individual fitness. *Urosaurus ornatus*, is polymorphic for throat coloration with throat morph-type being related to social dominance and aggression. In addition, the size of the extensible belly patch has been shown to positively correlate with bite force. This study examines the link between badge morphology (belly patch, dewlap, and background area and throat morph), performance (sprint speed and bite force), and field behavior (percent time displaying: PTD, displays per minute: DPM, Percent time moving: PTM, moves per minute: MPM) among 43 adult males at Wet Beaver Creek, AZ. We expected that morphs would not differ in performance but would differ in field behavior with more aggressive morphs having higher display and movement rates than subordinate morphs. Additionally, we expected individuals with larger belly patches to have larger bite forces and higher display rates than individuals with smaller belly patches. We found that morphs did not differ in bite force, sprint speed or any measure of field behavior. Additionally, we found that belly patch and dewlap size positively correlate with bite force and field behavior but not sprint speed. Our results support previous findings that throat coloration is not related to performance but belly/dewlap patch size are positively correlated with bite performance. In addition, we show that the relationship between badge size and performance translates into field behavior: individuals with larger patches and bite forces have higher display and movement rates.

8.3 MCGOWAN, C. P.*; SKINNER, J.; BIEWENER, A.A.; University of Colorado at Boulder, University of South Australia, Harvard University; *mcgowac@colorado.edu*

Musculoskeletal scaling of the hindlimb of kangaroos and wallabies (Superfamily Macropodoidea)

This study seeks to extend prior analysis of the locomotor mechanics and physiology of marsupial hopping by examining how the hindlimb musculoskeletal system scales with body mass in species of Macropodoidea, the superfamily containing wallabies and kangaroos. We do this to provide a broader context for interpreting empirical results obtained from experimental studies carried out on a more restrictive sample of members of this group. A morphometric analysis was conducted on cadavers of 15 species and skeletal specimens of 21 species spanning a size range from 0.8 to 27 kg, which included representatives of 12 of 16 extant genera of this group. The results of this analysis indicate that macropodoids are able to match increasing force demands associated with increasing body size primarily through a combination of a disproportionate increase (positive allometry) in muscle area and muscle moment arms, with relatively little change in locomotor limb posture. In contrast, isometric scaling of the primary long bones of the hindlimb suggest that larger animals experience relatively greater bone stresses. As previously observed, muscle to tendon area ratios of the ankle extensors scaled with strong positive allometry indicating that peak tendon stresses also increase with increasing body size, but to a lesser degree than previously reported. Consistent with previous morphological and experimental studies, large macropodoids are therefore better suited for elastic strain energy recovery, but operate at lower safety factors which likely poses a limit to body size. Our data suggests extinct giant kangaroos (~250 kg) were likely quite limited in locomotor capacity.

S1-2.7 MCHENRY, M.J.*; STROTHER, J.A.; VAN TRUMP, W.J.; NETTEN, VAN, S.M.; U.C. Irvine, Univ. of Groningen, NL; *mmchenry@uci.edu*

Sensing moving fluid: Hydroreception in the lateral line system of zebrafish

Fish sense water flow with numerous microscopic structures on the surface of their skin. These structures, known as superficial neuromasts (SNs), are part of the lateral line system, which provides sensory cues that influence rheotaxis, schooling, mating, and predator-prey interactions. Despite the importance of these cues to the sensory ecology of fish, it is unclear how the mechanics of SNs influence the transduction of hydrodynamic signals. We examined the mechanics of hydroreception in SNs with a combination of quasi-static stiffness measurements, morphometrics, and computational modeling in zebrafish larvae (*Danio rerio*). Our results suggest that the boundary layer at the body's surface behaves as a filter that significantly attenuates and phase shifts stimuli. Signals are further filtered by the SN in a manner that depends on its stiffness and drag coefficient. The kinocilia of hair cells at the base of the SN function to stiffen the structure and the surrounding compliant matrix generates drag. This drag causes deflections in the kinocilia that generate graded potentials in the hair cell bodies. The results of our computational modeling suggests that the observed mean dimensions of SNs (~40 microns tall, ~10 microns in diameter) are close to optimal sensitivity. However, the large morphological variation that we measured among larvae is predicted to result in highly differing filtering characteristics. This suggests that different fish may extract very different information from the same flow field.

21.4 MCMILLAN, D.M.*; ADOLPH, S.C.; IRSCHICK, D.J.; University of Massachusetts Amherst, Harvey Mudd College; *mcmillan@nsm.umass.edu*

Does the thermal tolerance of the Western Fence Lizard change with air temperature?

Understanding the effects of global climate change on populations of natural organisms is a difficult task because often the differences caused by changes in the climate can be subtle, and detecting these differences requires data over long time periods. One predicted outcome of global climate change is that the number of days of extreme temperatures in a given environment may increase even if the overall mean temperature does not. One measure of an organism's ability to withstand extremely warm temperature is the Critical Thermal Maximum (CT_{max}). The CT_{max} is defined as the temperature above which an animal loses voluntary muscle control. For this study we measured the CT_{max} of the western fence lizard *Sceloporous occidentalis*, collected in the San Gabriel Mountains of California first in 1983 and then again in 2006. With this study we address the question; Does a shift in the thermal profile of the local habitat lead to a change in the way these animals withstand periods of extreme temperature? Our work points toward new ways of integrating the thermal physiology of animals with information on global climate change.

23.5 MCPHERSON, D.R.; SUNY Geneseo; *mcpherso@geneseo.edu*
Anterior cluster serotonergic neurons in the cerebropleural complex of Melibe leonina and their effects on other neurons
Like many other opisthobranch mollusc species, the nudibranch *Melibe leonina* has two bilaterally symmetrical clusters of serotonergic neurons in the anterior region of the cerebropleural complex of the central nervous system. This region corresponds to the anterior part of the cerebral ganglia in species with separate cerebral and pleural ganglia. In most species there is a symmetrical pair of relatively large cells, the metacerebral giant cells, which are involved in feeding behavior. Relatively little is known about the function of the other anterior serotonergic neurons in behavior, but the homologous neurons in *Clione limacina* have an excitatory effect on the central pattern generator for swimming. I have begun examining the effects of the activity of the anterior serotonergic neurons in an isolated brain preparation of *Melibe*. The metacerebral giant cells are not distinguishable by size, because many of the neighboring serotonergic neurons are comparably large. Pairwise intracellular recordings indicate that some of the serotonergic neurons have a slow excitatory effect on neurons in the pedal ganglia, and extracellular recordings from the pedal commissure indicate that some of the serotonergic neurons project directly to the pedal ganglia. These results suggest that their behavioral function in *Melibe* may parallel that observed in *Clione*.
Supported in part by a Research Incentive grant from SUNY Geneseo.

S7-1.2.2 MCVEA, DA*; PEARSON, KG; University of Alberta; *dmcvea@ualberta.ca*
Obstacle avoidance during walking
Two basic features of animal locomotion are 1) avoidance of obstacles that either impede progress or endanger the animal, and 2) withdrawal responses from obstacles that unexpectedly contact the animal. In walking mammals, the former depends primarily on visual information, while the latter depends on sensory information from the receptors in the skin. A major goal of the research program in our laboratory is to understand the neurobiology of these two aspects of obstacle avoidance in walking cats. One project is to establish the mechanisms that allow cats step precisely over visible obstacles. In this project we have focused on the role of short-term working memory in guiding the movements of the hind legs. Our results show that the hind legs are guided by a very long-lasting and precise memory of the position and size of the object, and that the movement of the forelegs over the obstacle is crucial for establishing this memory. Another major project in our laboratory has been to understand how an animal changes its stepping movements in response to persistent cutaneous stimulation of a hind leg. We have found that a relatively small number of cutaneous stimuli result in very long-lasting changes to the walking pattern. Interestingly, these changes are only expressed in the context in which the animal experienced the stimuli. Cortical areas of the brain play an important role in establishing this plasticity, as decerebrate cats show no long-term changes to stepping with the same stimuli. Our results to date clearly demonstrate that a full understanding of the neurobiology of walking will require knowledge about how the location of objects relative to the body and the environmental context in which the animal is walking are represented in neuronal networks in the brain, and how this information influences the basic neuronal networks in the spinal cord.

38.1 MCWILLIAMS, S.R.*; BAUCHINGER, U.; KEIL, J.; STARCK, J.M.; University of Rhode Island, University of Munich; *srmcwilliams@uri.edu*
Faster with use: exercise affects turnover rate of carbon isotopes in some but not all organs
Most contemporary applications of stable isotopes in ecology and physiology rely on untested assumptions about the turnover rate of isotopes in various tissues. These assumptions are particularly relevant for studies that test hypotheses about how increased energy demands, like those associated with exercise, affect organ size and cell turnover. We studied turnover rates of carbon isotopes in 16 different tissues of Zebra Finch (Taeniopygia guttata) that were either exposed to cold temperatures, regularly exercised, or sedentary. Although cold-acclimated and exercised birds had higher energy demands and ate significantly more than sedentary birds, we detected no significant differences in size of organs associated with digestion. However, carbon turnover rates of organs associated with exercise (e.g., pectoral muscle, heart) were significantly more rapid in exercised birds compared to cold-acclimated and sedentary birds. In general, carbon turnover rate differed substantially between organs with small intestine and liver the most rapid and leg muscle among the slowest. These measures of carbon turnover rate provide insights into which tissues are best for accurately assessing interactions among key life history stages of the annual cycle such as reproduction, molt, and migration.

55.5 MEADOWS, M. G.*; MCGRAW, K. J.; Arizona State University, Tempe; *melissa.meadows@asu.edu*
How hummingbirds choose their fights: the role of iridescent coloration in aggressive interactions.
Pigmentary feather color in birds has been widely studied as an honest signal of individual quality that can used by conspecifics in mate choice and other social interactions. However, the signaling role of structural color, including iridescence, is less well-known, particularly in intrasexual competitions. In birds, this type of status signaling has only been studied twice (in blue tits and collared flycatchers), and has never been studied in a species with iridescent structural colors. Here, we examine the use of iridescent gorget color and size as potential signals in aggressive interactions in male Anna's hummingbirds (*Calypte anna*). Two separate experiments were conducted in which individual birds were placed in an arena with the choice to feed near 1) a more colorful male or a less colorful male and 2) a male with a larger gorget or a male with a smaller gorget. To separate signaling based on gorget color/ size from behavior, we used freeze-dried hummingbird mounts as stimuli rather than live animals. We predicted that if color and/ or size are used to honestly signal aggressive ability by competing males, the birds would choose to feed near the mounts displaying smaller or drabber gorgets. This would maximize the likelihood of winning and being able to feed while minimizing the energetic cost of the fight. Results will be discussed.

65.4 MEAGHER, E/M*; MCLELLAN, W/A; WILLIAMS, T/M; BLUM, J/E; PABST, D/A; UNC Wilmington, UC Santa Cruz; *emm3005@uncw.edu*

Comparing heat loss and O_2 consumption rates in captive bottlenose dolphins (Tursiops truncatus)

Measurements of heat loss have been used to estimate marine mammal metabolic rate (MR), but few studies have directly tested the accuracy of this experimental approach. This study compared MR, estimated by using multiple heat flux (HF, W/m^2) measurements, to those measured *via* O_2 consumption rate in two captive, adult male bottlenose dolphins under three different metabolic states [resting (n=11), post-feeding (n=11), post-exercise (n=7)]. HF measurements at the lateral body wall (thoracic, tailstock) and appendages (dorsal fin, pectoral flipper, flukes), and O_2 consumption rates were collected near-simultaneously for each dolphin under each metabolic state. MR determined from total heat loss was calculated by multiplying body and appendage surface areas (m^2) by HF from those sites. Resting MRs measured *via* HF were significantly lower than post-feeding and post-exercise MRs (p=0.0026; ANOVA), which were similar to each other. Resting and post-feeding MRs measured by O_2 consumption were similar, but both were significantly lower than post-exercise MRs (p2 consumption MRs (p=0.0285; ANOVA). MRs estimated *via* HF were always lower than those measured using O_2 consumption, but the relationship between these values was dependent upon metabolic state. Thus, it appears as though heat flux measurements can predict trends in MR, but not absolute MR, for captive bottlenose dolphins. Differences between the MR estimates obtained *via* HF and O_2 consumption may be partially explained by heat losses not assessed in our study, such as waste excretion, and changes in vasomotor state caused by exercise that could affect HF measurements.

16.6 MEDEIROS, M.J.; University of California, Berkeley; *m_j_m@berkeley.edu*

Colonization of Caves by Flightless Hawaiian Moths

Cave-adapted fauna are hypothesized to colonize separate caves either via available underground connections, or in independent invasions which result in speciation events, because individuals of a cave-adapted species are unlikely to survive in the epigean environment. This may be especially true in Hawaii, where lava tube caves on different islands are separated by kilometers of ocean and the cave fauna is typically flightless. To determine the number of independent cave colonization events and the number of times that flightlessness has evolved in a group of Hawaiian moths, I collected *Schrankia* (Noctuidae) individuals from seven caves on two different islands. A phylogeny based on approximately 1100bp of COI and a fragment of the nuclear gene wingless shows that surface *Schrankia* have invaded caves separately at least two times on the Big Island. In both of these cave species, at least some females were flightless when collected, suggesting that flightlessness has arisen through convergence. One of these two species, *S. howarthi*, is distributed across the Big Island and forms a clade along with cave *Schrankia* on Maui, where flightless females also occur. For this widely distributed species, underground connections do not appear to be the only mode of colonization of new caves, because on both Maui and the Big Island, some individuals were found living above ground as well. These individuals, which are capable of flight, provide an example of how a seemingly cave-adapted species is able to facilitate above-ground colonization of new caves that are separated by ecological barriers. This is the first example of a species that occurs deep in Hawaiian caves to be distributed on two separate islands.

18.3 MEHTA, R.S*; WAINWRIGHT, P.C.; Univ. of California, Davis, Univ. of California,Davis; *rsmehta@ucdavis.edu*

Eating big: Innovation in the moray eel feeding mechanism

Suction feeding is ubiquitous among aquatic vertebrates. We report the discovery that a major radiation of teleost fishes, the moray eels of the anguilliform family Muraenidae, do not use suction to capture prey. Suction feeding is characterized by a series of quick tightly integrated movements that rapidly expand the buccal cavity to generate a water flow that moves the prey into the mouth. In a kinematic evaluation of prey capture mechanisms we measured no movement of prey toward eels. Morays exhibit several major anatomical novelties of the head region associated with the absence of suction during prey capture, including reduction of the hyoid bar, pectoral girdle and sternohyoideus muscle. We tested the hypothesis that the loss of suction feeding has freed temporal constraints on prey capture kinematics by comparing two moray species to four suction feeding teleosts: a suction feeding anguillid eel, two centrarchids, and a cichlid. While all six species showed a similar sequence of kinematic events during prey capture, the moray cranial movements were significantly slower compared to the suction feeders. In addition, morays frequently reversed the direction of jaw and cranial rotation in the midst of the strike, something that has never been reported in a suction feeding fish. Timing variables alone represented 65% of the feeding variation observed across the six taxa in kinematic space. Morays also showed significantly higher variance in kinematic variables than the four suction feeders. The absence of suction feeding as a prey acquisition behavior in morays not only permits temporal variation in feeding kinematics but increased functional capacity of the pharyngeal jaw apparatus. Morays appear to have modified the general teleost feeding patterns in order to eat big prey.

44.11 MELVIN, III, Paul D.*; BOYD, Amy; ANGUS, Robert A.; University of Alabama at Birmingham; *pdmelvin@uab.edu*

Sperm production in Gambusia affinis as a biomarker of endocrine disruption

Many anthropogenic compounds with endocrine disrupting activity have been detected in aquatic environments. The mosquitofish, *Gambusia affinis*, is a useful biomonitor species for endocrine disrupting compounds (EDCs) in aquatic environments because of its widespread occurrence around the world, large environmental tolerances, and ease of use in the laboratory. Previous studies have shown that vitellogenin production in males and modified anal fin development (masculinization) in females are reliable indicators of exposure to endocrine disrupting compounds. Other experiments have shown that endocrine disrupting compounds affect courtship behaviors, sperm motility, egg fertilization rates, and sperm counts in fish. The current study tests the hypothesis that a decrease in sperm production in male mosquitofish will serve as reliable indicator of exposure to estrogenic compounds. Laboratory exposure to the synthetic estrogen 17α-ethynylestradiol significantly decreased sperm production in *G. affinis* males. Sperm counts of males collected from a nonpolluted spring in central Alabama showed little seasonal variation. Additionally, wastewater treatment plants (WWTPs) are a potential source of endocrine disrupting chemicals in aquatic systems, particularly those with estrogenic activity. Male mosquitofish collected below the effluent outfall of a WWTP had significantly lower mean sperm counts than controls. These results indicate that sperm count is a useful biomarker of endocrine disruption in mature male *G. affinis*.

37.3 MENON, JAISHRI/G*; CHRIST, MICHELLE; GARDNER, EILEEN; William Paterson University; *menonj@wpunj.edu*

OXIDATIVE STRESS & INTESTINAL REMODELING DURING AMPHIBIAN METAMORPHOSIS: A BALANCING ACT!

Anuran metamorphosis is characterized by extensive remodeling of the intestine which involves cell proliferation, apoptosis and cell differentiation. Involvement of reactive oxygen species (ROS) in tail regression has been reported, but practically nothing is known about the role of ROS in tissue remodeling of the intestine. Our earlier biochemical studies have shown that the cellular environment in the intestine becomes progressively more oxidizing during its remodeling. Presently we evaluated the role of catalase and superoxide dismutase (SOD) during intestinal remodeling in tadpoles of *Xenopus laevis* (staged according to Nieukoop and Faber, 1967) using western blot analysis and immunohistochemistry (IHS). To identify the proliferating cells, live tadpoles were injected with BrdU and paraffin sections were stained with anti BrdU. Western blot analyses for catalase and SOD have shown presence of both proteins from stage 58 onwards. IHS at stage 60 (just before remodeling begins) revealed intense staining for catalase in typhlosole (a larval organ) as well as mucosa destined to become adult type, whereas SOD was found to be present only at the boundary of mucosa. Some SOD positive cells in the lumen of the intestine were observed, which could be due to the fact that apoptosis occurs mainly in the cells that line the lumen and these epithelial cells are sloughed in the lumen. Positive BrdU staining in mucosa, typhlosole and connective tissue indicated ongoing cell proliferation which may need protection from oxidative stress. Our results support the contention that a) adult intestinal epithelium probably originates from larval epithelial cells and b) presence of catalase and SOD afford protection to these cells from oxidative assault.

60.1 MENSINGER, Allen F.; University of Minnesota Duluth; *amensing@d.umn.edu*

Sensitivity of utricular afferent fibers to intraspecific calling via inductive neural telemetry in free ranging oyster toadfish, Opsanus tau.

Male toadfish acoustically attract females to nesting sites by producing boat-whistle calls. To determine how the fish localize sound underwater, inductive neural telemetry was used to record from microwire electrodes chronically implanted into the utricular nerve of the toadfish, *Opsanus tau*. The telemetry tag allowed both laboratory and field monitoring of unrestrained, naturally behaving fish. The sensitivity of utricular afferent nerve fibers to male toadfish boat whistle calls and pure tone stimulus was determined in water depths ranging from 0.4 to 1.0 meters. Hydrophones were placed approximately 5 cm above the otoliths to determine the physical characteristics of the sound impinging on the utricle. Approximately half the afferents fiber exhibited increased firing to sound stimulus with many showing directional sensitivity. Thus, toadfish may be able to use information from the utricular afferents to localize sound underwater.

4.3 MERRY, J. W.*; RUTOWSKI, R. L.; Arizona State University; *jmerry@asu.edu*

Is visual performance constrained by body size in Drosophila melanogaster?

Past research on insect eyes has revealed the presence of a strong, allometric relationship between eye size and body size, both within and among species. This finding has been explained as being the result of competing selection pressures: on one hand, selection favoring increased visual performance drives an increase in eye size. On the other, selection favoring reduced costs (mechanical, metabolic, etc) constrains eye size relative to body size. According to this hypothesis, as body size increases, the relative costs of maintaining an eye of a given size decrease, allowing improvement in visual performance via the construction of a larger eye. Here, we present data evaluating the strength of the constraint of body size on eye size in *Drosophila melanogaster*. To evaluate the magnitude of genetic variation in relative eye size, we first conducted a full-sib heritability analysis. We found that there was significant broad-sense heritability in both absolute eye height (H^2=0.53) and thorax length (H^2=0.39), but that the two variables were highly correlated (r=0.92). Nevertheless, we detected a smaller but highly significant heritability in the ratio of eye height to thorax length (H^2=0.19). This suggests that strong selection could drive divergence in this trait. With this in mind, we have begun a selection experiment that aims to disrupt the eye size to body size relationship. We predict that if the constraints imposed by body size on eye size are substantial, selection favoring individuals with large eye height to thorax length ratios will not cause a substantial change in this ratio. In contrast, lines subjected to selection favoring small eye height to thorax length ratios should experience a reduction in relative eye size. Results from the selection experiment will be presented.

53.4 MEYER, E.*; MANAHAN, D. T.; Univ. Southern California; *elishame@usc.edu*

Amino Acid Transporter Gene Expression During Sea Urchin Development

The mechanisms that regulate transport of organic nutrients during early animal development are not fully understood. Several amino acid transporter genes were cloned from a cDNA library of 4-cell-stage embryos of the sea urchin *Strongylocentrotus purpuratus*. Two of these genes (spAT2 and spAT17) have sequence similarities with transporters of organic solutes characterized in other animals. Heterologous expression of these sea urchin genes in frog oocytes (*Xenopus laevis*) showed that spAT2 and spAT17 encode novel, functional alanine transporters. Transport rates by sea urchin larvae of alanine from seawater decreased in the presence of a specific antibody raised against spAT2, demonstrating the *in vivo* alanine transport function of this gene. During sea urchin development, alanine transport rates increased 6-fold between 5-hr-old embryos and 4-d-old larvae. Corresponding changes in gene expression were measured during this developmental period. The high initial transcript abundance of spAT2 in eggs decreased 24% in 4-d-old larvae. In contrast, the transcript abundance of spAT17 was very low in eggs, and increased 1,100% in 4-d-old larvae. Ontogenetic patterns of expression of these two alanine transporter genes, each with different amino acid sequences, suggest the possibility that known physiological changes in capacities and affinities of amino acid transport during development are regulated by differential gene expression. These findings represent a functional characterization of amino acid transporter genes in marine invertebrate larvae and provide new tools for investigating long-standing questions regarding the mechanisms of dissolved organic nutrient transport by marine animals.

42.5 MEYERS, R.A.*; MCFARLAND, J.C.; Weber State University, Ogden, UT; *rmeyers@weber.edu*

Anatomy and Histochemistry of Golden Eagle Flight Muscles

Previous research in our laboratory and elsewhere has show that soaring birds such as albatrosses, vultures and pelicans possess a slow-contracting deep layer to the pectoralis that is presumed to function during sustained periods of gliding and soaring flight. Albatrosses even possess a collagenous shoulder lock to further reduce energy expenditure during soaring. As part of our ongoing study of avian posture, we examined the flight musculature of Golden and Bald Eagles (*Aquila chrysaetos* and *Halieeatus leucocephalus*) and used immunohistochemistry to test for the presence morphological specializations and slow muscle fibers suitable for soaring in these species. Contrary to our expectations, both species lacked a deep layer to the pectoralis, and had pectoralis muscles typical for raptors, though much larger. In addition, there were no significant numbers of slow muscle fibers; most muscles that have been found to be soaring-specialized in other birds (e.g., M. coracobrachialis cranialis, cranial border and deep region of M. pectoralis) lacked any slow fibers or had very small, functionally-insignificant fiber populations (~25). It is unknown if fast fibers perform the soaring role in these birds, as has been suggested for gulls, or if the collagenous fascia of the pectoralis may aid in wing support, as in albatrosses. This lack of slow fibers in the flight muscles of eagles may represent a functional or phylogenetic constraint. Supported by NIH grant # DC004390.

39.9 MEYERS, J.J.*; IRSCHICK, D.J.; University of Massachusetts, Amherst; *meyerhoffer@gmail.com*

Performance and niche space in a community of lizards.

Studies examining niche relationships of lizard communities have focused primarily on spatial, temporal and trophic utilization of resources to explain niche partitioning. While ecomorphological work has established a strong link between these niche dimensions and organismal morphology, there are surprisingly few examples examining how species performance at similar ecological tasks influences community structure. In this study we examine niche partitioning not based on the resources used, but rather, on how well species perform at tasks that allow them to utilize these resources. We examined a riparian lizard community in central Arizona that contains nine sympatric species. We measured two important aspects of lizard performance, bite force, because of the relevance to dietary breadth, and sprint speed, which has important consequences for prey capture, predator escape and feeding. Because the habitat is primarily composed of arboreal and terrestrial components, sprint speeds were measured on vertical and horizontal substrates to estimate the ability to utilize available habitat. Comparison of these two performance traits with respect to resource availability and use may provide insight into how performance measures influence the fundamental and realized niches of the different species.

25.5 MIDDLETON, K.M.*; GARLAND, T., Jr.; GOLDSTEIN, B.D.; GUDURU, P.R.; KELLY, S.A.; SWARTZ, S.M.; Brown Univ., Univ. Calif., Riverside; *kmm@brown.edu*

Within-bone Variation in Stiffness Measured by Nanoindentation in High-running Mice

A bone's loading response is, in part, a reaction to dynamic forces filtered through multiple levels of structure, from micro-scale material properties to macro-scale geometry. Studies of large mammals and the complex shape of the mouse femur, suggest that regions of both compression and tension will be present during loading. We hypothesize that stiffness will vary according to anatomical quadrant in bone's cortex and that modulus will differ among groups experiencing different levels of exercise. We measured modulus in femora of 48 female mice, half from lines selected for high levels of voluntary wheel running (37 generations) and half from control lines. Additionally, half had access to a wheel for 13-14 weeks beginning at 53-60 days of age, allowing the separation of selection effects from activity effects. Modulus was measured at the mid-shaft via nanoindentation at four quadrants (anterior, posterior, medial, lateral). No significant variation in modulus in any single quadrant was found due to selection, activity, or an interaction. However, when all samples were pooled for a quadrant, significant differences were present. Moduli in the anterior and lateral quadrants were significantly higher (32.1 and 32.4 GPa, respectively) than at the posterior and medial quadrants (30.1 and 29.8 GPa). This pattern of higher modulus in the anterolateral vs. posteromedial cortex agrees with published data for some bones of large mammals (e.g., horse radii and metacarpals, human tibiae), but such a pattern has not previously been demonstrated in small mammals. These data suggest that the long bones of large and small mammals may respond to similarly at the tissue level despite vastly different loads. Supported by NIH 1F32AR053008-01 to K.M., NSF IOB-0543429 to T.G., and NSF CMS-0547032 to P.G.

69.1 MIKLASZ, K.A.*; SOCHA, J.J.; LABARBERA, M.; University of Chicago, Argonne National Laboratory; *kmiklasz@gmail.com*

Understanding aerodynamic force generation in gliding snakes using physical models

Snakes of the genus *Chrysopelea*, the only limbless animal flyers, have no specialized structures used to produce lift, suggesting that snakes use their body as a functional wing'. When airborne, snakes dorsoventrally flatten the body by expanding the ribcage, creating a concave shape whose aerodynamic characteristics are currently unknown. In this study, we determine the aerodynamic characteristics of this cross-sectional shape by measuring the lift and drag coefficients of model body segments in a wind tunnel. The concavity, edge sharpness, and backbone protrusion of the models were varied in order to determine the effect of specific aspects of cross-sectional shape on force generation. The models exhibited maximum lift-to-drag ratios of 2.6-2.9 (corresponding to minimum glide angles of 19°-20°) and lift and drag coefficients of 1.4 and 0.5 at the angle of attack where minimum glide angle occurs. These values fall within the range of previous estimates based on actual snake trajectories. Two features of the models illustrate that snakes can use multiple angles of attack and still perform near maximally. First, the lift-to-drag ratio decreases gradually after stall, which occurs near 30°. Second, there is a 20° range of angles of attack where lift-to-drag is relatively high. When two model segments were placed in series to more closely mimic the snake's body posture in flight , the lift-to-drag ratio of the posterior segment significantly increased. Overall, the lift and drag coefficients found in this study indicate that treating the snake's body segments as separate airfoils may account for most of the forces that snakes generate while gliding, suggesting that conventional static-wing aerodynamics can explain how snakes glide.

S1-1.9 MILLER, L P; Hopkins Marine Station, Stanford University; *millerlp@stanford.edu*

Feeding is a drag: cautious cirripedes curtail cirral casting when waves wash wildly

Size and form of filter feeding appendages have direct consequences for the efficiency of particle capture and the drag resulting from flow around the appendages. Barnacles are able to plastically alter the morphology of their cirral net between moults in response to the flow environment in which they live, but there appears to be a limit to the extent of alteration. As a result, in the most wave-exposed environments, high water velocities would be potentially damaging to barnacles, were it not for the benefits of behavior. To ascertain whether behavior allows barnacles avoid the consequences of drag, observations of barnacle feeding behavior on a wave swept shore were made using a video monitoring system. Barnacles react quickly, withdrawing their legs into the shell as large waves wash over them, and resuming feeding as soon as the flow slows. As larger waves and faster flows impact the site, barnacles withdraw more often. At flow speeds exceeding 4-5 m/s, barnacles withdraw for nearly every wave. By virtue of this behavioral trait, barnacles may in fact tune their cirral morphology to a measure of the environment more akin to the average or mode of the water velocities at a site, rather than to the extreme velocities that are more commonly measured and correlated with leg morphology

S5.8 MILLER, David J*; DE JONG, Danielle M; SCHIERWATER, Bernd; HAYWARD, David C; BALL, Eldon E; James Cook University, Australian National University, Tierärztliche Hochschule Hannover; *david.miller@jcu.edu.au*

Implications of cnidarian gene expression data for the origins of bilaterality is the glass half full or half empty?

The last two years have seen a dramatic increase in the available sequence and gene expression data for cnidarians and other lower Metazoa, and a flurry of recent papers has drawn on these to address the origins of bilaterality. Cnidarian homologs of many genes that play key roles in the specification of both the A/P and D/V axes of bilaterians have been characterised, and their expression patterns determined. Some of these expression patterns are consistent with the possibility of conservation of function between Cnidaria and Bilateria, but others clearly differ. Moreover, in some cases very different interpretations have been made on the basis of the same or similar data. In part these differences reflect the inevitable uncertainties associated with the depth of the divergence between cnidarians and bilaterians. In this paper we briefly summarise the cnidarian data on gene expression and organization relevant to axis formation, the varying interpretations of these data, and where they conflict. Our conclusion is that the presently available data do not allow us to unequivocally homologize the single overt axis of cnidarians with either of the bilaterian axes.

S1-5.8 MILLER, L. A.; University of North Carolina, Chapel Hill; *miller@math.utah.edu*

To make a valve you have to put your heart into it

The embryonic vertebrate hearts develops from a simple heart tube that moves blood with a wave of contraction to a valve and chambered pump through a series of complicated morphological changes. During this transformation, the flow patterns within the heart are constantly changing due to variations in the viscosity of the fetal blood, chamber and valve morphology, and the kinematics of contraction. Cardiac endothelial cells can sense and respond to local variations in shear stress caused by such changes in the larger scale fluid dynamics. A number of recent studies suggest that these fluid dynamic signals are responsible for triggering biochemical cascades within the cell, leading to the transcription of genes necessary for cardiac morphogenesis. One aspect of heart development that is particularly sensitive to alterations in cardiac flow patterns is the development of the heart valves. The broad focus of this study is to understand how the cardiac cushions, which later become the valves, are formed through a complex interaction of flow, mechanosensing, biochemical cascades within the cell, and changes in morphology. In this paper, we will focus on larger scale fluid dynamic transitions in the growing heart. Cardiac flow patterns change as the chambers form, the heart loops, and the cardiac cushions begin to expand. Such changes in flow cause temporal and spatial variations in shear stress along the endothelial lining of the heart tube. Computational fluid dynamics and physical models were used to describe how variations in shear depend upon scale and morphology. The immersed boundary method was used to determine the flow patterns and shear stresses in a model heart over a range of Reynolds numbers and morphologies. These results were validated using a physical model of the developing heart.

24.6 MILLER-SIMS, V*; ATEMA , J; GERLACH, G; KINGSFORD, MJ; Boston University Marine Program, Marine Biological Laboratories, James Cook University; *vms@bu.edu*

Olfactory imprinting in coral reef fish

Most marine organisms have a pelagic larval dispersal phase, leading to the question of how far larvae disperse. Larval behavior and odor preferences may play an important role in larval dispersal and settlement. Apogonid larvae prefer the odor of the reef on which they were caught over other reefs and ocean water. It is possible that this response is due to acclimatization to the odor of water the fish have been recently swimming instead of a long term preference. We tested apogonid larvae settling on One Tree Island by catching them as they came onto the reef and testing their preference for water for One Tree vs. water from Heron Island in a flume preference test. We then held the fish in either One Tree or Heron water and tested them over a period of nine days. The preference for One Tree water declined in both groups over time; there was no significant difference between the animals held in One Tree or Heron water and both groups maintained a preference for One Tree throughout the testing period. Odor preferences remain stable over time despite exposure to other odors and it is possible they are the result of olfactory imprinting to the home reef odor. Olfactory imprinting has been shown in anemonefishes, but the sensitive period is unknown. Breeding pairs of Amphiprion melanopus were held either with or without an anemone. Eggs and larvae were exposed the anemone from egg laying through hatching (1), from egg laying to just prior to hatching (2), just previous to and 1 hour after hatching (3) or had no anemone exposure (4). At 15 days those larvae in groups 2 and 4 had no preference for the anemone while those in groups 1 and anemone showed a strong significant preference for anemone odor. In this species of reef fish larvae must be exposed to the imprinting odor after hatching in order to learn it.

42.6 MONROY, J.A.*; GILMORE, L.A.; KREBS, L.; LAPPIN, A.K.; LINDSTEDT, S.L.; PIEROTTI, D.J.; NISHIKAWA, K.C.; Northern Arizona University; *Jenna.Monroy@nau.edu*

Elastic properties of muscle during active shortening

Recent work demonstrates that muscles themselves store elastic energy during isometric tetanus. When the force is reduced rapidly, muscles recoil elastically. Elastic recoil of muscle contributes to high power output of ballistic movements. At maximum isometric force, the depressor mandibulae muscles of toads develop strains up to 17.5% *ML*. This study tested the hypothesis that elastic properties of toad depressor mandibulae muscles are particularly adapted for power enhancement compared to other skeletal muscles. Using load-clamp experiments, we quantified the elastic properties of a variety of vertebrate muscles, including the depressor mandibulae muscles of *Ceratophrys* (which lacks ballistic tongue projection), the soleus (slow) and extensor digitorum longus (fast) muscles of *Mus*, and the semimembranosus and sartorius muscles of *Rana*. From the load-clamp data, we calculated the displacement from equilibrium (x) and spring constant (k_m) of each muscle. Our results demonstrate that all muscles responded similarly to changes in load. For a given initial level of force, the displacement from equilibrium increased exponentially as the change in force increased. The spring constant decreased non-linearly with the change in force, providing self-stabilization. All muscles experienced displacements of ~ 8% *ML* when the load was reduced to ~ 10% maximum isometric force. Maximum observed shortening was 15.3 19.4%·*ML* at the lowest loads. These results suggest that the displacement from equilibrium of intrinsic elastic elements within muscle is constant, relative to muscle length, across different muscles and different species, and that the ability to recoil elastically during rapid unloading is a general feature of skeletal muscle.

54.3 MOON, B.R.*; TULLIS, A; University of Louisiana at Lafayette , University of Puget Sound; *BradMoon@louisiana.edu*

The evolution of high-performance tail muscles in snakes

Rattling by rattlesnakes is one of the fastest vertebrate movements and involves some of the highest contraction frequencies sustained by vertebrate muscle. Specifically, the shaker muscles in the tails of rattlesnakes can sustain contraction frequencies up to 100 Hz for minutes to hours. To study the evolution of these high-performance muscles, we compared the activities of the enzymes citrate synthase (an indicator of aerobic capacity) and lactate dehydrogenase (an indicator of anaerobic capacity) in the tail muscles of rattlesnakes and their relatives. Rattlesnake tail muscles contracted at the highest frequencies and had the highest aerobic capacity, but only moderate anaerobic capacity. In other species that vibrate their tails, contraction frequencies and enzyme activities varied. Among species, there appears to be a clear relationship between muscle contraction frequency and aerobic capacity, but not between contraction frequency and anaerobic capacity. Furthermore, moderate to high aerobic capacities in the tail muscles probably gradually in viperid snakes, well before the evolution of rattlesnakes, rattles, and highly specialized shaker muscles. We are currently testing whether aerobic capacity is associated with the duration of tail vibration bouts or with the different levels of mechanical energy output that occur with different tail morphologies.

49.10 MORAN, A.L.**; WOODS, H.A.; Clemson University, Clemson, SC, University of Montana, Missoula; *moran@clemson.edu*

Egg mass physiology: Comparative morphology and physiology of experimental and natural invertebrate egg masses from temperate and Antarctic sites

Embryos of many marine invertebrates are encased in gelatinous masses for part or all of development. Both experimental evidence and physiological models suggest that egg masses of a given morphology (size, shape, and density of embryos) perform differently at warm compared to cold temperatures. In particular, because the metabolic oxygen demand of ectothermic embryos decreases with decreasing temperature, egg mass morphologies that would result in severe internal hypoxia in warm environments may be permissible' in extreme cold environments. Our biophysical models predict that at a given embryo density, masses at 0 degrees C can have diameters 6-fold greater than masses at 20 degrees C; likewise, for a given size, Antarctic masses can have higher densities of embryos, more globular morphologies, and thicker protective layers than temperate masses. We test these hypotheses in two ways. First, we constructed low-temperature artificial egg masses using embryos of Antarctic invertebrates, in which we experimentally manipulated size, shape, and embryo density. Second, we compared the morphologies and oxygen distributions in egg masses of temperate nudibranchs versus their Antarctic relatives.

64.2 MOREHOUSE, Nathan I.*; RUTOWSKI, Ronald L.; VUKUSIC, Peter; Arizona State University, University of Exeter; *nmorehouse@asu.edu*

Innovative Optics of Bright Wing Colors in Pierid Butterflies: Morphological Determinants and Implications for Use as Visual Signals

Animal color signals have been traditionally classified as either pigment based or structurally generated. However, little work has addressed the interplay between structures and pigments in color production, which has caused important interactions between these two color producing mechanisms to be overlooked or misunderstood. We have tested the hypothesis that collections of pigment molecules may in some cases act as structural scatterers, thereby increasing reflection of light wavelengths they do not absorb. We demonstrate that in pierid butterflies, pterin pigments are deposited within wing scales as oblong granules. These granules have been implicated as optical scatterers. Using both correlative and manipulative studies of the optical properties of single pierid wing scales, we probed the contribution of pterin granule arrays to backscattering of light from single scales. Our results support two conclusions: 1) the presence of pterin granules increases the reflectance of wing scales, and 2) denser granule arrays reflect more light than wing scales with less dense granule collections. Because male wing scales contain more pterin granules than do those of females, the sexual dichromatism found in many pierid species may be explained by differences in wing scale pterin deposition. Additionally, the color pattern elements produced by these pterins are known to be important during mating interactions in a number of pierid species. Therefore, we discuss the potential relevance of our results within the framework of sexual selection and color signal evolution.

S10.1 MORSE, M/P; Univ. of Washinngton Seattle; *mpmorse@u.washington.edu*

Vision of the SICB Digital Library

The Society of Integrative and Comparative Biology has established a Digital Library (SICBDL) on the website (http://www.sicb.org/dl/). The mission of this electronic resource is to provide peer-reviewed instructional materials, resources and activities in integrative and comparative biology for faculty as a resource to enhance undergraduate education at two- and four-year colleges and universities. The library architecture has been established by utilizing the first topic area addressed, Biomechanics. The library is totally electronic, receiving only materials that are submitted in appropriate software via the computer. The library is to be connected to the AAAS BEN portal (http://www.biosciednet.org). The founding advisory board has established a way for any group to create topics within or across divisional lines. We present to you today the vision of this library for the future, a sample of the topic biomechanics, the importance of that topic in the classrooms and for utilizing a multidiscipline approach and the guiding educational principles, based on research, that are being utilized to maximize the effectiveness of these undergraduate materials. A short guide for the SICBDL has been prepared to help the Society's Divisional members take new leadership roles in creating and shaping this important resource.

48.8 MOSTMAN-LIWANAG, H.E.*; WILLIAMS, T.M.; Univ. of California, Santa Cruz; *mostman@biology.ucsc.edu*

Share the warmth: Thermal benefits of huddling behavior in California sea lions (Zalophus californianus)

Otariids are highly communal pinnipeds that often congregate in large numbers on coastal rookeries. Although this behavior serves a social role, it also has the potential to change the microhabitat, and thus the local thermal conditions experienced by the animals. However, the thermal consequences of huddling in pinnipeds has neither been quantified nor tested despite a propensity for close proximity in some species. To investigate this, we quantified the huddling behavior of California sea lions by measuring the proximity of individuals from digital photographs, and determined the thermal microhabitat of huddles using infrared temperature monitors. All animals were measured on San Nicolas Island (California) for six days in winter (mean T_{air}=15.5°C) and summer (mean T_{air}=22.7°C). We found that sea lion huddling behavior increased in colder weather, as determined from three indices. First, a larger proportion (up to 97%) of the animals participated in huddles rather than resting alone during the winter season. Second, the number of animals per huddle was larger (reaching 172 animals) during the colder season. Lastly, sea lions participating in this behavior huddled more tightly (i.e. a greater proportion of skin surface area was in contact) in cold temperatures. The temperature differential between the animals' skin surface and that of the surrounding substrate was significantly greater ($P<0.001$) for huddling sea lions (6.0±3.6°C) than for animals resting alone (3.0±2.8°C). Furthermore, this differential was inversely proportional to ambient temperatures. These results suggest that huddling behavior in California sea lions provides a significant thermal benefit that likely shapes the social behavior on rookeries. Supported by the Alaska SeaLife Center.

S1-4.4 MOUNTCASTLE, A.M.*; DANIEL, T.L.; Univ. of Washington, Seattle; *mtcastle@u.washington.edu*

A new insect flight model is just around the bend

Models of insect flight commonly assume wings behave as rigid airfoils. Many insect wings are flexible, however, with dynamic bending occurring as a consequence of flapping flight. In moths, wing deformations are most prominent at stroke reversals, and their kinematics may have significant aerodynamic consequences that are not considered in previous flight models. The ventral wing stroke reversal of the hawkmoth *Manduca sexta* is accompanied by a transient chordwise wave passing from leading to trailing edge. Such waves have not been explored as a potential source of aerodynamic force in insect flight. Here we document the wing wave propagation at stroke reversal of *Manduca* during free-flight hovering and estimate the impulse of the wave using blade element theory. We used high speed digital videography to quantify three-dimensional wing kinematics from hawkmoths hovering in free flight. Wing deformation was measured at each time step relative to a two-dimensional plane best fit to the wing surface, representing a rigid wing model. We then employed a blade element analysis by dividing the wing into a series of longitudinal strips extending from the leading to trailing edge, fitting each strip with a model of a harmonically oscillating two-dimensional plate, and calculating the induced force on each strip. Forces were summed over all strips of the wing surface. Our results suggest that rapidly propagating waves of deformation can contribute aerodynamic forces significant to flight, on the order of the impulse of the animal's weight.

S1-2.4 MUNK, Y.; Univ. of California, Berkeley; *yonatanmunk@berkeley.edu*

Reactive Forces in Undulatory Swimming, with Reference to the Common Garter Snake (Thamnophis sirtalis)

Classical studies of the swimming of long and narrow animals have treated anguilliform propulsion as driven largely by resistive (drag-based) forces acting on the body, with 'reactive' forces (resulting from the acceleration reaction force) generated solely at the tail as predicted by Lighthill's elongated body theory. This separation of resistive and reactive forces is strictly only valid when the undulatory waves propagate along the body with constant speed; however, it has been previously noted that many swimming snakes exhibit an accelerating propulsive wave. I have digitized the kinematics of swimming garter snakes (*Thamnophis sirtalis*) from high speed video and used nonlinear regression techniques to demonstrate conclusively that there is a significant increase in the propagation speed of the undulatory wave as it moves rearward along the animal. I will explain how this phenomenon contributes a component to the total thrust via acceleration reaction forces, and discuss the circumstances under which this phenomenon should be considered in general.

22.3 MUñOZ-GARCIA, Agustí*; COX, Robert M.; WILLIAMS, Joseph B.; Ohio State University; *munoz-garcia.1@osu.edu*

Phenotypic flexibility in cutaneous water loss and lipids of the stratum corneum in House sparrows (Passer domesticus) following acclimation to high and low humidity

Resistance to water vapor diffusion through the skin is thought to be conferred by lipids in the stratum corneum (SC), the outer layer of the epidermis. We tested the effect of ambient humidity on cutaneous water loss (CWL) and lipid composition of the SC by acclimating house sparrows (*Passer domesticus*) to either a dry (6.5 g/m^3 absolute humidity) or a humid (31 g/m^3) environment for three weeks at a thermoneutral temperature (30ºC). Sparrows in the dry acclimated group reduced CWL by 36% compared with those in the humid environment. Relative to initial values, both groups of sparrows decreased CWL, 45% in the dry acclimated group, 23% in the humid group, suggesting that temperature is also an important stimulus for CWL apart from humidity. Both groups of acclimated sparrows decreased quantities of cholesterol, free fatty acids, and cerebrosides, and increased the proportion of ceramides in their SC. Lipid amounts or proportions in the SC did not differ between dry- and humid-acclimated sparrows, but the free fatty acid:ceramide ratio was significantly lower in dry-acclimated birds. Also, lipid composition was only correlated with CWL in dry-acclimated sparrows, suggesting that structural changes to SC lipids are more tightly linked to CWL regulation in response to low humidity. Our results demonstrate phenotypic flexibility in CWL and lipid composition of the SC and provide support for a functional relationship between these traits.

17.2 MYERS, M.J.*; WALL-SCHEFFLER, C.M.; WEAVER, T.D.; STEUDEL-NUMBERS, K.L.; College of St. Catherine, St. Paul, University of Wisconsin-Madison, University of California-Davis; *mjmyers@stkate.edu*

Complex Effect of Limb Length on Cost of Transport in Running Humans

It is unclear whether longer limbs relative to body mass (BM) should increase the cost of transport during running (greater mechanical work due to larger limb inertia) or decrease it (longer stride lengths, fewer strides), or whether these effects might offset one another. We recruited 13 subjects (6F,7M; 18-30 y) whose legs were relatively long or short for their BM (BM 50.0-96.4 kg, limb length 73.5-99.0 cm). Subjects ran on a treadmill at 2.68 m/s while expired gases were collected to calculate net metabolic cost of transport (NCOT, met power/distance). Kinematic variables were determined from high-speed video. Leg moment-of-inertia (LI) was calculated from anthropometric and kinematic measures: (avg distance from hip to limb center-of-mass during swing)squared*(estimated limb mass). BM explained 82% of variation in NCOT; limb length (LL) explained an additional 12% and the effect was negative (relatively longer limbs correlated with lower NCOT). This effect was mainly due to relatively shorter-legged people who chose a longer stride length (SL) for their BM. Although relatively longer limbs (residuals from regression against body mass as a control for body size) have relatively higher LI, which should increase NCOT, relatively longer-legged individuals use kinematic patterns that counteract the expected increase in cost. The effect of LL/LI on NCOT (not accounted for by BM), depends upon the SL chosen (when speed is fixed). Subjects with the lowest NCOT have relatively long legs/high LI/long SL and swing their legs with lower angular velocity for their BM. Subjects with the highest NCOT have relatively short legs/low LI/long SL and swing their legs with higher angular velocity for their BM.

S4-1.5 NAGY, J.D.; Scottsdale Community College; *john.nagy@sccmail.maricopa.edu*

Why Don't All Whales Have Cancer? A Novel Hypothesis Resolving Peto's paradox.

Cancer rates in blue whales (*Balaenoptera musculus*) should be at least 2000 times higher than in humans simply because blue whales have 2000 times more cells. But the rates appear to be about equal. Three competing hypotheses have been advanced to resolve this paradox--called "Peto's paradox"--in mammals. First, mutation rates may be inversely proportional to body size. Second, malignant cells may enjoy a smaller advantage in larger versus smaller hosts. And third, selection might favor more redundant anticancer mechanisms--like tumor suppressor genes--within the genomes of larger organisms. Here I present a novel hypothesis explaining Peto's paradox. Mathematical models of cancer predict that natural selection will tend to favor malignant cell strains that trade off secondary physiological abilities, like secretion of angiogenesis factors, for growth potential. Such strains then grow as a tumor on their parent tumor, creating a hypertumor that damages or destroys the original neoplasm. Evolutionary models based on these systems suggest that, given enough time, hypertumors will always develop. However, in humans they fail to develop because required mutations do not always arise before the tumor becomes lethal, which occurs when it reaches a mass of one to 2.5 kilograms. However, lethal tumors in blue whales probably weigh at least 2500 pounds. Therefore, they would take at least twice as long to develop in blue whales, providing more time for hypertumors to arise. In this study I test this idea by parameterizing models that originally predicted hypertumors in humans to represent neoplasia in beluga and blue whales. Preliminary results suggest that the hypertumor mechanism may in fact explain Peto's paradox in cetaceans.

11.4 NAKATSUJI, T.*; WATSON, R.D.; Univ. of Alabama, Birmingham; *terunakatsuji@hotmail.com*

Cyclic Nucleotide Phosphodiesterase from Crustacean (Procambarus clarkii) Y-Organs: Molecular Cloning, Heterologous Expression, and Functional Link to Calcium Signaling and Regulation of Ecdysteroidogenesis.

Crustacean molt-inhibiting hormone (MIH), a polypeptide secreted by the X-organ/sinus gland complex of the eyestalks, regulates molting by inhibiting the synthesis of ecdysteroids by Y-organs. Our previous results suggest that molt cycle-associated changes in cyclic nucleotide phosphodiesterase (PDE) activity affect the ability of MIH to stimulate cGMP accumulation and suppress ecdysteroidogenesis in Y-organs of the crayfish *Procambarus clarkii*. We report here (a) molecular cloning of a cDNA (*PcPDE1*) encoding PDE from *P. clarkii* Y-organs, (b) expression of the recombinant PcPDE1 protein in *Escherichia coli*, and (c) studies revealing the functional link of PcPDE1 to calcium signaling and MIH-mediated regulation of ecdysteroid production in Y-organs. Sequence analysis of the cloned cDNA revealed a 2061 base pair open reading frame. Analysis of the deduced amino acid sequence showed that PcPDE1 contains putative calcium/calmodulin binding and catalytic domains, suggesting that PcPDE1 is a calcium/calmodulin dependent PDE (PDE1). Recombinant PcPDE1 was expressed in *E. coli*. The refolded recombinant enzyme had PDE catalytic activity, and that activity was enhanced by addition of calcium and calmodulin. Incubating Y-organs with a calcium ionophore (ionomycin) increased glandular PDE activity three-fold and decreased MIH-induced suppression of ecdysteroid production in Y-organs. Quantitative real-time PCR revealed expression of the *PcPDE1* gene in Y-organs was highest during middle premolt, a stage when the responsiveness of Y-organs to MIH is lowest. The combined results suggest that PcPDE1 is a key enzyme linking cellular calcium signaling to MIH-mediated regulation of ecdysteroid production in Y-organs. Grant sponsor: National Science Foundation, IBN-0213047 (RDW).

58.5 NAY, L.A.I.; STEVENSON, K.T.*; VAN TETS, I.G.; Kotzebue High School, Kotzebue, AK, University of Alaska Fairbanks/ University of Alaska Anchorage, University of Alaska Anchorage; *ftkts2@uaf.edu*

Seasonal changes in the reproductive organs and body condition of northern redbacked voles (Clethrionomys rutilus) in coastal, southcentral Alaska

Arvicoline rodents (voles and lemmings) are small, non-hibernating mammals that play important ecological roles in high-latitude environments. Vole reproduction can be species-specific and generally occurs in spring and summer, but almost all arvicolines are known to at least occasionally breed in winter. Our aim was to determine whether seasonal change occurs in the relative reproductive organ masses of the northern redbacked vole (*Clethrionomys rutilus*) in coastal, southcentral Alaska (61°N), and, if so, to test whether these masses were correlated with the rodents' body condition. We measured seasonal change in the masses of three male organs (seminal vesicle, testis, and epididymis) and two female organs (ovary and uterus) for adult and subadult voles, used histological methods to define male reproductive state, and measured body condition (percentage body fat) using dual-energy X-ray absorptiometry (DXA). The relative masses of all male and female organs showed significant seasonal change ($P < 0.05$), but there was no correlation between any of the relative organ masses and the voles' body fat percentage ($P > 0.05$, $R^2 = 0.0$ to 0.1). All of the male and female organ masses were significantly heavier in the Spring and Early Summer seasons. Reproductive condition was tightly linked to season but not to body condition. The reproductive condition of northern red-backed voles may continue to follow season by responding to changes in photoperiod, regardless of any changes in the energetic demands placed on the animal due to climate change.

29.8 NEWBREY, J.L.**; REED, W.L.; FOSTER, S.P.; ZANDER, G.L.; North Dakota State University, Fargo, South Milwaukee, WI; *jennifer.newbrey@ndsu.edu*

Intraclutch Variation in Carotenoid Concentrations in Yellow-headed Blackbird Eggs

Asynchronous hatching creates a size hierarchy among siblings and a survival disadvantage for last-hatched nestlings. Female birds can either maintain (brood reduction strategy) or reduce this survival disadvantage (brood survival strategy) by differentially investing maternal resources, such as carotenoids, across the laying sequence. We quantified intraclutch variation in the concentrations of four carotenoids, beta-carotene, beta-cryptoxanthin, lutein, and zeaxanthin, in Yellow-headed Blackbird eggs collected from five free-living breeding colonies. We also quantified the relationship between egg metrics (i.e., egg mass, yolk mass, and yolk water content) and carotenoid allocation to eggs. Concentrations of four yolk carotenoids were significantly related to egg laying order, but there were differences in their patterns. The concentration of lutein decreased from first to last-laid eggs, supporting a brood reduction strategy, whereas the concentrations of beta-carotene, beta-cryptoxanthin, and zeaxanthin increased from first to last-laid eggs, supporting a brood survival strategy. The differences in carotenoid-concentration patterns we observed across Yellow-headed Blackbird clutches suggest that the carotenoids may compete with each other during absorption, they may be of different value to the developing embryo due to differences in antioxidant function, or they may be differentially available in the diets of females during egg production. Carotenoid concentrations were not significantly related to any of the egg metrics measured despite previous research that has found an effect of egg size on carotenoid allocation to eggs.

S4-1.4 NEWMAN, T J*; ANTONOVICS, J; MCKANE, A J; Arizona State University, University of Virginia, University of Manchester; *timothy.newman@asu.edu*

A fluctuation-induced mechanism for cycling behavior in disease dynamics

We discuss a new mechanism for oscillations in host-pathogen populations based on an amplification of the intrinsic stochasticity of demographic and disease-transmission events. This mechanism can trigger oscillations in systems which, when modeled deterministically, fail to exhibit cycling. We also discuss the influence of this new mechanism on explicitly spatial host-pathogen systems.

24.1 NICHOLS, Amy/E*; ZIMMER, Richard/K; ZIMMER, Cheryl Ann; Univ. of California, Los Angeles; *amynichols@ucla.edu*

The interactive effects of flow, chemistry, and behavior on mate attraction

Finding a mate is a critical first step towards sexual reproduction. Despite significant advances in understanding pheromone signaling in terrestrial mating systems, little is known of mate attraction within aquatic habitats. The marine hermaphroditic gastropod, *Aplysia californica*, forms large breeding aggregations that contain conspecifics and egg masses laid one on top of another. Egg proteins have been isolated, characterized, and described as mate attraction pheromones. These molecules are believed to coordinate aggregation formation, but support for this hypothesis is based only on results from experiments in still water. Here, we investigated *Aplysia* mate attraction using a large (10 m long x 0.75 m wide x 0.15 m deep), open-channel, flume having fully developed, one-dimensional, boundary layer flows. Mate attraction was maximal at flow speeds of 0.5 2 cm/s and shear velocities (u*) of 0.1 0.2 cm/s, in the simultaneous presence of eggs and a conspecific. A significant decline in mate attraction occurred in faster flow (speed = 4 cm/s; u*=0.4 cm/s), and when only eggs or a conspecific was present. Thus, both eggs and conspecifics are critical sources of attractants, and successful mate search is highly dependent on flow conditions. The mechanism used by *Aplysia* to navigate within an attractant odor plume differed significantly from whelks (an alternative gastropod species), but was the same as that described for blue crabs. Search behavior dynamics are therefore sensitive to ecological or environmental context, and are not dictated strictly by phylogenetic constraints.

10.2 NICKEL, M; Stuttgart University, Germany; *michael.nickel@bio.uni-stuttgart.de*

The elementary (pre-)nervous system reconsidered: new evidence from poriferans

In 1919 Parker presented basic ideas on the elementary nervous system. He assumed it became manifest due to the evolutionary pressure to coordinate independent effectors. The concepts behind his theory continued to hold with little changes over time. In 1956 Pantin stressed the evolutionary importance of coordinating cell networks. Passano (1963) postulated pacemaker cells to be the nucleous of nervous system evolution. Mackie (1990) reviewed the topic. All concluded that the cnidarian nervous system is the primary nervous system. However, Mackie pointed out that more work on sponges is needed. The recent (re-)postulation of the paraphyly of the Porifera consequently means that a sponge like animal would be within the ancestral line of all metazoans. The question arises, if the first modules of the rather complex elements of later nervous systems evolved in such a sponge like archimetazoon. Our work on the coordination systems in poriferans, which particularly focused on neurosecretory substances, is summarized. Monitoring contractile response of our model organism *Tethya wilhelma*, we recorded and analyzed a variety of specific responses to a variety of neuromodulating substances. Our results as well as recent sponge EST sequencing projects clearly show the presence of complex networks of regulatory circuits within a system of effectors, signal conductors and pacemakers. All criteria for the elementary nervous system given by former investigators are met. Even if no true neurons are present in poriferans, the physiological functionality and complexity can only be explained by a well-defined pre-neuronal system. Consequently, the evolutionary origin of the nervous system dates back to the basal Metazoa, most likely extinct archimetazoans.

47.9 NOEL, M. L.*; NUNEZ, B.S.; Univ. of Texas Marine Science Institute; *noelml@mail.utexas.edu*

Steroidogenic capacity of the Atlantic stingray (Dasyatis sabina) brain

We investigated the steroidogenic capacity of the Atlantic stingray (*Dasyatis sabina*) brain by examining the expression of steroidogenic genes in six sections of the brain (cerebellum, telencephalon, optic lobe, medulla, hypothalamus and pituitary). Complementary DNA (cDNA) sequences specific for *D. sabina* steroidogenic factor-1 (SF-1), side chain cleavage (SCC), steroidogenic acute regulatory protein (StAR) and 11β-hydroxylase (11β-OH) were determined through a nested primer strategy with degenerate primers derived from teleost sequences. Aromatase and 3β-hydroxysteroid dehydrogenase (3β-HSD) sequences for the *Dasyatis* genus were taken from the literature (Ijiri et al., 2000 and Nunez and Trant, 1998, respectively). Primers specific for these cDNAs were used in RT-PCR to determine if their corresponding mRNAs are present in *D. sabina* brain from unstressed and stressed adult stingrays (disc width > 30 cm). Between both sexes and stress states, each of the genes investigated was present in at least one area of the brain, with usually more than one gene being present in a specific brain region. Unstressed females expressed three of the six genes investigated (StAR, aromatase, and 11β-OH) in brain tissue, while stressed female brain tissue expressed all six genes. Stressed and unstressed males expressed all genes investigated, though the distribution of expression was different depending on the animals' stress condition. In general, stressed animals expressed steroidogenic genes in more tissues than unstressed animals. This study suggests that the brain of the *D. sabina* is capable of steroidogenesis, and that stress may play an important role in regulating steroidogeneic gene expression, though further work is needed to determine the types of neurosteroids produced.

55.6 NOLAN, PM*; NICOLAUS, M; BAJZAK, C; COQUEL, A-S; JOUVENTIN, P; The Citadel, C.E.F.E.-CNRS; *paul.nolan@citadel.edu*

Ornamental colors signal sex, health, and breeding status in king penguins, Aptenodytes patagonicus

We investigated the relationship between colored integumentary ornaments and health, sex, and time of breeding in the king penguin, *Aptenodytes patagonicus*. Ornamental traits have previously been found to signal condition in other avian species, but very little is known about the signal function of ornamental colors in seabirds such as king penguins. Individuals of this species are characterized by bright yellow-orange patches on their breasts and auricular body regions, and by orange, ultraviolet-violet (UV-V) reflecting beak spots. We examined the relationship between ornamental color and individual quality by examining plumage and beak colors relative to sex, health, time of breeding, and body condition (mass corrected for body size). Colors of the breast and auricular plumage were significantly more saturated on early breeders and healthy individuals, respectively, while the colors of sick birds were significantly brighter than those of healthy birds on both plumage patches. Health status also related significantly to hue and saturation in the yellow-orange wavelengths (450-700 nm) on the beak although not in the UV-V (320-450 nm), where time of breeding related significantly to UV-V saturation. Brightness of all ornamental colors differed significantly between the sexes in healthy breeders, with females exhibiting the brightest feathers and males exhibiting the brightest beaks. We also found significant interactions between sex and health, with sick females displaying particularly bright reflectance from the beak in both the UV-V and longer wavelengths. These results suggest that beak and plumage colors in the king penguin are honest signals of body condition, potentially functioning in pairing to help select mates of the highest possible quality.

68.5 O'CONNOR, M.P.*; AGOSTA, S.J.; HANSEN, F.; KEMP, S.J.; SIEG, A.E.; MCNAIR, J.N.; DUNHAM, A.E.; Drexel University, University of Pennsylvania, Academy of Natural Sciences of Phildelphia; *mike.oconnor@drexel.edu*

Phylogeny, regression, and the allometry of physiological traits

Most functional allometric relationships are reported as ordinary least squares (OLS) regressions. Unfortunately such relationships usually involve independent and dependent variables, each of which includes intrinsic and measurement error for each data point (usually different species) and no clear causal mechanism designating one variable as causal and the other as a response variable. In addition, the data are, at least potentially, phylogenetically constrained rather than independent. None of these features are strictly consistent with the OLS regression model. Alternate models employing phylogenetic contrasts and major axis or reduced major axis (RMA) have been used but the extent to which they remedy the problems of OLS regression are often not evaluated. To explore the importance of regression methodologies and phylogenetic contrasts in estimating regression slopes for phylogenetically constrained data, we simulated Brownian diffusive evolution of functionally constrained characters. Both OLS and RMA regressions under and over-estimated regression slopes under different circumstances, but that a modified orthogonal (LSVOR) regression was less biased than either OLS or RMA regressions. The LSVOR technique is conceptually intermediate between OLS and RMA regression and depends on variance estimates likely to be available in allometric regressions but often unavailable for other analyses. For strongly phylogenetically structured data, failure to use phylogenetic contrasts as regression data resulted in overestimation of the strength of the regression relationship and a significant increase in the variance of the slope estimate.

29.10 OKAMOTO, Kazu*; FREAMAT, Mihael; SOWER, Stacia; Univ. of New Hampshire; *ker2@unh.edu*

Characterization of the Lamprey GnRH Receptor

The recently cloned lamprey gonadotropin-releasing hormone (GnRH) receptor was shown to have several unique features, including the longest intracellular C-terminal tail (120 aa) of any previously described GnRH receptor (Silver et al., 2005, Silver and Sower, 2006). Activation of the lamprey GnRH receptor was shown to stimulate cAMP production in a dose dependant manner when treated with either lamprey GnRH-I or lamprey GnRH-III. Truncation analysis indicated that the first 40 amino acids of the lamprey GnRH receptor C-terminal tail contained a motif required for cAMP accumulation. Competitive, intact cell binding assays suggested that the lamprey GnRH receptor was lamprey GnRH-III selective. The lamprey GnRH receptor was also shown to undergo rapid ligand dependant internalization, which was significantly diminished in the tail-less truncated form. In the current study further characterization of the first 40 amino acids of the C-terminal tail was performed in which lamprey GnRH-III was used to stimulate cAMP accumulation. The HFRK like motif HVRR occurring in the first 5 amino acids was found to be required for cAMP accumulation by exhibiting a drastic decrease in cAMP accumulation when mutated. Moreover, truncations of 10, 20, and 30 amino acids of the first 40 amino acids of the c-terminal tail yielded a significant decrease in ligand mediated receptor internalization implicating specific residues required for internalization to occur. These data support the significance of the HFRK like motif HVRR in stimulating cAMP. In summary, the study of the GnRH receptor binding from the ancestral lamprey can provide insight into the evolution of the binding properties of the GnRH receptor family. This was supported by NSF 0421923 to SAS.

7.4 ORR, T.J.*; WOLF, B.O.; Univ. of California, Riverside, Univ. of New Mexico; *teri.orr@email.ucr.edu*

Isotopes, Cacti and Mice: Exploration of Cactus Use by a Sonoran Desert Rodent Community Across Time.

Cacti such as the saguaro (*Carnegiea gigantea*) are considered keystone producers due to their production of energy and water rich flowers and fruit. These plants may be of particular importance to consumers during the hottest and driest periods of the annual cycle. Their role in the nutritional ecology of consumers is, however, known mostly from anecdotal observations. Saguaro production results in a pulse of nutrients during summer months, that is expected to be reflected in rodent tissues in the form of different Carbon signatures. We investigated the importance of cactus resources to the small mammal community using stable isotopes. Cacti use a CAM photosynthetic pathway that results in tissues with carbon isotope ratios that differ from most of the plant community, which perform C3 photosynthesis (CAM approximately δ13C = -13 , C3 approximately δ13C = -26 VPDB). Because an animal's diet is reflected in the isotopic composition of its tissues, we measured d13C of plasma and used a simple two-way mixing model to estimate the proportion of carbon derived from ingestion of cactus tissues. We also used Nitrogen 15 enrichment to assess trophic level differences among species. Hoarders such as *Dipodomys merriami* had isotope ratios consistent with C3 resources (δ13C between -25 and -23 VPDB) with little seasonal change. Herbivores such as *Neotoma albigula* consuming cactus stems had δ 13C between -18 and -13 VPDB. Several species (e.g. *Chaetodipus penicilatus* and *C. baileyii*) exhibited a dramatic increase in diet breadth during CAM fruit production (May-July). We discuss rodent community use of cacti over the period of one year at Organ Pipe Cactus National Monument.

48.3 OSTERBERG, J.S.*; ROMANO, J.; MCCLELLAN-GREEN, P.; Duke University Marine Lab, North Carolina State University, CMAST; *jso6@duke.edu*

Antioxidant defenses and stress biomarkers in molluscs from Lau and North Fiji Basin hydrothermal vents

Deep-sea hydrothermal vent environments are known to have extremely elevated heavy metal concentrations, especially those in the Lau Basin. How endemic organisms deal with this burden is not fully understood. Cellular mechanisms to defend against metal-induced oxidative stress include the oxyradical scavenging and metal transport tripeptide glutathione and the enzymes catalase and superoxide dismutase. Lipid peroxidation is used as a biomarker of oxidative stress. Activities of these two enzymes and levels of glutathione and lipid peroxidation were quantified spectrophotometrically in foot and endosymbiont-bearing gill tissue in gastropods of the genus *Alviniconcha* and mussels of the genus *Bathymodiolus* collected from deep-sea hydrothermal vents in the Lau and North Fiji Basins. Glutathione levels in the gastropod gills were consistently and significantly higher in the foot and similar for each site, and conversely glutathione levels in the mussel were similar in the two tissues but varied significantly among the sites. Catalase activity did not generally vary among sites in either mollusc but differed significantly between tissues in the mussel. Levels of cytosolic and mitochondrial superoxide dismutase were similar among sites and tissues but were significantly elevated in the foot tissues of both species at the White Lady vent site. Lipid peroxidation was strikingly and significantly elevated in the gills of both species at the White Lady vent site, but reduced in foot tissues at this site. These results suggest that different antioxidant defense mechanisms are prominent at different sites and in different tissues for these two molluscs and that the White Lady site is a stressful environment.

62.2 OSWALD, M.E.*; ROBISON, B.D.; University of Idaho; *oswa2750@uidaho.edu*

Behavioral syndromes and adaptation to captivity in the zebrafish, Danio rerio

Behavioral syndromes are defined as individual consistency in a suite of behaviors across multiple situations (e.g. being very bold regardless of whether predators are present or absent). The concept of behavioral syndromes has significant implications for behavioral evolution. In particular, behavioral adaptation to captivity (i.e. the process of domestication) may be effectively studied in the context of behavioral syndromes. In this study, we analyzed behavioral responses to varying levels of potentially threatening stimuli across four strains of zebrafish that varied in their domestication histories. We found significant variation among strains in their willingness to obtain food from the surface of the water (feeding latency) as well as in the degree of reaction to varying threat levels. In general, wild zebrafish were slower to begin feeding than domesticated zebrafish. Wild zebrafish were also more sensitive to potentially threatening stimuli and altered their feeding latency at a lower threshold of threat than laboratory strains. We observed significant correlations within strains, both among behaviors and within behaviors across situations. The exact pattern of correlations, however, varied by strain, a result seen previously in several other taxa. Our results suggest that behavioral syndromes do exist in zebrafish, and that these syndromes may be relevant during adaptation to captivity.

66.3 OTT, Brian D.*; SECOR, Stephen M.; The University of Alabama; *brian.d.ott@ua.edu*

Implications of meal type effects on specific dynamic action for optimal foraging

Specific dynamic action (SDA), the cost of meal digestion and assimilation, is proposed to be a large component of the energy budget of amphibians and reptiles. If SDA varies among different meal types, theories of optimal foraging would predict the preference for those meals with lower SDA, thereby more energy could be allocated to activities, growth, and reproduction. Therefore, we examined potential meal type effects on SDA for Burmese pythons (*Python molurus*) and green anacondas (*Eunectes murinus*) fed rat, bird, and alligator meals, and eastern garter snakes (*Thamnophis sirtalis*) fed mouse, minnow, frog, tadpole, earthworm, and beetle larvae meals (all meal mass 25% of snake mass). For Burmese pythons, rat and bird meals generated very similar SDA responses, whereas alligator meals produced a lower peak VO_2 and SDA, and a higher SDA coefficient (SDA as a % of ingested energy). For green anacondas, peak VO_2 did not vary among the three meals, bird meals generated a higher SDA, and the SDA coefficients were 19.5%, 25.1%, and 29.4%, respectively, for rat, bird, and alligator meals. For garter snakes, the beetle larvae meal generated a much lower postprandial peak VO2 (2.8-fold of resting metabolism), SDA, and SDA coefficient (9.5%), compared to the other five meals. Mouse meals resulted in the largest peak VO_2 (6.2-fold) and SDA, with tadpole meals producing the highest SDA coefficient (43%). Although alligators are less costly to digest, the advantage of the rat and bird meals for pythons and anacondas is the greater amount of ingested energy. Similarly for garter snakes, the less costly beetle larva and tadpole meals are relatively energy poor and the snake instead benefits energetically from consuming the more costly mouse and minnow meals. Optimal meal selection may more so reflect the tradeoffs between the costs and gains from a meal and meal availability.

14.1 OWERKOWICZ, T.; BLANK, J.M.; EME, J.; GWALTHNEY, J; HICKS, J.W.*; University of California, Irvine; *jhicks@uci.edu*

Removal of the right-to-left shunt affects cardiac dynamics in the American alligator

Cardiac shunting is present in all non-avian reptiles and many hypotheses have been proposed to explain why it has evolved. However, no study to-date has looked at the haemodynamic consequences of removing the ability to shunt blood on overall heart function. The morphology of the crocodilian heart, with completely separated ventricles, allows the right-to-left (R-L) shunting to be prevented by occluding the left aortic arch (LAo) at its base, proximal to the foramen of Panizza. In anaesthetized and artificially ventilated juvenile alligators, we measured blood flow and pressure in the pulmonary artery (PA), left aorta (LAo) and right ventricle (RV) before and after LAo occlusion. We used stimulation of the vagus nerve and breathholding to elicit shunting. We confirmed that right vagal stimulation leads to a pronounced bradycardia, whereas left vagal stimulation results in a smaller reduction in heart rate and a significant increase in pulmonary vascular resistance. Prior to occlusion, both vagal stimulation and breathholding resulted in a large reduction in mean PA flow and pressure and an increased forward flow in LAo, indicative of R-L shunt. Occlusion of the LAo resulted in a reduction of net LAo blood flow to zero, even during vagal stimulation. In addition, there was a transient increase in blood flow in PA. Following a stabilization period, vagal stimulation produced bradycardia, a significant rise in RV systolic pressure and reduction in PA blood flow and pressure. Reductions in PA flow and pressure were less than prior to LAo occlusion. The data suggest that the capacity for a R-L shunt acts to reduce cardiac work under conditions of increased parasympathetic tone. Supported by NSF IOB grant #04445680 to JWH.

71.3 OWERKOWICZ, T.; University of Adelaide, South Australia; *tomasz.owerkowicz@adelaide.edu.au*

Thyroid hormones increase rates of resting metabolism and skeletal growth in hatchling archosaurs

Palaeontologists suggest that bone microstructure of fossils can be used to infer whether an extinct animal was endo- or ectothermic. This is based on the assumption that resting metabolic rate (RMR) is a major determinant of bone growth in vertebrates. While endotherms show higher rates of bone formation and remodelling than similar-sized ectotherms, no experimental evidence exists to support this correlation. Thyroid hormones may provide a link between RMR and growth rate. Endotherms have higher plasma levels of free thyroid hormones (fT3, fT4) than ectotherms, and RMR is elevated in hyperthyroidism. Thyroid hormones are also known to accelerate bone formation and resorption, which underlie skeletal development. I tested this hypothesis by altering plasma fT3 and fT4 levels in hatchlings of the saltwater crocodile (Crocodylus porosus) and emu (Dromaius novaehollandiae). Experimental animals received daily doses of T3 and T4, and controls received saline. Normal thyroid gland activity was suppressed with methimazole in experimental emus. For 12 weeks, growth was monitored and animals were injected with fluorescent dyes to label new bone. Rates of oxygen consumption were measured with open-flow respirometry at the end of each experiment. Both RMR and growth rate were elevated by a combination of T3 and T4. Growth rate in crocodiles increased as plasma fT3 and fT4 levels rose, and the growth response was dose-dependent. Growth rate in emus slowed as plasma fT3 and fT4 levels decreased, but accelerated again with higher doses of T3 and T4. Faster-growing hatchlings formed new bone with higher vascular density than their slower-growing siblings. This suggests that both RMR and skeletal growth rate are dependent on plasma levels of thyroid hormones, and may explain why endotherms grow faster than ectotherms.

33.2 OYARZUN, FX*; BRAVO, MJ; University of Washington; *foyarzun@u.washington.edu*

Plasticity in Brooding Time of a Species with Alternative Reproductive Modes

Species with alternative reproductive modes are rare, but serve as excellent models to study reproductive tradeoffs without phylogenetic confounding factors. *Boccardia proboscidea* (Polychaeta: Spionidae) has two main reproductive modes: some females produce only planktotrophic larvae while others produce a mix of planktotrophic larvae, nurse eggs and adelphophagic larvae. Females actively care for the capsules with embryos and at some point take the decision of opening the capsules to hatch the larvae. The hatching time of the larvae may have important effects on the dispersal and survival of larvae and the population dynamics, especially in cases of a mixed reproductive mode with intracapsular sibling cannibalism. In addition, populations of *B. proboscidea* vary geographically in reproductive modes. The populations from the north of the Pacific coast of North America reproduce only with the mixed reproductive mode; populations from the south have both reproductive modes, that solely with planktotrophs and no cannibalism being the most common. The goal of the study was first to test, in common garden conditions, if the females from the northern and southern populations differ in number of capsules and in the nurse egg to larva ratios, then to test whether the timing of the decision of the mother to open the capsules is plastic and whether this response is different in females with different reproductive modes.

20.10 O\'BRIEN, S.*; BENTLEY, G. E.; TSUTSUI, K.; WINGFIELD, J. C.; Univ. of Washington, Seattle, Univ. of California, Berkeley, Hiroshima Univ., Higashi-Hiroshima; *sobrien@u.washington.edu*

Neuroendocrine regulation of breeding in white-crowned sparrows (Zonotrichia leucophrys)

Gonadotropin inhibitory hormone (GnIH) & Kisspeptin (KiSS) are two recently discovered hypothalamic neuropeptides found in a variety of vertebrates. In white-crowned sparrows (*Zonotrichia leucophrys*) (WCSP), GnIH rapidly inhibits plasma LH in castrates, as well as in intact, gonadotropin-releasing hormone-treated birds, and in free-living WCSP with naturally high plasma LH. In contrast, KiSS dose-dependently increases plasma LH in captive, cannulated WCSP. GnIH shows seasonal changes in neuronal attributes implying changes in storage and expression. Thus, we have evidence for potential roles for GnIH & KiSS in the timing of breeding. Subspecies of WCSP exhibit different lengths of breeding seasons. *Z. l. gambelii*, are arctic breeding birds that must precisely time the onset and cessation of breeding in order to maximize fitness in harsh arctic environments while *Z. l. nuttalli* are non-migrating sparrows that enjoy a longer breeding season on the coastal chaparral of northern California. *Z. l. pugetensis* is intermediate in breeding season length, and is expanding its range from coastal to high-altitude mountain sites. GnIH & KiSS peptides may play an important part in the regulation of these variable breeding seasons seen within these subspecies. Furthermore, studying subspecies with different breeding season lengths may illuminate which different ecological factors and reproductive mechanisms influence seasonal breeding.

46.2 O\'NEAL, D.M.*; REICHARD, D.G.; PAVLIS, K; KETTERSON, E.D.; Indiana University, Bloomington, Saint Mary\\\'s College of Maryland, University of Guelph; *daoneal@indiana.edu*

Does Testosterone Mediate Parental Care in Female Dark-eyed Juncos?

Hormonal manipulations allow us to create novel phenotypes in order to learn how existing phenotypes evolve and why they persist. In the male dark-eyed junco (*Junco hyemalis*), experimental elevation of testosterone (T) is known to decrease male parental care and offspring survival, but to result in higher overall fitness owing to higher mating success. To understand this surprising result and also to understand selective forces that influence variation in T in birds, we focused our attention on females. Previous studies in juncos demonstrated that elevated T in female juncos does not suppress female incubation behavior, suggesting that female parental behavior is insensitive to T. In this study we asked whether T might mediate parental care behaviors other than incubation. T levels in females were experimentally elevated to their spring maximum using subcutaneous implants. We videotaped free-living females at the nest and measured brooding behavior when the young were three days old and feeding behavior when the young were six days old. We also measured nest defense behavior by quantifying responses to a mounted predator placed near the nest. T-implanted females showed a significant reduction in the amount of time spent brooding when compared to controls. They did not differ from controls in the number of nestlings fed per hour or in overall provisioning rate. Interestingly, males mated to T-implanted females fed young significantly more than males mated to control females. With respect to nest defense, T-implanted females performed significantly more dives at the predator than control females but did not differ in other behaviors. We conclude that some aspects of female parental behavior are sensitive to T and others are not, and we consider the implications for the evolution of T-mediated characters in both sexes.

57.2 PACE, C. M.*; GIBB, A. C.; Northern Arizona University; *Cinnamon.Pace@nau.edu*

Effects of substrate on the terrestrial locomotion of the ropefish.

The ropefish, *Erpetoichthys calabaricus*, is an elongate polypterid that makes terrestrial excursions. Because ropefish rely on body-substrate interactions to produce forward thrust, the nature of the substrate likely affects locomotor efficacy. Ropefish were imaged (Redlake PCI 10005) moving across a moisture gradient of dry sand, moist sand, and wet sand substrates. Velocity and kinematics were quantified across all substrates. On all substrates the body was the propulsive organ and the pectoral fins played little or no role (in contrast to aquatic locomotion). During dry sand trials, sand adhered to the fish's slime layer, movement was discontinuous, and body movements were relatively uncoordinated. During wet sand trials there was little or no adhering of sand particles, movement was typically continuous, and movement was coordinated and sinusoidal. During the moist sand trials, which were intermediate in water content between the dry sand trials and wet sand trials, movement parameters were also intermediate between those of the dry sand and the wet sand trials. For example, the average velocity for the trials occurring across wet sand (0.81±.16 cm/s) was slightly faster than the average velocity for the trials occurring across moist sand (0.72 ± .38 cm/s), but both were faster than the average velocity of the trials occurring across dry sand (0.12 ± .03 cm/s). These results imply that substrate impacts terrestrial locomotion and that ropefish possibly require both a wet and somewhat non-yielding surface to effectively move on land. It is important to determine the effects of substrate on locomotion in order to both increase our understanding of the dynamic nature of movement and to better evaluate the methods by which we assess animal locomotion in the laboratory setting.

34.4 PADIAN, Kevin; University of California, Berkeley; *kpadian@berkeley.edu*

Lessons Learned from the Intelligent Design Trial

On December 20, 2005, Judge John E. Jones III ruled in a Harrisburg, Pennsylvania courtroom that intelligent design is not accepted as science by the scientific community and could not be taught as such in public school science classes. Several important lessons have emerged from this trial: 1. Whereas the ruling applies only to central Pennsylvania, it was not appealed and so is likely to have broad impact especially because the judge issued a highly detailed opinion in order that the whole process would not need to be repeated elsewhere. 2. The decision effectively nullified further public debate on whether or not intelligent design is science and therefore the Discovery Institute's claim to being a scientific endeavor. 3. The decision is not likely to curtail the activism of antievolutionists at the local level. Evolution will continue to be labeled controversial, and community pressures will ensure that it will continue not to be taught in most districts where it is already not taught. 4. The emphasis of the antievolutionists in the near future is likely to be on what they call critical thinking in other words, criticizing thinking that they don't like. A major focus of the educational community must now be on educating children about what critical thinking really is. 5. The American public accepts microevolution change within species but it understands little or nothing about the evidence for macroevolution how major evolutionary transitions have occurred. This is because macroevolution has never been sufficiently treated in American textbooks at any level. If scientists want the American public to understand the evidence for evolution, the textbooks must change, the state curricula must change, and scientists must be actively involved in this process in each individual state.

2.11 PAITZ, Ryan T.*; HEIDENREICH, Byron A.; BOWDEN, Rachel M.; Illinois State University, Illionis State University; *rpaitz@ilstu.edu*

Do yolk steroids influence sex in a species with temperature-dependent sex determination?

Maternally derived yolk steroids can affect numerous offspring phenotypes in oviparous species. Many studies in reptiles have demonstrated a critical role for steroids in sex determination, but whether or not steroids of maternal origin affect sex determination has yet to be clearly illustrated. If yolk steroids affect sex determination, their respective receptors must be present early in development. Several studies have detected sex specific steroid levels in the brain prior to their presence in the gonads, indicating that the brain may be important in the sex determination process. We characterized yolk steroid levels across development and preformed immunocytochemistry (ICC) in the brains of developing red-eared slider (*Trachemys scripta*) embryos to characterize estrogen receptor development. Clutches were incubated at either male (26°C) or female (31°C) producing temperatures and sampled every five days. Initial work conducted at a female producing temperature demonstrates that yolk steroid content declines dramatically prior to day 15 of development coincident with the presence of estrogen receptors in the brain. In this study we, compare the pattern of yolk steroid decline and estrogen receptor development in both sexes. Characterizing yolk steroid levels and steroid receptor patterns during development is critical in determining if maternally derived yolk steroids play a role in sex determination.

4.1 PALACIOS THEIL, E.*; GONZALEZ-ORTEGON, E.; GARCIA-RASO, E.; SCHUBART, C.D.; CUESTA, J.A.; Instituto de Ciencias Marinas de Andalucía, CSIC, Spain, Universidad de Málaga, Spain, Universität Regensburg, Germany; *emma_pt@yahoo.es*

Genetic population structure of the shrimp Atyaephrya desmarestii (Millet, 1831) in dependence of the distance to the sea

The freshwater shrimp *Atyaephyra desmarestii is present in rivers of Europe, North Africa and the Middle East up to Iran. In the Iberian Peninsula, the populations of the Atlantic rivers seem to occur relatively farther from the sea than the populations of the Mediterranean rivers. Furthermore, frequent occurrence of sudden rises in the level of the Mediterranean rivers may sweep individuals of A. desmarestii, larvae as well as adults, to the sea. This would facilitate their transport to other river basins and allow an increased gene flow between different populations, which a priori should have a high isolation level. The longer distance to the sea could thereby result in a higher degree of genetic structure in Atlantic populations of A. desmarestii compared with Mediterranean ones. In this study, information about the genetic population structure of A. desmarestii was obtained based on the mitochondrial genes 16S rRNA and COI. Populations from different river basins of the Iberian Peninsula were analyzed as well as populations of different tributaries to the same river basin. Data for 14 populations from five Atlantic and five Mediterranean river basins were obtained. These data were also compared with those from the populations of two German rivers. The obtained information allows the estimation of the genetic diversity of a population, and of the genetic distance between populations of rivers of the same and of different basins.*

34.2 PAPASANI, MR*; HALTERMAN, K; HILL, RA; University of Idaho; *papasani@uidaho.edu*

Defining the promoter region of a second insulin gene in zebrafish

A second insulin gene, *insb* has been identified and shown to be expressed in the pancreas, head and blastomeres during embryonic development of zebrafish. Towards understanding gene regulatory networks underlying *insb* mRNA expression, we have isolated and characterized the proximal promoter region of *insb*. We have conducted luciferase reporter assays to investigate the promoter activity of three different fragments of the 5'flanking region of *insb*, -668 (-668/+3), -373 (-373/+3), and -180 (-180/+3) relative to the transcription start site (+1). We have transfected two different cell lines: 1) zebrafish embryonic cell line (ZF4) that expresses *insb* mRNA, and 2) mouse pancreatic islet &beta-cell line (&betaTC3) containing the mammalian &beta-cell specific regulatory network. In transfected &betaTC3, the regions -668/+3 and -373 /+3 were strongly activated showing relative luciferase activity levels of 20.6581, 18.4248 respectively compared to baseline levels of the promoterless luciferase vector. In contrast, the activity levels of -180/+3 region were not above baseline levels. Data from transfected ZF4 cells were consistent with the &betaTC3 model as -668/+3 and -373/+3 showed relative luciferase activity levels of 2.9076, 2.1234 respectively and -180/+3 activity levels were below baseline. In &betaTC3, activity levels of -668/+3 and -373/+3 were similar (P>0.05). However in ZF4, -668/+3 showed an increase in promoter activity compared to -373/+3 (Pinsb.

S2-2.2 PASCOAL, Susana*; CARVALHO, Claúdia; RODRIGUEZ-LEóN, Joaquín; DELPHINI, Marie Claire ; DUPREZ, Delphine; THORSTEINSDóTTIR, Sólveig ; PALMEIRIM, Isabel; Life and Health Sciences Research Institute (ICVS), School of Health Sciences, University of Minho, Instituto Gulbenkian de Ciência, CNRS, Université Pierre et Marie Curie, Departamento de Biologia Animal, Faculdade de Ciências, Universidade de Lisboa; *spascoal@ecsaude.uminho.pt*

A cellular molecular clock is ticking during proximo-distal limb outgrowth

Temporal control can be considered the fourth dimension in embryonic development. The identification of the somitogenesis molecular clock brought new insight into how embryonic cells measure time. We provide the first evidence for a molecular clock operating during proximo-distal limb outgrowth and patterning, by showing that the expression of the somitogenesis clock component hairy2 cycles in autopod limb chondrogenic precursor cells with a 6 hour periodicity. We determined the time period required to form an autopod skeletal limb element and propose that an autopod limb skeletal element is formed by cells with n and n+1 hairy2 expression cycles. This work demonstrates that temporal control exerted by cyclic gene expression is not an exclusive property of the somitogenesis process, leading us to the exciting possibility that a molecular clock can be operating in many embryonic tissues with tissue-specific time periods, controlling the formation of various morphological units.

7.1 PAWAR, S.; University of Texas at Austin; *samraat@mail.utexas.edu*

The evolution and emergence of food-webs in fluctuating environments: diversity begets stability, or vice versa?

All natural food-webs are assembled and persist in environments that exert perturbations in energy input as well as living conditions. In this study, we focus on the effects of external stochasticity on food-web emergence, evolution, and persistence. To generate predictions about the effects of different kinds of fluctuations on food-web dynamics, we use a network-theoretic approach. The basic theoretical structure is a weighted, directed graph with nodes representing populations and edges the interactions between them. To consider the effects of environmental stochasticity realistically, we use observed patterns in environmental variables (such as climate) to motivate the models. The results provide insights into the effects of environmental uncertainty on dynamical and structural (topological) properties of food-webs, and indicate that extrinsic stochasticity can have counterintuitive effects. We elucidate the concept of the stochastic fitness of a food web, and show that selection on certain life-history parameters of component populations can result in the emergence of persistent food-webs that maximize this fitness. The end result is that given sufficient time for network evolution, dynamical properties such as stability and assembly rate, and topological features such as degree distributions and chain lengths can be expected to be consistently associated with the pattern of stochasticity in the external environment. We discuss the implications of these results for food-web theory, and evaluate some of the predictions with data from real-world webs along environmental gradients.

S7-1.2.1 PEARSON, K.G.*; MCVEA, D.A.; University of Alberta, Edmonton; *keir.pearson@ualberta.ca*

Short- and long-term adaptation of the motor pattern for walking

An obvious feature of animal locomotion is the ability to rapidly change motor patterns to adapt movements to a changing environment. Less obvious is the capacity to modify motor patterns to compensate for changes in body mechanics and to persistent changes in the environment. In this presentation we will describe recent investigations in our laboratory aimed at establishing the neuronal mechanisms underlying these forms of adaptation in the walking system of cat. The short-term adaptations we have examined are responses to unexpected changes in ground support and walking up and down steps of different slopes. In both situations significant changes occur in the level of activity in leg extensor muscles that function to compensate for changes in loading of the legs. Changes in extensor activity depend in part on the existence of positive feedback pathways from force-sensitive afferents to extensor motoneurons. The long-term adaptations we have examined include changes in response to weakening ankle extensor muscles and modifications in the swing phase of the hind legs to avoid an obstacle that contacts a hind paw during the swing phase. These perturbations result in persistent increases in the level of activity in ankle extensor and knee flexor muscles, respectively, with the latter depending on the environmental context in which the animal received the stimuli.

S1-3.3 PEATTIE, A M*; MAJIDI, C; CORDER, A B; FULL, R J; Univ. of California, Berkeley; *peattiea@socrates.berkeley.edu*

Similar Elastic Modulus of Setal Keratin for Two Species of Gecko

Typical bulk adhesives are characterized by soft, tacky materials with elastic moduli well below 1 MPa. Geckos possess subdigital adhesives composed mostly of β-keratin, a relatively stiff material. Biological adhesives like the geckos' have inspired empirical and modeling work that predicts even stiff materials can be effective adhesives if they take on a fibrillar structure. Models suggest that fibrillar adhesives benefit from increased stiffness by allowing higher packing density while avoiding clumping. The structure of β-keratin is highly conserved across birds and reptiles, suggesting that material properties of gecko setae should be constant, but this has yet to be established. Since elastic modulus for β-keratin has only been published for bird and reptile scales, we measured elastic (bending) modulus of setal keratin in two species of gecko. We used a resonance technique to perturb loaded setae and recorded the natural frequency of the setal stalk (eliminating the base and branched tips). Modeling the seta as a cylinder, we inferred the elastic modulus from the known length, radius and natural frequency. We found no significant difference ($p = 0.49$) in elastic modulus between *Gekko gecko* (1.57 GPa ± 0.061 SE; n=189) and *Ptyodactylus hasselquistii* (1.51 GPa ± 0.060 SE; n = 194). We observed no effect of relative humidity ($p = 0.93$) or temperature ($p = 0.23$) over the experimental range (15%-65% RH; 20-27°C), and setae did not show a consistent change in stiffness over time after being harvested. If the elastic modulus of setal keratin is conserved across species, it suggests a design constraint that must be compensated for structurally, and possibly explain the remarkable variation in gecko adhesive morphology.

20.4 PERFITO, N.*; UBUKA, T.; ZANN, R.A.; HAU, M.; BENTLEY, G.E.; Univ. of California, Berkeley, LaTrobe Univ., Melbourne, Australia, Princeton Univ., New Jersey; *nperfito@berkeley.edu*

Opportunism at work: regulation of the reproductive axis in wild populations of zebra finches.

Zebra finches *Taeniopygia guttata* are thought to maintain their reproductive systems in a near-ready state in order to respond quickly to environmental conditions favorable for breeding. This strategy differs markedly from that used by obligately photoperiodic species in which changing photoperiod is used as a cue to modulate gonadotropin-releasing hormone (GnRH) release and thus reproductive activation on a seasonal basis. The discovery of a novel RFamide neuropeptide, gonadotropin inhibitory hormone (GnIH), and its subsequent characterization in mammals, provides an exciting and completely new avenue for investigating reproductive systems. GnIH acts in opposition to GnRH in birds, inhibiting gonadotropin synthesis and release by the anterior pituitary gland in vitro and in vivo. The goal of the present study was to characterize immunoreactivity of GnIH and GnRH in zebra finches captured in the field under two very different environmental and breeding conditions: one from a seasonal population during springtime breeding conditions and another from a population in a more unpredictable habitat during non-breeding conditions and while experiencing drought. We expected from previous findings that ir-GnRH cell number and size would be similar between populations, but that ir-GnIH cells would be larger and more numerous in the non-breeding drought population. Differential regulation of these two important reproductive hormones might help to explain the physiological underpinnings of opportunism.

7.9 PEROTTI, Elizabeth A*; LINDBERG, David R; University of California, Berkeley; *marinelizard@berkeley.edu*

Does geologic history matter? The effects of substratum on rocky intertidal communities.

Rocky intertidal communities, which have been hotbeds for conceptual advances in community ecology, exist in a mosaic of rock substrates. Nowhere else in the world is this mosaic more pronounced than along the western edge of North America because of the geologic origins and tectonics of this region. The organisms living on these substrates have their own histories as well and have been interacting on various substrates with other organisms for different amounts of time. The Marin Headlands possesses abundant rock units of disparate origins in close proximity, providing a unique opportunity to directly test substrate effects on intertidal ecology. This study begins to 1) evaluate the relative importance of an important rock property-surface roughness-on local diversity and community structure in the rocky intertidal, 2) test how substrate type influences succession, structure, and diversity of communities of intertidal organisms, and 3) identify species-specific or clade-specific responses to substratum and substrate properties. Experimental plots in each of three adjacent rock types (i.e. chert, basalt, sandstone) included replicated control and cleared rock plots as well as three ferroconcrete plates of different roughness. Results suggest that surface roughness may not be the primary substrate property structuring intertidal communities. However, roughness seems to be important for some organisms such as certain barnacles and algae. Species composition and diversity also differ between sandstone and other rocks. Natural substrates supported different communities than artificial substrates. Resource managers and conservation biologists will be able to use information acquired through this study to implement more effective initiatives designed to protect these natural resources and evaluate the recovery of disturbed communities.

31.3 PETES, L.E.**; MENGE, B.A.; Oregon State University; *petesl@science.oregonstate.edu*

Carotenoids accumulated in intertidal mussels as a potential response to oxidative stress

Globally, marine invertebrates are under increasing stress due to steadily rising water and air temperatures. High temperatures and desiccation lead to oxidative stress, especially in the stressful high zone of the rocky intertidal. Carotenoid pigments can be used to defend organisms from tissue-damaging oxygen radicals. Monthly field surveys of mussel pigmentation were conducted at intertidal sites on the Oregon coast. *Mytilus californianus* from the high and low zones were dissected, and gonad coloration was assessed. At all sites and during all months, females from both zones had orange gonads; males in the high zone also had orange gonads, while males in the low zone had white or peach gonads. Carotenoid pigmentation was highest for individuals immediately prior to spawning. Spectrophotometry and HPLC analyses revealed that orange pigmentation was a result of high carotenoid content in gonadal tissue. Levels of superoxide dismutase (SOD) activity were quantified to determine if oxidative stress was occurring in the high-zone mussels. Since carotenoids are used to protect tissue from oxidative stress, it is possible that mussels in the high zone accumulate carotenoids in order to protect their gametes from oxidative damage.

44.4 PETSCHAUER, D.M.**; REYES, J.A.; KELLEY, K.M.; California State University, Long Beach; *drgnfly0602@aol.com*

Location-associated Differences in Sex Steroid Levels in Flatfish of the Santa Monica Bay, California Human-derived Sources?

Santa Monica Bay (SMB) is utilized extensively for both recreational and commercial purposes, and it receives input of treated wastewater from two of the larger wastewater treatment plants (WWTP) in the world, highlighting this marine bay as an at-risk area for potential human-derived impacts. Over the last few years, we have observed that flatfish sampled within SMB exhibit significantly higher circulating concentrations of 17beta-estradiol (E2) than do fish from other locations in the Southern California Bight. Therefore, this field-based endocrine study has aimed to determine whether elevated E2 levels in flatfish, particularly in males, are associated with their proximity to a significant WWTP outfall location within SMB, and whether environmental delivery of exogenous E2, from outfalls, may represent a possible mechanism underlying elevated E2 levels in wild fish. Data on E2, testosterone and 11-ketotestosterone levels will be presented for Pacific sanddab (*Citharicthys sordidus*), an important species from commercial and recreational standpoints, and on the hornyhead turbot (*Pleuronichthys verticalis*), a species emphasized in regional ocean monitoring programs, and these will be discussed with respect to the potential environmental factors involved. [Supported by Southern California Sea Grant Program NOAA#NA06OAR4170012].

51.4 PIERCE, S. K. **; CURTIS, N. E.; SCHWARTZ, J. A; MASSEY, S. E.; University of South Florida, Tampa; *pierce@cas.usf.edu*

Functional algal nuclear genes are present in a sea slug genome--horizontal gene transfer demonstrated.

The digestive cells of the sacoglossan sea slug, *Elysia chlorotica* (Gould), harbor intracellular, symbiotic chloroplasts captured from the alga, *Vaucheria litorea*, during feeding. Several chloroplast proteins, including some that are nuclear-encoded such as FCP, LHC 1 and LHC 2, are synthesized while the *V. litorea* plastids reside in the host cytoplasm, for as long as 9 months. Using PCR, we have identified the nucleotide sequences for *fcp*, *Lhcv 1* and *Lhvc 2* in genomic DNA and mRNA from adult slugs, and in genomic DNA from pre-hatched veliger larvae. These results show that the algal nuclear genes are present in the animal cell, are transcribed and are transmitted to the offspring. This is the first demonstration of the natural transfer of functional, inheritable genes between multicellular organisms. (Supported by NSF #IBN 0315227)

2.8 PIERCE, AL*; DICKEY, JT; SWANSON, P; DICKHOFF, WW; Univ Hawaii, Univ Washington, Nat Mar Fish Svc; *piercea@hawaii.edu*

Metabolic hormones directly regulate insulin-like growth factor-2 mRNA level in primary cultured salmon hepatocytes

Insulin-like growth factors (IGF-1 and IGF-2) stimulate growth and development of vertebrates. Both IGFs are expressed widely; however, circulating IGFs are produced by the liver. In mammals, IGF-1 stimulates postnatal growth, and is chiefly regulated by growth hormone (GH). IGF-2, in contrast, acts mainly during placental development, and is not regulated by GH or other metabolic hormones in adult mammals. IGF-2 appears to play a greater role in postembryonic growth regulation in fishes, insofar as it responds to GH and metabolic status. However, little is known about the hormonal regulation of hepatic IGF-2 production in non-mammalian vertebrates. We examined the regulation of IGF-2 mRNA level by metabolic hormones in primary cultured salmon hepatocytes. Insulin, the glucocorticoid agonist dexamethasone (dex), and GH increased, whereas glucagon and triiiodothyronine (T3) decreased IGF-2 mRNA levels. In concentration-response studies, insulin was stimulatory at the lowest concentration tested (10-9 M), dex at concentrations comparable to stressed circulating cortisol (10-8 M and above), and GH at physiological concentrations (2.5 x 10-10 M and above). The effects of insulin, dex, and T3 were additive with that of GH, whereas stimulation by GH was dominant over suppression by glucagon. These results show that IGF-2 is directly regulated by metabolic hormones in salmon hepatocytes, unlike IGF-1, which is regulated only by modulation of sensitivity to GH. Further, the strong regulation of IGF-2 by metabolic hormones in salmon hepatocytes suggests that hepatic IGF-2 has an important function in postembryonic fishes. (Supported by NRI Competitive Grants 2003-35206-13631, 2006-35206-16447 from the USDA CSREES)

S7-1.1.2 PIRTLE, T.J.*; SATTERLIE, R.A.; Abilene Christian University , Univ. North Carolina, Wilmington; *Thomas.Pirtle@acu.edu*

The Ionic Mechanism Underlying Postinhibitory Rebound in Clione limacina Swim Interneurons

Swimming locomotion in *Clione limacina* is produced by alternate dorsal-ventral flexions of its wing-like parapodia which are ultimately controlled by two groups of pedal interneurons that interact via reciprocal inhibition, forming a fairly simple central pattern generator (swim CPG). One cellular property that is important for rhythmic pattern generation is postinhibitory rebound. Serotonergic enhancement of postinhibitory rebound amplitude has been shown to participate in swim acceleration. Here we describe the ionic mechanisms underlying postinhibitory rebound in swim CPG interneurons. Single electrode voltage clamp and current clamp experiments reveal that both calcium and sodium conductances contribute to postinhibitory rebound in *Clione* swim interneurons.

S6-2.4 PITNICK, Scott*; BJORK, Adam; PATTARINI, James; Syracuse University; *sspitnic@syr.edu*

Complex male X female interactions and the evolution of ejaculate characterstics

Ejaculate-female interactions are poorly understood but are expected to be widespread, complex and to have important implications for differential male fertilization success, the evolution of polyandry and diversification resulting in reproductive isolation. We discuss and integrate research on (1) genetic compatibility and female remating, (2) the role of male X female interactions in sperm competition and (3) mechanisms by which sperm achieve competitive fertilization success to better understand the significance of ejaculate-female interactions. We then describe results from two experiments. In the first, using an outbred Drosophila melanogaster population exhibiting continuous genetic variation, we quantified sperm precedence across multiple sperm competition bouts. We show that both offensive and defensive sperm competitive ability are significantly repeatable only across matings involving the ejaculates of the same pair of males competing within the same female. These repeatabilities decrease when the rival male stays the same but the female changes, and they disappear when both the rival male and the female change. In the second, experimental evolution was used to manipulate known interacting components: sperm length and female sperm-storage organ length in order to reveal the mechanisms underlying this aspect of ejaculate-female interaction. Our results are discussed with a focus on the complex nature of sperm precedence and the maintenance of genetic variation in ejaculate characteristics.

45.5 PLACE, AJ; Northwestern Oklahoma State University; *ajplace@nwosu.edu*

Frequency of Rattle Use by Free-ranging Western Diamondback Rattlesnakes

The rattle system of rattlesnakes (Genera *Crotalus* and *Sistrurus*) is an adaptive suite of morphological, physiological, and behavioral characters. Previous studies have addressed the morphology and physiology of the rattle system. While previous studies have addressed proximate factors influencing rattle use, a more complete understanding of the adaptive value of the rattlesnake rattle requires a better understanding of the context and frequency in which the rattle in employed by free-ranging rattlesnakes. Data were collected from randomly encountered and radio-telemetered western diamondback rattlesnakes to assess the frequency and context in which the rattle was used. Twenty-five of 45 randomly encountered snakes rattled when approached. Coiled snakes were more likely to rattle than snakes moving. There was no association between rattling and sex. Seven radio tagged snakes were observed 140 times, five of which resulted in a rattle response. Moving radio-tagged snakes were more likely to rattle than coiled snakes. The results reported here are compared to previous reports for other species. A behavioral threshold model for the origin of the crotaline rattle is also introduced.

10.4 PLACHETZKI, David C.*; OAKLEY, Todd H.; Univ. of California, Santa Barbara; *plachetzki@umail.ucsb.edu*

New Insights on the Evolution of Metazoan Photoreceptors

Duplication and divergence models are commonly invoked as a means of explaining evolutionary processes. While these concepts are usually applied to the gene and species levels, here we examine their role in the evolution of cell types. Metazoan photoreceptor cells are grouped into either ciliary (C) or rhabdomeric (R) classes. One hypothesis for the evolution of these cell types is that they originated by duplication from a common ancestor prior to the evolution of Bilateria. Support for this hypothesis comes from reports of both C and R photoreceptors in various deuterostome and protostome phyla; however, molecular data from non-bilaterian animals have not been applied to the problem. The phylogeny of opsin proteins, G-protein coupled receptors (GPCRs), can be used to infer the evolutionary history of photoreceptors. Screens of genome trace data for opsin loci from the sponge *Reniera* and the cnidarians *Hydra magnipapillata* and *Nematostella vectensis* yielded three significant results. First, we uncovered multiple GPCRs in the sponge, but did not obtain any opsins. Although opsin gene loss in sponges is a distinct possibility, this absence is consistent with an origin of opsins after the origin of animals, but before the cnidarian/bilaterian split. Second, we obtained an opsin sequence from *Nematostella* that falls within the C-/R-opsin clade previously known only from bilaterian animals. This result suggests an emergence of both cell types at or before the ancestor of Cnidaria + Bilateria. Finally, we obtained clear support for a new class of opsin present in both *Hydra* and *Nematostella*. Expression appears confined to neuronal cell types in *Hydra*. These results suggest the possibility of a new type of animal photoreceptor that can be considered paralogous to C and R types, and may be unique to Cnidaria.

68.11 PODOLSKY, R.D.; College of Charleston, Grice Marine Lab; *podolskyr@cofc.edu*

Plasticity of embryo encapsulation and density in intertidal egg masses

Reproduction in intertidal habitats can expose offspring to variable and extreme physical conditions, particularly when embryos are contained in benthic clutches. The high density of embryos in clutches can exacerbate the negative effects of intertidal conditions, especially with regard to the supply of oxygen to embryos. For this reason, gel in clutches is thought to function in spacing embryos and reducing oxygen limitation. The opisthobranch mollusc *Melanochlamys diomedea* deposits gelatinous egg masses in shallow pools on soft-sediment tidal flats. Embryos are enclosed in small capsules, which are contained within a tube that spirals through the gel matrix. Comparisons from three populations of *M. diomedea* showed population differences in embryo densities, a pattern that is explained partly by differences in the number of embryos per capsule. These populations also experience differences in physical conditions that could lead to different degrees of oxygen limitation. In the laboratory, I manipulated temperature and oxygen conditions experienced by adults from a source population with almost exclusive single-embryo encapsulation (and, consequently, relatively low embryo densities). Under certain temperature-oxygen conditions, adults were induced to incorporate a greater number of multi-embryo capsules per egg mass (leading to higher embryo densities). Because adults produce relatively few large masses in a season, egg masses with greater embryo densities allow higher reproductive output. Adults of *M. diomedea* appear able to manipulate the density of embryos in response to ambient conditions. These preliminary results indicate that plastic responses by adults that alter risks for embryos can involve not only the location or timing of reproduction but also the design of brooding structures.

8.11 PONTZER, Herman*; RAICHLEN, David A.; LIEBERMAN, Daniel E.; Washington University, University of Arizona, Harvard University; *hpontzer@artsci.wustl.edu*

Is arm swing active or passive during human walking and running?

Humans habitually swing their arms in phase with the contralateral leg during walking and running. This arm motion is generally thought to counteract the torque about the body's vertical axis (i.e., yaw moment) that is generated by the legs as they swing with each step. Thus it has been argued that the motion of the arms is a tuned, habitual, active response that is critical for maintaining stability during human locomotion, especially running. In this study, we investigated whether arm swing is in fact an active behavior, or is instead a passive response that follows solely as a consequence of our anatomical design. Human subjects walked and ran on a treadmill under different arm- and leg-weighting conditions, and without armswing, while kinematic and surface EMG data were recorded. A modeling study was also performed to determine the inherent effect of leg swing on arm movement in a human-like biped. Results of both studies suggest that arm swing is largely a passive response, and is not entirely an active, tuned behavior. Arm swing may therefore be an emergent property of human bipedalism, with the arms acting largely as passive damping mechanisms that decrease whole-body yawing.

25.7 PORTER, ME*; KOOB, TJ; Univ. of California, Irvine, Univ. of South Florida; *porterm@uci.edu*

Structural properties of shark vertebrae: the functional contribution of mineral in mineralized cartilage

Mineral content is an important predictor of material properties in bone. Altering mineral content of bone can have dramatic effects on stiffness (the material's ability to resist compression) and strength (the maximum stress the material can withstand before failing). The mineral content of elasmobranch vertebral cartilage varies across species and this variation significantly impacts both stiffness and strength. We reported that relatively high mineral fractions were found in cartilaginous vertebrae with stiffness and strength values nearing those of trabecular bone. In this study, we manipulated mineral content in elasmobranch cartilage from a single species to determine the functional contribution of the mineral phase to the material properties of the vertebrae in compression. We examined the compressive properties of vertebrae with their full mineral component and those in various states of demineralization. Also, vertebrae were compressed using 4 different strain rates (1%, 5%, 10%, and 20% per second) to determine viscoelastic effects. We tested vertebrae from five *Mustelus californicus* (Carcharhiniformes: Triakidae), the grey smooth-hound. All animals were male and approximately 80 cm total length to control for potential ontogenetic changes in the pattern of vertebral mineralization. Mineral was removed from vertebrae using EDTA. After material tests were performed the mineral content was measured by ashing each vertebra. Completely removing the mineral from the cartilage decreased the stiffness from 500MPa to 50MPa and strength from 40MPa to 8MPa. Strain rate had a significant effect by increasing strength but not stiffness. These observations establish that mineral content governs both strength and stiffness of mineralized vertebral cartilage in this shark, and is ultimately responsible for the differing material properties in other shark species.

52.2 PRADA, Carlos*; SCHIZAS, Nikolaos; YOSHIOKA, Paul; University of Puerto Rico Mayaguez; *cprada@cima.uprm.edu*

GENETIC VARIATION AND PHENOTYPIC PLASTICITY OF THE GORGONIAN Plexaura flexuosa IN PUERTO RICO

Caribbean octocorals are relatively abundant and visually dominant in low relief hard ground habitats with preference for high water motion areas. As other Anthozoans, octocorals display a tremendous phenotypic plasticity. The common Caribbean gorgonian *Plexaura flexuosa* is found in many depths and habitats, showing high levels of morphological variation in colony, branch and sclerite size. Nested ANOVAs for each character showed significant differences (p75%) the colonies for each environment. Higher scores were found when colonies were assigned to either deep or shallow regardless the reef. *P. flexuosa* in shallow areas (17m) exposed to low water motion. Reciprocal transplants showed that variation in sclerite size between colonies in shallow and deep areas is due, in part, to ecophenotypic response to water motion. The sclerites of shallow water colonies became larger when transplanted to deeper water and vice versa. Neither of the two transplanted groups reached the average size of individuals originally found in each depth. AMOVA analysis of the mitochondrial *Msh* gene and the nuclear 18S/ITS region showed significant differences among the shallow and deep populations. The morphological variability among shallow and deep *P. flexuosa* is due to a combined effect of environmentally induced plasticity and genetic differentiation. The data suggest that *P. flexuosa* represents a complex of at least two cryptic taxa.

S1-1.2 PRATT, Marney C.; University of New England, Biddeford, ME; *mpratt6@une.edu*

A star on the rise: how temperature affects distribution and abundance of sea stars on the coast of Maine.

There are two species of sea stars in the genus *Asterias* that are common on the east coast of North America. The northern species, *A. rubens* (=*vulgaris*), has historically dominated the intertidal in Maine, but recent observations suggest that the southern species, *A. forbesi*, is beginning to dominate some sites. I am investigating the effects of temperature on these two species of sea stars to determine whether climate change may be affecting their distributions. Specifically, I measured growth, respiration, and feeding rates in these two species at a warm (18&degC) and cool (8&degC) temperature. While there is no difference in respiration rates between species within a temperature treatment, respiration is higher for both species at 18&degC than at 8&degC. Growth and feeding rates were similar between species at the cooler temperature, but *A. forbesi* grew significantly faster and ate more at the warmer temperature. Not only did *A. rubens* grow much slower and eat less at 18&degC, survival was also much lower at this temperature. While sea surface temperatures do not stay at 18&degC for months at a time in the local waters of Casco Bay, it is not an uncommon temperature in the summer. Thus, growth and survival is likely to be lower for *A. rubens* in the intertidal in the summer and this may allow the *A. forbesi* population to expand more than it was able to in the past when summer water temperatures were cooler. In addition, since the feeding rate of *A. forbesi* is higher in warmer temperatures, this important predator may have a stronger impact than *A. rubens* in shaping the rocky intertidal community during the summer months.

S7-2.1.1 PROCHAZKA, A.*; YAKOVENKO, S.; University of Alberta, Edmonton, University of Montreal, Montreal; *arthur.prochazka@ualberta.ca*

GENERAL PROPERTIES OF LOCOMOTOR CONTROL SYSTEMS

Complex tasks such as locomotion involve the neural integration of sensory input, spinal pattern generation and predictive control. The contributions of these mechanisms have recently been investigated with neuro-biomechanical models (Yakovenko et al. Biol Cybern 90: 146-155, 2004; Ekeberg and Pearson J Neurophysiol 94: 4256-4268, 2005). These studies produced the following conclusions regarding locomotor control. The control of phase durations by the locomotor CPG may rely on relatively simple biasing controls involving persistent inward currents. The centrally generated pattern can operate through the intrinsic force-generating properties of limb muscles and mechanical coupling between the limbs, to generate stable locomotion even in the face of small variations in terrain. Stretch reflexes provide some additional force adjustment and a limited means of changing speed and posture. Larger speed and terrain adjustments require higher-level control strategies similar to fuzzy logic control. Global rules based on sensory input are required for movement selection, predictions about upcoming movements and overall balance. We will discuss the following propositions regarding locomotor control: 1. Sensory input is generally multivariate, complex and noisy . 2. Motor actuators are nonlinear and difficult to model precisely. However, these nonlinearities seem to allow control strategies in biological systems that would be inappropriate or unstable in linear systems, e.g. positive force feedback. 3. There are numerous ways of performing a sensorimotor task successfully. 4. Combinations of control strategies (PID, finite state, fuzzy logic, global targets) are more likely to control complex systems successfully than single strategies.

33.1 PRZESLAWSKI, Rachel A; Stony Brook University; *rachel@bio.life.sunysb.edu*

Does spawning behaviour minimize exposure to environmental stressors for encapsulated embryos on rocky shores?

Organisms in intertidal environments are often exposed to a range of potential stressors. Whereas adults are able to seek shelter to avoid stress associated with low tides, embryos within egg masses are effectively sessile for the duration of their encapsulation. Here, I surveyed molluscan egg masses on two rocky shores in SE Australia over two years to test the hypothesis that eggs are deposited in order to minimize exposure to environmental stress. I predicted that egg masses are predominantly deposited in shaded habitats not prone to environmental extremes. Furthermore, I anticipated that egg masses deposited in habitats exposed to UVR, desiccation, and/or extremes in temperature and salinity will occur less frequently in these habitats during seasons of high environmental stress. Egg masses from 34 taxa were unambiguously identified, and only four of these spawned on rock platforms in full sun (*Bembicium nanum, Nerita atramentosa, Siphonaria zelandica* and *S. denticulata*). As anticipated, summer had the highest UVR index, water temperature, and air temperature as well as the lowest daytime tides. Univariate and multivariate analyses confirm that egg mass abundance was highest during this season with no change in egg mass size. Therefore, those species spawning on the upper surfaces of rocky reefs do not modify their spawning behaviour to confer protection to their encapsulated offspring by avoidance of physiologically stressful conditions, particularly UVR. Reasons for this potentially risky spawning behaviour may include food availability, juvenile or adult welfare, or response to predation.

70.6 QUARANTA, K.L.*; FERRY-GRAHAM, L.A.; Moss Landing Marine Laboratories; *kquaranta@mlml.calstate.edu*

Characterization of jaw mechanics and feeding kinematics among surfperch (Embiotocidae)

Morphological differences in feeding mechanisms are assumed to relate to differences in feeding mode and prey capture performance. Such differences are thought to explain how the Embiotocidae (Perciformes, Acanthopterygii) manage to co-exist in spite of tightly overlapping geographic ranges and habitats. Embioticids can possess one of several different feeding modes: browser-picker, crusher, and oral-winnower. We hypothesize those mechanical models such as the anterior jaws 4-bar linkage model can be used to interpret the differences in underlying morphology, tying anatomy to feeding mode and ultimately performance. Several specimens (n ~ 10) representing each of the 14 genera of Embiotocidae were examined using the concepts of lever mechanics to quantify the anterior jaw musculoskeletal system; these incorporated replicates from the same species sampled from distant locations in order to examine geographic variation in mechanics. Preserved specimens were dissected and the components of the anterior 4-bar linkage measured along with other morphological variables associated with feeding (e.g. gape, jaw protrusion, jaw levers, and muscle mass). A subset of these species was investigated using high-speed video (250 - 500 fps) in order to identify differences in prey capture performance with different feeding modes. This kinematic study further suggested that differences in the feeding mechanism directly relates to differences in feeding performance. KT's appear to be larger in winnowing species than in species that use other modes suggesting a higher efficiency of transfer of momentum to the maxilla and premaxilla in winnowers. Our findings support the notion that feeding morphology is in large part responsible for the embiotocids' ability to utilize different ecological niches and may indeed explain overall diversification within the family.

17.1 RAICHLEN, D.A.*; PONTZER, H.; SOCKOL, M.D.; University of Arizona, Washington University, University of California, Davis; *raichlen@email.arizona.edu*

The energetics of quadrupedal and bipedal locomotion in chimpanzees

For decades, researchers have worked to discover general principles governing the energetic costs of terrestrial locomotion. The Force Production Hypothesis satisfies many of the requirements of a general explanation. The muscle force produced to support body weight explains differences in the energetic costs of locomotion between organisms that differ in body size, between organisms of similar size yet with very different limb designs, and within an organism but between walking and running. In this study, we show that force production also explains the difference in cost within individuals using vastly different locomotor postures. Chimpanzees are able to walk and run both quadrupedally and bipedally, with bipedalism generally more energetically costly than quadrupedalism. We measured energy expenditures, kinematics and kinetics for a sample of three chimpanzees using both bipedal and quadrupedal locomotion. We estimated active muscle volumes for each gait using inverse dynamics and compared muscle volumes with energy expenditures. Differences in energy expenditure between bipedal and quadrupedal locomotion are well explained by differences in muscle force production and the amount of muscle volume activated, adding further support to this general explanation of locomotor costs in terrestrial organisms.

56.4 RAINCROW, J.R.*; GAO, L.Z.; AMEMIYA, C.; CHIU, C.H.; Rutgers University, VMRC, Seattle, Washington; *raincrow@biology.rutgers.edu*

Relaxed selective constraints on Hox clusters of ray-finned fishes: Patterns and frequencies of mobile DNA element insertions

Hox genes, which share sequence homology with the *Hom-C* genes of *Drosophila*, originated early in metazoan evolution and are distributed throughout the animal kingdom. *Hox* genes encode transcription factors that establish the body plan along the primary anterior-posterior axis (AP) extending from the mid-brain/hind-brain junction to the tail and the secondary proximo-distal (PD) axis of the limbs. Evidence to date suggests that jawed-vertebrates ancestrally possess four *Hox* clusters (A,B,C,D) and this condition is present in extant sharks, lobe-finned fishes, and basal ray-finned fishes. All derived ray-finned fishes (teleosts) examined to date possess at least seven *Hox* clusters. The *Hox* gene complex of chordates represents a highly constrained genetic system. *Hox* genes are organized in clusters (about 120 kilobases in humans) and do not exhibit gene duplications or re-arrangements. The nature of this constraint remains poorly understood. It is hypothesized that *Hox* cluster integrity is maintained largely due to the exclusion of mobile element insertions into *Hox* clusters. Mobile, or transposable elements, are prevalent in the genomes of animals and plants and are drivers of genome evolution. In this study, Repeat Masker (RM) was used to test for the presence of mobile elements (DNA transposons, autonomous retrotransposons, and nonautonomous retrotransposons) in *Hox* clusters of different jawed vertebrates.

18.1 RAMSAY, J.B.*; WILGA, C.D.; Univ. of Rhode Island; *jasonramsay@mail.uri.edu*

Hyoid mechanics and muscle function during feeding in white-spotted bamboo sharks, Chiloscyllium plagiosum.

The feeding apparatus in white-spotted bamboo sharks, *Chiloscyllium plagiosum* exhibits many characters associated with suction feeding such as labial cartilages to occlude the lateral portions of the gape and hypertrophied hypobranchial musculature to power hyoid depression against high negative pressures generated in the buccal cavity. The medial hyoidiomandibular ligament may assist in lower jaw depression by harnessing and amplifying force generated by the coracohyoideus (CH) and coracoarcualis (CA) and transferring it to the lower jaw to assist the coracomandibularis (CM) in generating posteroventral rotation of the mandible. Hyoid, upper and lower jaw kinematics and fascicle shortening in the CM and CH were quantified using high-speed video and sonomicrometry, while muscle activity and buccal pressure were recorded simultaneously. Peak active shortening of the CM occurs at ~50% of fast jaw opening, just after the onset of buccal pressure decrease, while peak gape occurs just prior to passive CM lengthening. The CH lengthens prior to shortening and hyoid depression. CH lengthening peaks midway through slow hyoid depression, while fast CH shortening peaks simultaneously with peak hyoid depression and jaw closure. Initial lengthening of the CH may be due to shortening of the more caudal in-series CA, thereby preloading the CH. Peak CM shortening, onset of CH shortening and depression of the hyoid occur simultaneously. Consequently, the CM initiates lower jaw depression while the CH and CA drive the jaw and hyoid to peak depression. The hyoidiomandibular ligament in *C. plagiosum*, also present in most orectolobiform species, appears to be a biomechanical link coupling lower jaw and hyoid depression that is convergent with the mandibulohyoid ligament in teleosts, the most derived bony fishes.

9.2 REDDING, Chrystal L.*; MEYERS, Jay J.; HERREL, Anthony; NISHIKAWA, Kiisa C.; Northern Arizona University, Tulane University, University of Antwerp, Belgium; *chrystal.redding@nau.edu*

The scaling of tongue projection in chameleons: morphology and kinematics

Within a year of hatching, chameleons can grow by up to two orders of magnitude in body mass. Rapid growth of the feeding mechanism means that bones, muscles and movements change as the chameleon grows. In this study, we investigated the structural and functional scaling of prey capture kinematics in the veiled chameleon, *Chamaeleo calyptratus*. Snout-vent length (SVL), jaw length, head width, and muscle lengths and masses were measured in order to identify patterns of growth. The chameleons used in this study varied in size from approximately 3 18 cm SVL (1-200 g). Feeding sequences of each chameleon (N= 12) were filmed at 250 frames per second with a high-speed digital camera. Timing of movement, velocity, and acceleration of the jaws, tongue and the hyolingual apparatus were quantified. The data were log transformed and graphed against log SVL. Results showed that lengths of external morphological variables grew with negative allometry. Muscle lengths and masses scaled isometrically with a few exceptions. Kinematic durations scaled with negative allometry. Distances and angles scaled with isometry, while velocities and accelerations scaled either with isometry or with positive allometry. These data suggest that head size of chameleons becomes smaller relative to SVL with growth, whereas velocities and accelerations of ballistic tongue projection are the same or faster relative to SVL in adults than in juveniles. This surprising result may be due in part to the isometry of many of the hyolingual muscles despite negative allometry of the hyoid. The involvement of elastic-energy storage and recovery also appears likely.

68.10 REICH, K.J.*; BJORNDAL, K.A.; MARTÍNEZ DEL RIO, C.; Univ. of Florida, Univ. of Wyoming; *kreich@zoo.ufl.edu*

Incorporation and Isotopic Spacing of ^{13}C and ^{15}N in a Rapidly Growing Ectotherm; Consequences of Growth and Tissue Type

Understanding the rate at which animals incorporate ^{13}C and ^{15}N isotopes from their diets and the factors that determine the magnitude of the difference in isotopic composition between the animal's diet and its tissues is necessary to interpret stable isotope data accurately when investigating animal diet, habitat use, and trophic level. Both rate of isotopic incorporation (turnover) and isotopic spacing values (discrimination) can be affected by size of the animal, tissue type, rate of growth of that tissue, and nutrient composition of the diet. We determined the contribution of growth and catabolic turnover to the rate of ^{13}C and ^{15}N incorporation into skin, scute, whole blood, red blood cells, and plasma solutes in two age classes of a rapidly growing ectotherm (loggerhead turtles, *Caretta caretta*). We found significant differences in C and N incorporation rates and isotopic spacing among tissues and between age classes. Due to the significant contribution of growth to the rate of isotopic incorporation, variation in rates among tissues was lower than reported in previous studies. The isotopic spacing of nitrogen ranged from 0.64 to 1.77 , lower than the conventional 3.4 . Our results demonstrate that in rapidly growing ectotherms 1) the magnitude and constancy of incorporation rates vary among tissues; 2) physiological and ontogenetic status of an animal influence incorporation rates; 3) variance in incorporation rates among tissues is reduced in organisms undergoing rapid growth; and 4) isotopic spacing differs among tissues and is influenced by growth and diet.

S1-1.14 REIDENBACH, M.A.*; KOEHL, M.A.R.; GENIN, A.; MONISMITH, S.G.; KOSEFF, J.R.; University of California, Berkeley, The Hebrew University of Jerusalem, Stanford University; *mattr@berkeley.edu*

The effects of coral morphology and ambient flow on mass transfer in coral communities

Water flow over benthic communities, such as coral reefs, controls many biologically important processes, including food capture by benthic organisms, uptake of dissolved nutrients, larval dispersal, and waste removal. How are these transfer processes affected by the physical flow environment and the morphology of the coral? The fine-scale dynamics of turbulent mixing and mass transport between a *Porites compressa* reef and the overlying water were studied in a laboratory flume where unidirectional currents could be compared to wave-dominated flows. The flow velocities and wave characteristics used in the flume were based on field measurements of water velocities above and within *P. compressa* reefs in Kaneohe Bay, HI. Turbulent shear and rates of mixing were measured using laser-Doppler anemometry, while planar laser-induced fluorescence was used to create a 2-dimensional map of the flux of dissolved materials from the reef. We found that wave action dramatically increased intermittent shear and mixing events, thus enhancing mass transfer rates up to three-fold over those in equivalent unidirectional currents. We also compared mass transfer rates of *P. compressa* to two other coral species with different branching structure: *Stylophora pistillata* and *Pocillopora verrucossa*. Mass transfer rates, which increased with flow velocity and with wave frequency, were lower in species with closely-spaced branches. Our results showed that the vertical mixing of the water within the reef and the boundary layer thickness along reef surfaces both affect the rate of transport between the reef and the overlying water.

3.9 REILLY, Christian; Reed College; *heron@reed.edu*

Sensory Ecology of Low-Light Vision in Kelp-Forest Rockfish (genus Sebastes).

An animal's ability to behave appropriately in response to the events in its environment depends on the ability of its sensory systems to detect those events. The absolute limits to low-light visual sensitivity are thought to be set by thermal noise arising in the rod photoreceptors and caused by temperature-induced rhodopsin isomerizations. I examined the low-light sensitivity of a group of kelp-forest fishes (genus *Sebastes*) using the electroretinogram (ERG) to determine whether low-light sensitivity of rockfish is significantly affected by environmental changes in temperature, and, if so, how changes in low-light sensitivity translate into changes in ecological interactions. I introduce a computational model of the submarine light environment used to assess the ecological significance of variations in retinal sensitivity. Changes in threshold sensitivity vary the length of time that environmental light levels are greater than measured retinal threshold (visaul activity window). The model predicts that local average seasonal temperature changes (~4 &deg C) have no significant affect on the visual activity window, but greater temperature changes, such as those associated with increasing sea-surface temperature trends (~10 &deg C), could significantly affect visual activity windows. Visual activity window durations are compared between diurnal species and nocturnal species, and the greater sensitivity measured in nocturnal species is found to translate into a 3-5 hour advantage in daily visual activity window over the diurnal congeners. In addition, local rockfish community diel activity patterns are predicted to be sensitive to potential increases in coastal light pollution.

24.2 REISENMAN, CE*; RIFFELL, JA; HILDEBRAND, JG; University of Arizona; *carolina@neurobio.arizona.edu*

Importance of odorant chirality in an insect-plant interaction

Olfaction plays decisive roles in moths for finding mates, food, and oviposition sites. Odor compounds differ in structural features, and the importance of enantiomers (mirror-image forms of a single chemical compound) is well established in olfaction. Depending on the receiver, some enantiomers might be discriminated while others might have similar representations. We investigated this issue from the perspectives of neurobiology, chemical ecology, and behavior in the sphinx moth *Manduca sexta*. By means of intracellular recording and staining, we found that certain female-specific neurons in the primary olfactory centers respond preferentially to the (+) enantiomer of linalool, a volatile compound commonly emitted by plants. We investigated the enantiomeric composition of linalool emitted by *Datura wrightii*, a preferred hostplant of *M. sexta*. The flowers of this plant, which are almost exclusively pollinated by adult *M. sexta*, emit scent comprising several odorants including linalool, which we found to be >99% (+) enantiomer. Vegetative plant structures emit only trace amounts of linalool. In preliminary behavioral experiments individual female moths were confined overnight in a flight cage containing two *D. wrightii* plants one bearing an odorless paper flower (control) and the other, a paper flower impregnated with a synthetic mixture of *D. wrightii* floral odorants. We counted the eggs on each plant the following morning. In one series of experiments the floral blend contained (+)linalool, while in the other series, we used (-) linalool. Plants with the floral blend containing (+) linalool were preferred over control plants, while plants with the (-) linalool blend were avoided. These results show that enantiomers are discriminated by the moth's olfactory system and may be important for sensory control of natural behavior.

S1-3.11 REVZEN, Shai*; BISHOP-MOSER, Joshua; SPENCE, Andrew; FULL, Robert/J; Univ. of California, Berkeley; *shrevz@berkeley.edu*

Testing Control Models In Rapid Running Insects Using Lateral Ground Translation

Perturbation of simple passive, dynamic models of legged locomotion suggest the possibility of self-stabilization with minimal neural feedback. Rapid recovery from brief impulses to the body of fast, sprawled-posture runners and the absence of muscle activation pattern changes while traversing rough terrain support the hypothesis of recovery by mechanical feedback alone. Large and complex perturbations to rapid running insects imposed by a single, hip-high hurdle do produce significant leg phase and frequency changes showing that sensory feedback must play a role in recovery. To better determine the interrelationship between neural and mechanical feedback, we designed a trackway with a 10 x 25 cm platform insert that could translate laterally to a maximum acceleration of 10g in 50 msec. Cockroaches (*Blaberus discoidalis*; n=14) running at 30±8 cm/sec at a step frequency of 11.5±2.7 Hz onto a movable platform were accelerated laterally at 1g in a 100 msec interval providing a 56±3 cm/sec specific impulse. By automatically tracking body position and orientation and leg (tarsus) positions, we found no change in leg motion timing for at least 50 msec. Following this delay, animals decreased step frequency for one stride, and then partially recovered frequency thereafter. Results are consistent with previous research showing that the initial rapid recovery is accomplished by mechanical feedback promoting self-stabilization followed by neural feedback modulation of a central pattern generator at a slower rate occurring after a delay comparable to the duration of a step. Funded by NSF FIBR Grant.

6.6 RHODES, S/E*; TURNER, R/L; Florida Institute of Technology; *rturner@fit.edu*

Salinity Tolerance and Osmotic Response of the Estuarine Hermit Crab Pagurus maclaughlinae in the Indian River Lagoon, Florida

Pagurus maclaughlinae is the most common hermit in the Indian River Lagoon. Wide variations in salinity make it likely that *P. maclaughlinae* is euryhaline and that other hermit species in the area are stenohaline, at least in some stages of their life histories. In a study of salinity tolerance, crabs were held unfed at salinities of 5–50‰ (25‰ control) for up to 30 d. Based on LT_{50}s, *P. maclaughlinae* tolerated acute exposure to salinities of 10–45‰ for up to 18 d, and survivorship up to 30 d at 20–45‰ equaled or exceeded survivorship of the control. In a study of acclimation, the osmotic pressure of hemolymph was measured after crabs were held in the laboratory for 12, 48, and 96 h acutely exposed to salinities of 10–45‰. Paired *t*-tests revealed that the crabs weakly hyperregulated their hemolymph at 45–154 mOsmol above the external medium at all salinities and sampling times. In a third study, acclimatization of hemolymph was studied on crabs at four field sites that differed in their recent salinity histories. Field-collected crabs weakly regulated their hemolymph 72–84 mOsmol above the external medium at all sites sampled. Performance did not differ by site. The broad range of salinity tolerance in this crab explains their wide distribution, and the consistent osmotic differential of its hemolymph indicates that the osmoregulatory ability of this species is conserved in populations throughout the lagoon. Although some other hermit species in the region are euryhaline as adults, their tendency to hyperregulate strongly at low salinities possibly adds an energetic burden that, along with their stenohaline larvae, excludes them from the lagoon. Salinity tolerance of larval *P. maclaughlinae* has yet to be studied.

15.4 RHYNE, Andrew L.*; SCHIZAS, Nikolaos V.; LIN, Junda; Florida Institute of Technology, University of Puerto Rico, Mayagüez Campus; *arhyne001@hotmail.com*

Larval settlement and population ecology of a newly described sponge dwelling peppermint shrimp, Lysmata pederseni

The shrimps of the genus *Lysmata* have been studied rather extensively. In the past *Lysmata* species have been roughly divided into two informal, non-taxonomic groupings: 1) cleaner shrimps , with bright and contrasting coloration, including yellow and red colors and long white antenna, and famous for their ability to actively clean fish (*L. amboinensis*, *L. grabhami*, *L. debelius*, and *L. splendida*); 2) peppermint shrimps , with color patterns consisting of semi-translucent bodies with longitudinal and lateral red bands (e.g. *L. wurdemanni*, *L. californica*, and *L. seticaudata*). Aquarists and biologists have also noted that most if not all *Lysmata* species display a reproductive system unique among the decapods, protandric simultaneous hermaphroditism. The presented research investigates larval settlement, habitat use and preference, density, and social interactions for a newly described sponge-associated species from the western Atlantic, *Lysmata pederseni*. Close examination of the life history of the species provides an exceptional opportunity to study a species, which morphologically, appears as a peppermint shrimp, but displays some of the socio-ethological characteristics of the cleaner shrimp sub-group (e.g., low density). The unique relationship between host and shrimp appears be the driving force for the evolution of this species' life history.

S6-2.3 RICE, William/R*; STEWART, Andrew/D; MORROW, Edward/H; KUIJPER, Braum; Univ. of California, Uppsala University, Uppsala University; *rice@lifesci.ucsb.edu*

Measuring the costs & benefits of receiving sperm in Drosophila melanogaster

Female D. melanogaster commonly mate again (remate) before they have used all sperm form a prior mating. We evaluated the costs and benefits of this phenomena in a series of three experiments. First we measured the cost to females (in the currency of lifetime fecundity) of being inseminated different numbers of times. Second we measured the need for rapid remating by assessing the survival of stored sperm. Lastly, we measured the consequences of multiple mating on patterns of sperm precedence. We found that i) the cost of remating was initially small but that it accelerated rapidly as the number of remating increased, survival of stored sperm was high, and iii) patterns sperm precedence were stable over multiple matings.

69.11 RICHARDS, Christopher T*; BIEWENER, Andrew A; Harvard University; *richards@fas.harvard.edu*

modeling time-varying fluid forces on an anuran foot to determine the power requirements of the ankle joint during swimming

During swimming, the anuran foot generates drag-based hydrodynamic power both by moving parallel to the direction of swimming (translation) and by pivoting about the ankle joint (rotation). Although translation and rotation are continuous throughout the propulsive stroke, these two components of foot motion are likely to be driven by two distinct groups of muscles. Proximal muscles extend the hip and knee joints to translate the foot whereas ankle extensors rotate the foot. Because drag-based hydrodynamic power is proportional to the square of the total velocity of the foot (the sum of translational and rotational velocity), ankle muscles must produce power to rotate the ankle joint in addition to generating instantaneous force to resist drag as proximal muscles translate the foot. We hypothesize, therefore, that the role of the ankle is twofold: (1) to produce hydrodynamic power by rotating the foot rapidly and (2) to produce large forces rapidly to control the orientation of the foot as it translates. Preliminary model results suggest that proximal joints (hip and knee) generate roughly 84% of the drag power through translation alone. These findings suggest that the principal role of the ankle joint in anuran swimming is not to generate hydrodynamic power, but to transmit power from proximal joints by rotating the foot, such that it is oriented perpendicular to the flow during rapid translation.

22.1 RICHARDSON, C.S.*; WIDMAIER, E.P.; MARSH, R.L.; KUNZ, T.H.; BOSTON UNIVERSITY, NORTHEASTERN UNIVERSITY, BOSTON; *crichard@bu.edu*

Macro vs. Micro-Geographic Variation in Metabolism and Hormone Correlates in the Big Brown Bat (Eptesicus fucus)

We examined basal metabolic rate (BMR) and plasma levels of thyroid hormone (T3) and leptin in the big brown bat, Eptesicus fuscus, from seven maternity colonies in Massachusetts (MA) (northern population) and two maternity colonies in Alabama (AL)/Georgia (GA) (southern population) in 1997 and 1998 to test the hypothesis that these traits vary geographically. After accounting for effects of body mass and stage of pregnancy and within-population variation, we found that bats from the northern population did not differ significantly from those in the southern population for BMR, T3 and leptin. For all traits, the test for differences among colonies from both populations was significant. For BMR, bats differed significantly within MA colonies, and bats from the AL colony had a significantly higher BMR than those from the GA colony. For T3 and leptin, bats from colonies in MA did not differ significantly, whereas bats from the AL colony had significantly higher T3 and lower leptin than those in the GA colony. Thus, for BMR, T3 and leptin, most or all of the variation among colonies cannot be explained by differences between populations (i.e., macro-geographic variation). The absence of any predicted population differences along a clinal (adaptive) direction rules out evolutionary adaptations of bats to different thermal environments as the primary reason for differences observed among colonies for BMR and its hormone correlates. However, the presence of among-colony and within-population variation (i.e., micro-geographic) for these traits suggests that environmental factors (acting recently) may play an important role in shaping the observed intraspecific variation in BMR and its hormone correlates.

24.3 RIFFELL, J.A.*; CHRISTENSEN, T.A.; HILDEBRAND, J.G.; Univ. of Arizona; *jeffr@neurobio.arizona.edu*

Encoding navigational flight behavior to odors in the antennal lobe of Manduca sexta

In insects, complex odor blends dictate behavior, where key odorants at specific ratios and concentrations are necessary for olfactory-mediated responses. Surprisingly, few studies have characterized and quantified the emissions of behaviorally critical plant odor blends that mediate insect behavior. As a result, studies in electrophysiology and behavior have not been realistically scaled to natural odor concentrations. To reach an improved understanding of the importance of odor blends in controlling behavior, and how the blends are encoded in the central nervous system compared to single odorants, we used the moth, *Manduca sexta*, and flower volatiles of its hostplant, *Datura wrightii*. Using a multidisciplinary approach by coupling volatile characterizations, behavioral wind tunnel experiments, and electrophysiology, we have been able to determine how complex blends, at natural concentrations, control flight behavior and are encoded in the antennal lobe (AL). By initially quantifying the complex floral-volatile emissions, we were able to realistically scale our odor concentrations and blend ratios used in behavioral and electrophysiological experiments. Through a combination of behavioral experiments and multi-unit recordings in the AL, we demonstrate the importance of certain odorant constituents in the blend that dictates *M. sexta* flight behavior. Moreover, by coupling multi-electrode recording with gas chromatography, we compared neural ensemble responses to single odorants in relation to the blend. Together, these results provide new evidence that in moths, upwind orientation to blends is mediated by the precise integration of multiple glomerular pathways, and that blend input transforms the network representations in a manner that is not predicted from responses to single odor compounds.

11.2 RILEY, JR., Larry/G.*; FOX, B./Kai; KAIYA, Hiroyuki; DAVIS, Lori/K.; DOROUGH, Casey/P.; HIRANO, Tetsuya; GRAU, E./Gordon; Calif. State Univ., Fresno, Univ. of Hawaii, National Cardiovascular Center Research Institute; *lriley@csufresno.edu*

Effect of Fasting on Ghrelin Receptors and NPY Expression in the Brain of Tilapia, Oreochromis mossambicus.

Evidence to date indicates that ghrelin is an important endocrine peptide that links the gastrointestinal system and brain in the regulation of food intake and energy expenditure. In human and rat, plasma levels as well as stomach expression of ghrelin are elevated in fasted animals, suggesting that ghrelin is a driving force behind the elevated plasma levels of GH during fasting. Ghrelin's orexigenic actions are mediated by the GHS-Rs (1a and 1b) which are localized on NPY neurons. NPY is the most potent appetite stimulant identified thus far. It is suggested that GHS-R1a is the bioactive ghrelin receptor. We have identified tissue distribution of both GHS-R1a and GHS-R1b in tilapia. Studies were undertaken to investigate the effect of fasting on the GH/IGF-I axis, ghrelin, as well as on GHS-R1a, GHS-R1b and NPY expression in the tilapia brain. Brain expression of GHS-R1a was significantly reduced after 1-6 days of fasting. By contrast, GHS-R1b expression was unaffected by fasting. NPY expression was significantly elevated on the second day of fasting but was significantly reduced by day 6 of fasting. One to three days of fasting significantly reduced plasma levels of IGF-I. Conversely, plasma GH levels were unaltered until day 4 of fasting, when a significant elevation was observed. These results illustrate that fasting differentially regulates the expression of GHS-R1a and GHS-R1b in the brain. The observed different temporal response of NPY mRNA to fasting suggests that acute fasting may instruct the animal to search for food, whereas chronic fasting inhibits the feeding center.

49.7 RITSON-WILLIAMS, R.*; PAUL, V.J.; Smithsonian Marine Station at Fort Pierce; *williams@sms.si.edu*

Larval Metamorphosis of Phestilla spp. in Response to Water Soluble Cues

In marine systems many invertebrates depend on their larvae for dispersal and to find the appropriate habitat for adult survival, yet the mechanisms of habitat choice remain poorly understood. In Hawaii, the nudibranch *Phestilla sibogae* only feeds on *Porites compressa* and is known to metamorphose in response to a water soluble cue from this coral. We tested four different *Phestilla* species to determine if their larvae metamorphosed in response to whole coral fragments or to water soluble compounds from coral fragments (coral water). In Guam, *Phestilla sibogae* metamorphosed at high rates to coral water from multiple species of *Porites* corals. *Phestilla melanobrachia* metamorphosed at similar rates to its prey *Tubastrea aurea* coral polyps and coral water. *Phestilla minor* could distinguish between *Porites* spp. coral water but also had high rates of metamorphosis in response to filtered seawater. *Phestilla* sp. 2, which feeds on some species of *Gonipora*, had high rates of metamorphosis in response to *Goniopora fruticosa* coral water. *Phestilla* sp. 2 could distinguish among different species of *Goniopora* and only had high rates of metamorphosis to coral waters made with its preferred prey. All of the *Phestilla* spp. tested recognized host coral waterborne cues and most of these species required them for metamorphosis.

13.4 RIVERA, Ajna S.*; OAKLEY, Todd H.; Univ of California, Santa Barbara; *arivera@lifesci.ucsb.edu*

Myodocopid ostracods (Crustacea) as models for studies of eye evolution

Ostracod crustaceans are a valuable group for studying evolutionary biology in general, and developmental constraints on evolution in particular. Contrary to previous ideas concerning eye evolution, myodocopid ostracods have evolved compound eyes independently from other arthropods. While this does not seem parsimonious, there are several mechanisms by which compound eyes could have evolved at least twice within the arthropods. One possibility is that of switchback evolution, wherein a latent developmental program is retained and re-emerges to produce a lost trait. A remnant of this may be seen in the presence of dramatic sexual dimorphism in eye morphology in certain myodocopid taxa. In these groups, males have large compound eyes with 20-30 ommatidia while females have only rudimentary eyes lacking ommatidia. If the developmental differences between males and females of these species can be understood, a testable mechanism for eye evolution in ostracods will emerge. To this end, we are constructing a phylogenetic tree using both molecular and morphological data for a group of myodocopids showing sexual dimorphism of some species, the Philomedidae. Using this tree, we will be performing a character analysis of the sexual dimorphism to test if it has evolved separately or is present in the ancestral Philomedidae. In parallel, we are testing various eye-development genes for differential expression in the larvae of male and female philomdedids for later testing on the resolved character analysis. In this way, by studying the evolution of myodocopid compound eyes, we will gain understanding of the ways in which evolutionary trajectories are constrained by history and development.

12.6 RIVERS, TJ*; MORIN, JG; Cornell University; *tjr28@cornell.edu*

Female response behavior to complex, intermittent luminescent male displays in a Caribbean ostracod.

Although bioluminescence is much more prevalent in marine environments than terrestrial ones, describing female response behavior in mating systems where males utilize distinct, species-specific luminescent courtship displays to attract females has been restricted to a few terrestrial species of fireflies. Male myodocopid ostracods (<2mm) utilize luminescence in the most unique and complex displays known to date in marine environments. We focus on a grassbed-flashing species, where males display upward into the water column in a display that can contain up to 19 flashes of light secreted into the water column. Previous attempts to observe female behavior have been confounded by displaying males in the same tank intercepting and trying (unsuccessfully) to copulate with the female before she can exhibit choice. Here, by using a light-emitting-diode array to mimic a male display and Infra-red (IR) cameras to record behavior, we give evidence that females are indeed responding to luminescence and approach a moving, intermittent luminescent signal in a way to intercept a signaling male. We hypothesize that luminescence is the primary signal to attract receptive females, and that secondary chemical cues may prove to be vital for the final homing in on a displaying male.

67.5 ROARK, A.M.**; BJORNDAL, K.A.; Univ. of Florida, Gainesville; *amroark@ufl.edu*

Food intake and its effects on life history in a parthenogenetic insect

Changes in food availability throughout an animal's lifetime can influence physiology and life history. In this study, we assessed the effects of various combinations of ad libitum and restricted intake on rates of growth and development and evaluated the life-history responses to these diets in Indian stick insects (*Carausius morosus*). Insects were fed leaf discs cut from English ivy on one of five treatment schedules: (1) ad libitum, (2) restricted (60% of mean ad libitum intake), (3) ad libitum until the beginning of the fifth instar followed by restricted feeding, (4) ad libitum until first oviposition followed by restricted feeding or (5) restricted until the beginning of the fifth instar followed by ad libitum feeding. Intake pattern affected both age and size at each life-history transition. Although food restriction early in life extended lifespan, this longevity enhancement did not allow for compensatory reproductive output. Egg output was maximized when daily intake was maximized throughout life. These findings suggest that the beneficial effects of early-onset food restriction on lifespan were negated by the detrimental effects on reproductive output. Conversely, late-onset food restriction negatively affected both longevity and reproductive output, with reproductive output more severely affected when a food restriction was imposed during development than when it was imposed during adulthood. The present study indicates that fluctuations in food availability can significantly influence life-history traits and that the magnitude of these effects depends on the developmental stage during which food availability changes.

32.2 ROBERT, K.A*; BRONIKOWSKI, A.M; Iowa State University; *krobert@iastate.edu*

Testing the "free radical theory of aging" hypothesis: physiological differences in long lived and short lived Colubrid snakes

We test the free radical theory of aging using 6 species of Colubrid snakes (numerous, widely distributed, non-venomous snakes of the family Colubridae) that exhibit long (>15 years) or short (<10 years) life spans. We measured whole animal metabolic rate (oxygen consumption V.O2), locomotor performance (as a measure of fitness and survival), cellular metabolic rate (mitochondrial oxygen consumption) and oxidative stress potential (hydrogen peroxide production by mitochondria). The general assumption is that species with shorter life spans grow quickly and reproduce at a younger age, therefore investing heavily into growth and reproduction and less into somatic maintenance, performance and survival, whereas longer lived species invest heavily in somatic maintenance, performance and survival and less into growth and reproduction, hence grow slower and reproduce later. We hypothesized that longer lived species will exhibit: reduced metabolic rates, increased physical performance (fitness/survival), and efficient mitochondria that produce reduced amounts of oxidants in comparison to short lived species. We found that longer lived Colubrid snakes have greater locomotor performance and reduced hydrogen peroxide production than short lived species, while whole animal metabolic rates and mitochondrial efficiency did not differ with lifespan. Whole animal metabolic rates do not support the rate of living theory model and do not correlate directly with longevity. However, our results support the free radical theory of aging and hence, the rate of living theory at the cellular level, to provide some explanation for the differences in lifespan among the species examined. We present the first measures testing the free radical theory of aging using reptilian species as a model organism.

64.1 ROBERTS, SP*; CRUDGINGTON, HS; SNOOK, RR; Univ of Nevada Las Vegas, Univ of Sheffield; *stephen.roberts@unlv.edu*

Experimental manipulation of sexual selection and the evolution of locomotor performance in Drosophila pseudoobscura

Sexual selection typically yields sexual dimorphism in traits related to mate competition and mate choice, and among such traits in highly motile species is locomotor performance. Here, we subjected the naturally promiscuous fruit fly *Drosophila pseudoobscura* to enforced monogamy, standard levels of promiscuity, and elevated opportunities for promiscuity in four replicate lines. After over twenty generations of these selective regimes, we tested whether experimental variation in the intensity of sexual selection led to evolutionary changes in walking speed and flight capacity (as determined by the ability to alter trajectory during free-fall). Contrary to expectations, walking speeds of males from the elevated promiscuity lines were slightly slower than those of males from standard promiscuity and enforced monogamy lines, while males from the promiscuity lines had poorer flight performance than males from the enforced monogamy lines. The largest effect in the study was a 22% decrease in the walking speed of females from the enforced monogamy lines relative to females from the standard promiscuity and elevated promiscuity lines. Female flight performance did not significantly vary among the selection lines. These results suggest that increased sexual selection and competition in male *D. pseudoobscura* in turn select for enhanced locomotor performance in females.

42.2 ROBERTS, T.J.*; HIGGINSON, B.K.; Brown University, Providence, RI, Oregon State University, Corvallis; *Thomas_Roberts@Brown.edu*

The versatile mechanical function of two proximal hindlimb muscles in running turkeys

The muscles that power running must be remarkably flexible in their mechanical function. For example, the muscular system performs almost no net mechanical work during level running, but it must perform net positive work to produce mechanical energy during uphill running and net negative work to absorb mechanical energy during downhill running. We used sonomicrometry and EMG to test the hypothesis that the strain pattern in active muscles reflects the demand for mechanical work. Wild turkeys ran on a treadmill inclined to +6° or +12°, and declined to -6° and -12°. Muscle length and activity were measured in the femorotibialis muscle (FT), a knee extensor, and the caudal head of iliotibialis lateralis (ILPO), a knee and hip extensor. Both muscles were active during stance, and underwent cyclic stretch-shorten cycles. The amount of muscle shortening and lengthening during stance changed in demand for mechanical work at different treadmill inclines. Shortening strain increased with increases in running slope, from 0.078 ± 0.035 at -12° to 0.30 ± 0.038 at +12° for the ILPO, and lengthening strain decreased with running slope, from 0.156 ± 0.032 at -12° to 0.042±.025 at +12° for the ILPO. In contrast to the significant variation in strain with running incline, there was little change in strain of the ILPO or FT across the range of running speeds studied. Unlike changes in running slope, increases in running speed are not associated with a change in the demand for net mechanical work. Thus, the observed pattern of muscle strain with slope and speed in these muscles is consistent with the hypothesis that muscle length changes during running are modulated in response to the demand for mechanical work. Supported by NIH grant AR46499.

62.4 ROBISON, B.D.*; DREW, R.E.; SETTLES, M.; CHURCHILL, E.; MORETZ, J.; MARTINS, E.P.; University of Idaho, Indiana University; *brobison@uidaho.edu*

Variation in gene expression among the brains of behaviorally distinct zebrafish strains: no evidence for parallel transcriptome evolution during domestication.

Fearfulness and anxiety are often reduced in animals that have undergone prolonged bouts of captivity. This pattern is repeatedly observed across vertebrate taxa, strongly suggesting that the evolution of reduced fearfulness during domestication is an example of parallel evolution. However, it remains unclear whether these parallel patterns of behavioral evolution at the phenotypic level reflect common patterns of molecular evolution. We examined four behaviorally distinct zebrafish strains, two recently derived from wild populations and two from highly domesticated laboratory populations. The strains showed a dichotomy of behavior for several measures of fearfulness, with the wild strains exhibiting more fear-like behavior than the domesticated strains. In contrast, aggressive behaviors did not show patterns of parallel evolution during domestication, although there were significant differences among the strains. We then used Affymetrix microarrays to examine the patterns of brain gene expression in the four strains to test the hypothesis that convergent patterns of gene expression underlie convergent patterns of fear-like behaviors. Overall, 1316 genes showed significant variation in expression among strains (i.e. showed a significant main effect of strain), and many differentially expressed genes were candidate genes influencing behavior in other model species. However, only a small fraction of the genes (37) were differentially expressed between wild and domesticated strains, indicating the potential for different molecular mechanisms underlying parallel evolution of behavioral phenotypes.

17.4 ROLIAN, Campbell*; LIEBERMAN, Daniel E.; SCOTT, John W.; Harvard University, Vanderbilt University; *rolian@fas.harvard.edu*

Why are our toes so tiny? Walking, running and the evolution of a short forefoot in the genus Homo

Humans have an extremely short forefoot relative to total foot length. The derived pedal proportions of humans are thought to have evolved in the context of committed bipedalism, but the benefits of shorter toes for walking and/or running have not previously been tested. Short toes are typically associated with cursorial digitigrade mammals, where they improve the ability of the digital flexor apparatus - the muscles, tendons and ligaments that collectively flex and resist extension of the metatarsophalangeal (MTP) joints - to support the body and generate propulsion at the end of stance. We tested the hypothesis that in humans a shorter forefoot similarly improves locomotor performance by decreasing the force, power and work outputs of the digital flexor apparatus (DFA) during late stance, especially in running, when only one foot provides support and propulsion against high ground reaction forces. Kinematic, force and plantar pressure data were collected from a sample representing normal variation in toe length (n=12). Hindlimb kinematics, DFA force, power and work outputs were compared during barefoot walking and running in subjects with short, average and long forefeet in relation to body mass. Results suggest that individuals with relatively longer forefeet experience higher MTP joint moments, and their DFA generates more force, power and work than subjects with shorter forefeet, at both walking and running speeds. Contrary to our prediction, however, the difference between groups in DFA performance is not greater at running speeds. Implications for the evolution of endurance running in the genus *Homo* are discussed

4.6 ROMANO, J.*; HOLM, E.; MCCLELLAN-GREEN, P.; RITTSCHOF, D.; Duke University Marine Laboratory, Carderock Division, Naval Surface Warfare Center, North Carolina State University; *jar21@duke.edu*

Population- and family-level variability in toxicity of copper pyrithione to the barnacle, Balanus amphitrite

Experiments were conducted to assess variation in mortality of the barnacle *Balanus amphitrite* exposed to the antifouling booster biocide copper pyrithione (CuPT), among and within populations. The first experiment compared the sensitivity of stage II nauplii to CuPT for barnacles from four different sites along the Newport River estuary, NC. Sites were chosen to provide a gradient in levels of industrial and residential pollutants. The lethal concentration to kill 50% of larvae (LC_{50}) was evaluated by exposing larvae to various concentrations of CuPT, dimethylsulfoxide (DMSO, solvent control), and filtered seawater (FSW, negative control). LC_{50}) varied significantly among the four sites, ranging from 4.0 to 6.1 &microg L^{-1}. In the second experiment, variation within a population of *Balanus amphitrite* with respect to CuPT sensitivity was examined. Stage II nauplii from fifteen barnacle families were exposed to 6.1 &microg L^{-1} CuPT. Mortality varied significantly among the families ranging from 15.0% to 98.9%. This observed variability suggests there may be genetic diversity within and among barnacle populations with respect to tolerance of toxic stress. We discuss several possible mechanisms. The data suggest that extrapolating a general result (for example, a water quality standard) from tests on laboratory populations or particular field populations may result in conclusions that are too liberal or too conservative (as populations vary greatly in their susceptibility). A substantial number of individuals and populations must be sampled in the course of conducting toxicity tests in order to obtain results that are broadly applicable.

69.3 ROS, Ivo G.*; BIEWENER, Andrew A.; University of Groningen, Harvard University; *ivo.ros@gmail.com*

Kinematics and muscle patterns during level turns in pigeons

Theoretically, maneuvering techniques in flapping flight can be far more variable than those of fixed wing fliers. To extend the current understanding of aerial turning, low speed 90 degrees horizontal turns of *Columba livia* are investigated. The length changes and activation patterns were recorded *in vivo* in the pectoralis pars sterno- and thoracobrachialis, biceps brachii, humerotriceps and extensor metacarpi muscles together with whole body kinematics, to gain insight in the dynamics involved. Special attention is paid to the mechanisms by which the rock pigeons change their center of mass trajectory and their orientation. It appears that the turns are executed using banking to redirect the resultant aerodynamic force. Mechanisms to incur the roll required for banking are contralateral asymmetries in aerodynamic forces, in added mass and in angular momentum. Pitch and roll appear to be coupled. Maneuvering with flapping wings thus is more variable indeed compared to flight where lift and thrust production are decoupled.

65.11 ROSA, R/A*; SEIBEL, B/A; University of Rhode Island; *rrosa@etal.uri.edu*

Effect of high CO2 on the metabolism of jumbo squid Dosidicus gigas

The absorption of atmospheric CO2 causes ocean acidification, i.e., decreasing pH. Since the effects of environmentally relevant pH reduction on the marine biota are still poorly understood, here we investigate the impact of short-term exposure (up to 24 hours) of juvenile squid, *Dosidicus gigas* , to elevated CO2 levels (0.1%). This species show diurnal migrations, spending the daytime in deep, cold and oxygen-depleted water (oxygen minimum layer; -10 °C at around 300 m) and migrates at night to shallow, warm (up to 30 ºC) and aerated surface waters (where the specimen collection took place). Standard (SMR; between 4 and 21 &micromol h-1 g-1), routine (RMR, between 5 and 26 &micromol h-1 g-1) and active (AMR; between 7 and 38 &micromol h-1 g-1) metabolic rates showed a steady decrease of approximately 10-25% with high CO2 levels. The lowering of squid's metabolism was also evident with the reduction of number of intervals of elevated activity per hour (n h-1), the scope for activity (RMR-SMR) and the % SMR of total RMR. Blood oxygen binding experiments in other ommastrephid squids also demonstrated lowered blood oxygen binding capacity caused by elevated CO2 and on-going enzymatic analysis of octopine production may show the eventual switch to anaerobic energy production under these conditions. Therefore, elevated environmental carbon dioxide and the consequent acidification seemed to significantly interfere with this squid's respiratory physiology, which may have cascading and long-term impacts on its ecology.

47.8 ROSS, C.R.**; PAUL, V.J.; Smithsonian Marine Station at Ft. Pierce; *ross@sms.si.edu*

Signal Transduction in the Cyanobacteria Lyngbya confervoides and L. polychroa: Ecological Implications of Reactive Oxygen Species

The ecological significance of reactive oxygen species (ROS) and the emerging role of reactive nitrogen species (RNS) as defense response compounds as well as signal transduction agents in higher plant physiology have been well documented. While substantial chemical and enzymatic responses are known to be affected by ROS, the biochemical mechanisms of ROS/RNS production in marine cyanobacteria remain elusive. Furthermore, the ecological implications of ROS/RNS production have not been identified. Specimens of *L. confervoides* and *L. polychroa* responded to mechanical injury, changes in seawater osmolarity, and UV irradiation with a transient release of hydrogen peroxide and nitric oxide. By use of selected pharmacological probes, our results indicate that H_2O_2 production was based on the initial activation of an NADPH oxidase complex as demonstrated by pharmacological inhibition. The exogenous addition of millimolar concentrations of H_2O_2 promoted programmed cell death. The production and putative signaling roles of ROS/RNS will be discussed with emphasis on the ecology of marine cyanobacteria.

S9-2.2 ROSS, C.F.*; ECKHARDT, A.; HERREL, A.; METZGER, K.; SCHAERLAEKEN, V.; WASHINGTON, R.; WILLIAMS, H.; University of Chicago, University of Antwerp, Brown University, University of Antwerp, Ohio University; *rossc@uchicago.edu*

The evolution of modulation of amniote chewing

Mammalian mastication is a highly coordinated, highly modulated behavior. Determining which modulatory systems were in place prior to the evolution of mammalian mastication and which may have been key innovations is vital for understanding how this complex functional system evolved. Mammals are distinguished from most other vertebrates in having sensory afferents from the periodontal ligament and gamma motor neurons to the muscle spindles, both of which are implicated in feed-forward control of mastication. We hypothesize that mammals are unique in their ability to use feed-forward control of bite force and muscle activity during mastication, and that this feed-forward control made possible rhythmic, regular chewing. The hypothesis that mammals exhibit more rhythmic, regular chewing behavior than lepidosaurs was evaluated using data on variation in cycle length from the literature and from our own in vivo studies of EMG, bone strain and/or kinematics. Comparisons between 44 species of mammals and 9 species of lepidosaurs from a range of body sizes and eating a variety of foods suggest that mammals chew with less variable cycle lengths than most lepidosaurs. Mammals (n=61 species) also exhibit size-related changes (i.e., scaling) of cycle length, and shorter cycle lengths than lizards (n=22 species) of equivalent mandible lengths. The origin of periodontal afferents and fusimotor control of muscle spindle sensitivity in stem mammals was a key innovation in the evolution of mammalian mastication. It facilitated feed-forward, or anticipatory, control of jaw movements, allowing rhythmic, regular chewing behavior. This is hypothesized to have increased the rate of intra-oral food processing, fueling the elevated metabolic rates characteristic of mammals.

63.2 ROUSE, G.W.*; WORSAAE, K.; GOFFREDI, S.K.; VRIJENHOEK, R.C.; Scripps Institution of Oceanography, Zoological Museum, Copenhagen, California Institute of Technology, Monterey Bay Aquarium and Research Institute; *grouse@ucsd.edu*

The dwarf males of Osedax (Siboglinidae, Annelida).

All *Osedax* spp. discovered to date in Monterey canyon show marked sexual dimorphism, unlike all other siboglinids. Osedax males are found living in the lumen of the gelatinous tubes inhabited by the much larger females. The males appear to be arrested larval forms and are filled with all stages of spermiogenesis, with mature sperm accumulating in an anterior duct that opens the surface of the head. We have studied the anatomy of the males using light, confocal laser scanning and electron microscopy. Larval features appear to be the retention of an anterior ciliary ring (prototroch), two chaetae-bearing segments posteriorly, a typical annelid larval nervous system and the presence of yolk. The sperm structure is very similar to that of other siboglinids such as *Riftia* and *Siboglinum*, but there is no evidence of sperm being packaged as spermatozeugmata, or in spermatophores. The chaetae are long-handled hooks with curved teeth that are opposed in some cases, as seen in other siboglinids. There is no sign of the development of a gut, or any features typically seen in females such as the four anterior palps. Bacteria are present on the surface of males but there are no internal bacteria as seen in females. We present data showing the gradual accumulation of males by females as they grow and discuss the evolution of this life history.

S9-2.1 RUBEGA, M.A.; University of Connecticut; *margaret.rubega@uconn.edu*

Feeding mechanisms in birds

The most striking feature of avian feeding is the enormous degree of diversity, and the relative speed with which it evolved. The rapid evolution of the Neornithes, and the resultant (and persistant) difficulty of resolving the phylogenetic relationships among the extant clades of birds makes resolving evolutionary patterns of diversification in avian feeding mechanisms similarly difficult, but a few major themes emerge. Although tooth loss or reduction is widespread in vertebrates, birds are one of only two vertebrate lineages (turtles are the other) to exhibit total tooth loss; no extant species of bird possesses teeth. In both cases (birds and turtles) tooth loss is coupled with the covering of the jaws with a keratinaceous beak. However, birds differ in exhibiting dramatic diversification in the form of the jaws and beak, which is in turn associated with diversification in prey, the medium in which prey are taken, and the mechanics of prey capture. This diversification in birds may be attributable to the coupling of flight with the acquisition of a toothless beak. Convergence on similar morphology when similar prey are taken appears widespread (e.g., insectivory appears to have evolved repeatedly, accompanied by similar approaches to capture and similar jaw shapes), yet divergent morphological and mechanical solutions to the same problem are also common (e.g., piscivores differ substantially in mechanisms of prey capture and morphology). Compared to most other major vertebrate groups, there are still some very significant gaps in our understanding of the mechanics of feeding. For instance, direct observations of the use of the tongue during feeding by birds are limited to a very few species. Our understanding of the evolution of feeding morphology and mechanisms in birds would be greatly improved by resolution of the higher-level phylogenetic relationships among modern birds and more phylogenetically-directed sampling of study taxa.

S8-1.7 RUCKSTUHL, KE; University of Calgary; *kruckstu@ucalgary.ca*

Sexual segregation in ungulates: proximate and ultimate causes

The even-toed ungulates are the most successful group of large herbivores, being native to almost every continent, and inhabiting all latitudes and altitudes. In most social ungulate species, males and females live in separate groups outside the breeding season, sometimes using different home ranges and habitat types. In most of these species males are larger in body size than females. This dimorphism in body size can lead to sexual differences in ecology and behaviour making it difficult for the two sexes to stay in the same group. It is important for our better understanding of the evolution of sociality to find out why sexual segregation (by habitat or socially) is so widespread not only in ungulates but also in other mammals. Sexual segregation has important implication for management and conservation and might be the key to understand differences in mating systems between species. I will discuss the ecology of the two sexes by reviewing our current understanding of the proximate and ultimate causes of sexual segregation- comparing a range of species within ruminants and hindgut fermenters. Finally, by looking at the degrees of sexual size dimorphism in different species we'll be able to make predictions on the degree of sexual segregation to be found.

71.1 RUSSELL, GA*; HAMMOND, KA; Univ. of California, Riverside; Univ. of California White Mountain Research Station, Univ. of California, Riverside; *gruss001@student.ucr.edu*

Does growth rate differ across altitudes in deer mice?

When faced with a hypoxic challenge (e.g. high altitude), young growing mammals may respond by using energy that otherwise would have been allocated to growth. For example, an organism may accelerate growth of those organs or organ systems involved with oxygen acquisition at the cost of decreased whole animal growth rate or individual organ size. Alternatively, growth rate or adult size may not be compromised at high altitude. To investigate whether growth rate is different between low and high altitude, we measured body mass, snout-rump length (SR), and hindfoot length (HF) from 3-42 days of age in two groups of deer mice (*Peromyscus maniculatus*): the first group underwent gestation and growth at elevation 340 m (low-born, LB); the second developed at 3800 m (high-born, HB). We fitted each character to a Gompertz growth curve and compared overall curve shape by entering the coefficients into an ANCOVA, using litter size, parity, and family as covariates. Curve shape for SR differed between natal altitudes; the upper asymptote was higher and initial length was higher in LB mice. Curve shape for body mass also differed between natal altitudes: the upper asymptote was higher and the slope of the curve was steeper in LB mice. The absence of curve shape differences for HF may be because it is already ~50% of adult size at our first measurement, which results in less differentiation in later measurements. By contrast, SR and mass are

57.3 RUSSELL, A. P.*; JOHNSON, M. K.; Univ. of Calgary; *arussell@ucalgary.ca*

Natural substratum topography and its relation to the prolific adhesive capacity of geckos

Many taxa of gekkonid lizards have subdigital pads bearing fields of adhesive setae that allow them to bond to and climb on a wide variety of surfaces in any orientation. Measurements of the maximal adhesive force that can be produced by individual setae and, in turn, by entire setal fields exceed the force necessary to support the body mass of these animals by as much as several thousand times. This enormous safety margin may be related to the types of surfaces that have been employed in studies where the adhesive capacity has been measured. Such studies have used primarily smooth or microscopically rough surfaces; however, the natural substrata of geckos may be very rough, undulant and unpredictable. On natural surfaces the adhesive system may be limited to very small patches of contact, and on any given footfall the actual adhesive contact made is likely to be very modest. Here we evaluate the microtopography of rock surfaces used by a southern African species of gecko of the genus *Rhoptropus*, and compare this to the form, configuration, compliance and functional morphology of its setal fields. *Rhoptropus* is diurnal, clawless and rock-dwelling, making it an appropriate subject for initial observations of the relationship between substrate microtopography and setal field morphology. Our results suggest that the design and adhesive capacity of gekkonid setal fields may well be adaptive features associated with undulant irregular surfaces, rather than smooth ones, as *Rhoptropus* exhibits setal field surface area very similar to that of other pad-bearing geckos.

12.3 RUTOWSKI, R. L.*; MACEDONIA, J. ; KEMP, D. ; TAYLOR-TAFT, L.; Arizona State University; *r.rutowski@asu.edu*

UV reflectance in female sulphur butterflies: DIversity and Mechanisms

In some species of sulphur butterflies (Pieridae: Coliadinae) females as well as males display bright structural reflectance on their dorsal wing surfaces, although comparatively little attention has been paid to this coloration in females. We examined the spectral properties of female dorsal coloration and scale structure in three species of sulphurs for which published images show bright UV reflectance in females: *Anteos clorinde* and two species of *Eurema*, *E. hecabe* and *E. candida*. In *A. clorinde* and *E. hecabe*, female UV reflectance is iridescent and produced by thin film interference in a system of ridges and lamellae, as it is in conspecific males. Female *A. clorinde* exhibit the same spatial distribution and chromaticity of UV reflectance as seen in males, but the UV reflectance in female *E. hecabe* is much smaller in area compared to that of conspecific males and is both less bright and less chromatic than observed in males. In contrast, UV reflectance in *E. candida* females is diffuse, and arises from a lack of pterin pigments in the wings, which permits a broad-band scattered reflection to be seen. This latter mechanism also is known to produce bright UV reflectance in females of some confamilial whites. While the functional significance of female UV reflectance in these species is unclear, our results highlight the diversity of UV reflectances and underlying mechanisms in sulphurs and suggest multiple evolutionary pathways leading to this diversity in female sulphur butterflies.

59.6 SADLEIR, R.W.; Univ. of Chicago, Field Museum; *rsadleir@uchicago.edu*

Crocodylian Phylogeny & Cranial Ecomorphology

Conflicting phylogenetic signals, character homoplasies, and character atavisms typify crocodylian phylogeny. Most phylogenetic ambiguity involves Gavialis and Tomistoma, for whom a secondary signal showing 70% of the characters supporting incongruent topologies is associated with their slender skull. Slender-snout skulls are one of five identified eusuchian cranial morphotypes thought to reflect functional or ecological specialization. Using concentrated changes tests, the effect of ecomorphology on cranial character state gains in phylogeny was tested for transitions among general, blunt, and slender ecomorphs. 120 published cranial characters were tested on the gains of three skull ecomorphs using a 92-taxon morphological phylogeny, a 13-taxon molecular phylogeny, and a 62-taxon combined-data phylogeny. In addition, trees were reduced to 11 taxa to test the effect of taxonomic sample size on hierarchical signals identified by reverse successive weighting. Because concentrated changes requires resolved tree polytomies, its analytical power is limited. Therefore, tree-free character compatibility tests of character independence were conducted on the morphological data matrix. Test results suggest ecomorphs affect cranial character state gains in phylogeny. Concentrated changes identify 52 character state changes that significantly correlate with transitions to the slender ecomorph, and 40 character state changes that significantly correlate with transitions to general and blunt ecomorphs on morphological, molecular, and combined-data tree topologies. Since cranial ecomorphs affect character state transitions, non-phylogenetic variables could mislead crocodylian phylogeny by affecting cranial morphology.

S2-2.3 SALAZAR-CIUDAD, I; University of Helsinki; *isaac.salazar@helsinki.fi*

On the origins of morphological novelty and its diverse developmental bases: the case of teeth

Novelties have been repeatedly claimed to be an unresolved problem in evolutionary theory. Several definitions of novelty exist but most emphasize that novelties imply qualitative changes on the phenotype and not the quantitative gradual changes favored in the neo-Darwinian approach to evolutionary theory. This article discusses how the concept of novelty is used to describe aspects of morphological evolution that are not satisfactorily explained under the modern synthesis. In this article it is proposed that there are not two discrete qualitatively different types of morphological changes but a repertoire of types of morphological change. It is proposed how the nature of novelty can be understood from the diversity of developmental mechanisms existing in animal development. Specifically it is proposed that animal morphology and its variation can be understood from the spatial patterns produced by a set of basic developmental mechanisms and their combination. Some examples of these kinds of morphologic changes are explained.

46.5 SALVANTE, K.G.*; SOCKMAN, K.W.; Univ. North Carolina, Chapel Hill; *ksalvante@unc.edu*

Song culture affects noradrenergic activity in the auditory telencephalon of female starlings

In some songbird species, the spectro-temporal properties of a male's song may reflect his quality and hence suitability as a prospective mate. Thus, females make mate-choice decisions based on variation among males in their song. Female European starlings (*Sturnus vulgaris*) prefer males that primarily sing long songs over those that primarily sing short songs, and regions of the auditory telencephalon are sensitive to this song-length variation. However, exposure to other social information, such as the prevalence of long- versus short-song males, can modulate the sensitivity of the auditory telencephalon to song length. Due to the presence of noradrenergic input to the auditory forebrain and, in some species, the loss of song-based preferences when this input is lesioned, we hypothesized that norepinephrine secretion mediates the effects of song culture on telencephalic song-length sensitivity. Consistent with this hypothesis, we found that a 1-week exposure to short songs reduced forebrain immunoreactivity for the enzyme that converts dopamine to norepinephrine (dopamine beta hydroxylase, DBH-ir) compared to females exposed to long song or no song. Song-culture-dependent modulation of noradrenergic activity in the auditory telencephalon may form part of a mechanism for the integration of social information in the mate-choice process and social modulation of female choosiness.

S1-4.5 SANE, SP*; DIEUDONNE, A; DANIEL, TL; University of Washington, Seattle; *sane@u.washington.edu*

Role of antennae in insect flight control

The antennae of flying insects perform multiple sensory functions. In addition to being the primary olfactory organs, antennae serve an important mechanosensory role during flight. For example, in the hawk moth *Manduca sexta* , we have shown that the antennae vibrate during flight and are thus subject to strong gyroscopic forces during aerial maneuvers. The resulting strain patterns experienced by the basal mechanosensors of the antennae follow gyroscopic forces on the antenna. Moreover, intracellular records from afferent neurons in the basal mechanosensory Johnston's organs show that they are maximally responsive within the frequency regime of these strain oscillations. Thus, antennal mechanosensors are capable of reporting the gyroscopic forces. Here we show that the mechanosensory input from the antenna is crucial for flight control. We filmed the flight patterns of hawk moths in a darkened chamber illuminated by infra-red light. The moths were subjected three experimental treatments: those with (a) intact flagella, (b) amputated flagella and (c) their flagella removed and reattached, Moths with amputated flagella were significantly more likely to collide with the walls of the flight chamber or crash during flight and unable to fly in a controlled and sustained manner. When their flagella were rejoined, flight control was largely recovered. These experiments provide additional evidence that antennae operate as gyroscopic sensors in four-winged insects, analogous to halteres in the two-winged insects.

4.2 SANTOS, S.R.; Auburn University; *santos@auburn.edu*

Potential speciation in anchialine environments: the roles of life history and geology

Anchialine habitats, land-locked bodies of mixohaline water that fluctuate with the tides but have no surface connection to the sea, are known from around the world. A wide variety of organisms exploit anchialine environments, with many being endemic to these habitats. However, the mechanism(s) driving speciation in this unique niche have not been defined. This is particularly significant in light of the negative impact these habitats and their biota have experienced from anthropogenic causes such as coastal development and the human-mediated introduction and spread of exotic species. To explore the forces influencing the speciation of anchialine organisms, populations of the endemic atyid shrimp *Halocaridina rubra* were examined from across their range in the Hawaiian archipelago. Seven distinct mitochondrial lineages were identified from a sampling of over 600 individuals from ~40 habitats on three islands (i.e., Oahu, Maui and Hawaii), with the level of genetic divergence between lineages implying isolation over significant time-spans (~1-6 million years). In most cases, mitochondrial lineages of *Halocaridina* are compartmentalized in different aquifers by the rift zones of an island's volcanoes, leading to nearly perfect isolation (i.e., F_{ST}~1) between populations. Although *Halocaridina* produces free-swimming lecithotrophic zoeae that can remain in the plankton for 24 37 days, long distance oceanic dispersal appears to be rare in this shrimp, suggesting interisland dispersal and/or colonization occur on evolutionary, rather than ecological, timescales. Further work is required to define the taxonomic status of these mitochondrial lineages; however, the level of genetic divergence between them suggests that *Halocaridina* represents a cryptic species complex and elicits questions on how best to conserve these species and their habitats.

13.3 SANTINI, Francesco*; CARNEVALE, Giorgio; University of Toronto, University of Pisa; *francesco.santini@utoronto.ca*

INTEGRATING PALEOBIOLOGY AND DEVELOPMENTAL GENETICS: CONTRIBUTIONS OF THE FOSSIL RECORD TO THE STUDY OF FIN LOSS IN TELEOST FISH

With over 28000 species, teleost fish represent the largest vertebrate clade. Most teleosts rely on the movement of a combination of paired and median fins for their locomotion. As such, fins might be thought to be highly conserved structures. A survey of the morphological diversity of extant and fossil teleosts, however, reveals that some kinds of fins can be very easily modified or lost, while others are much more highly conserved. The pelvic fins, for example, have been lost at least 70 times independently, while the caudal fin is very rarely lost. Until now, relatively little attention has been paid to how fins are reduced or lost. In our presentation we will discuss briefly the pattern of fin loss in teleosts. We will discuss evidence that morphological modules can be identified within the skeletal system of these fishes. We will also show how some of these modules can be modified likely through processes taking place during the early stages of development until their final disappearance in adult individuals. Finally, we will formulate some hypotheses about the relationships between morphological complexity and developmental regulatory genes in this clade. These hypotheses could perhaps be tested experimentally using developmental genetic methods. We will also show how fossils play a key role in the study of fin loss in many groups, by providing intermediate stages that illustrate how morphological transitions occurred in lineages now characterized by extant taxa with highly divergent morphologies.

1.9 SANTOS, C.; ROE, P.; SADEGHIAN, P.; SUN, S.; NORENBURG, J.L.*; Smithsonian Institution National Museum of Natural History, Washington, DC, California State University Stanislaus, Turlock, CA, Santa Barbara Museum of Natural History, CA, Ocean University of China, Qingdao; *norenburgj@si.edu*

Phylogeny and co-evolution in Carcinonemertidae (Nemertea), ecto-symbiotic egg-predators on decapod crustaceans.

Carcinonemertid worms are Monostilifera, i.e., the proboscis is armed with a single stylet. Features of both proboscis and body structure, as well as of reproductive biology, can best be interpreted as evidencing significant modification that befits a quasi-parasitic, egg-sucking life-style. Eleven species were recognized until recently, from about 65 recorded host species. Our recent, relatively limited surveys have increased the number of known host species to about 100, including 20 brachyuran crab families, and yielded 10-20 presumptive new worm species. Previous diversity appears significantly underestimated. A phylogeny for carcinonemertids from 30 host species, based on about 2,300 nucleotides of sequence data from mt COI, mt 16S rDNA, and nuclear 28S rDNA, supports the hypotheses that *Carcinonemertes* s.s. is monophyletic and that of Thollesson & Norenburg (2003, *Proc. Royal Soc., Lond.* 270:407-415) that it is the sister group to the remaining approximately 400 known species of Distromatonemertea (Monostilifera minus the Cratenemertidae). The implication is that extant *Carcinonemertes* represent an ancient radiation. The maximum genetic divergence in the data is 23.4%, compared to about 30% for the Monostilifera. Some *Carcinonemertes* clades appear co-evolved with host clades, especially among the portunids, but there are significant exceptions. Surprisingly, the worm species that infests the largest number and range of host species also is among the most derived, rather than basal.

S7-1.1.1 SATTERLIE, Richard; University of North Carolina Wilmginton; *satterlier@uncw.edu*

Changing Speeds in a Central Pattern Generator

Several common threads run through the fabric of central pattern generator networks, including those at the circuit level, such as reciprocal inhibition, at the cellular level, such as postinhibitory rebound, and at the molecular level, such as specific ion currents that regulate the timing and stability of rhythmic activity. Similarly, changes in locomotory speed also involve alterations in all three of these CPG levels. At the circuit level, reorganization of CPG circuitry and recruitment of motoneurons (and muscle fiber types) create changes in both the frequency and intensity of limb movements. In addition, modulation of specific ion currents leads to changes in cellular properties, such as baseline depolarization of CPG interneurons and alterations in their postinhibitory rebound properties. Additional changes in ion currents may also help maintain the timing of mid-cycle inhibition in the face of an increase in cycle frequency. All of these examples are found in a model system used to investigate locomotory speed changes at circuit, cellular, and molecular levels the swim system of the pteropod mollusk, *Clione limacina*.

S8-2.3 SCALES, J.A.*; BUTLER, M.A.; Univ. of Hawaii, Manoa; *jscales@hawaii.edu*

Acceleration and power output in gravid green iguanas

A major selective pressure for the evolution of sexual dimorphism is differential reproductive roles of the sexes (Darwin, 1871). Females of many species experience large increases in mass and volume related to bearing a reproductive load. Carrying a reproductive load presumably encumbers locomotion, yet females must retain locomotor performance essential for predator escape and daily activities. Therefore, selection to maintain locomotor performance while gravid may lead to sexual dimorphism in morphology or performance abilities. In particular, acceleration is an ecologically important aspect of locomotor performance which should particularly be affected by reproductive load. We investigated the ability of female iguanas to produce force and power during accelerations while gravid. We found that gravid iguanas can accelerate at a similar rate to recovered normal iguanas by producing extremely high power (up to 1560 W/kg) for a given acceleration. The increase in power is not due to increases in peak forces, but high force production during an extended step duration. The high power outputs suggest that accelerations in gravid iguanas may be power limited, but the similarity in acceleration between gravid and recovered iguanas reveals that non-gravid iguanas have excess performance capacities. These results provide insight on the selective pressures or biomechanical constraints that may result in dimorphisms related to maintaining performance while gravid. I will discuss how these biomechanical findings may relate to other aspects of reproductive ecology.

54.2 SCHACHAT, F.; Duke Univ. Med. Ctr.; *f.schachat@cellbio.duke.edu*

Evolution of Vertebrate Striated Myosins: Myosin Heavy Chain Diversity in Amphioxus

The position of cephalochordates in vertebrate phylogeny is controversial (Gee, 1996; Delsuc et al., 2006). Nonetheless, whether cephalochordates are the most basal of living chordates or a sister phyla of chordates, they remain an important organism in which to explore early events in the evolution of chordate characters. These studies focus on one such character, striated muscle specialization, defined by myosin heavy chain diversity and patterns of expression. They suggest that celphalochordates are more primitive than tunicates, and that cephalochordate striated muscle exhibits highly derived, as well as primitive, characters. RNA from *Branchiostoma floridae* was amplified using RT-PCR with primers that span a region of the myosin head containing several key functional elements. Six distinct cDNA sequences were identified. The *Branchiostoma* trace sequence archive at GenBank was used to further analyze these coding sequences, and the genes that generate them. Their expression in notochordal, myomeric, ventral, velar and pharyngeal muscle was also investigated. One of the myosins is predominant in notochordal muscle, which expresses paramyosin and has filaments as long as 30 microns. Three of the myosins are present in myomeric and ventral muscles, which have vertebrate cross-striated character. Another sequence is restricted to the head region, and it is the only myosin that has known homologs in contemporary vertebrates. Interestingly the last myosin sequence is more closely related to smooth and nonmuscle myosins than to striated myosins.

69.5 SCHAEFER, Justin*; SUMMERS, Adam; Univ. of California, Irvine; *jschaefe@uci.edu*

Modeling a passive force channelization mechanism in batoid wing skeletons

The wing skeleton of batoid fishes (skates and rays) is composed of arrays of serially arranged skeletal elements emanating from the pectoral girdle. The joints between these skeletal elements are arranged in patterns that are specific both to the locomotor mode employed (oscillatory or undulatory) and to phylogeny. We modeled the effects of the spatial arrangement of these joints in 4 species of batoid, using the assumptions that a) joints constitute a localized point of bending, b) surrounding skeletal elements were rigid in comparison to joints, and c) muscle force acts along the line of the skeletal element proximal to the joint. Two oscillatory swimmers (*Myliobatis californica*, *Aetobatus narinari*) and two undulatory swimmers (*Urobatis halleri*, *Dasyatis Sabina*) were modeled based on radiographs. The modeled resultant force vectors varied with locomotor mode, and when interpreted in terms of the temporal and spatial variation of wave propagation between locomotor types, indicate that the joints form lines that passively dictate wing bending shape, and thus the direction of water along the wing and ultimately the direction of the thrust vector.

30.3 SCHAERLAEKEN, V.*; HERREL, A.; ROSS, C.F.; University of Antwerp, University of Chicago; *vicky.schaerlaeken@ua.ac.be*

Functional consequences of the loss of the lower temporal bar: a comparative study of bite forces and feeding kinematics in lepidosaurians.

One of the major conundrums in the evolution of vertebrate cranial design is the loss of the lower temporal bar in diapsids. Whereas it has been proposed that the reduction of the lower temporal bar allows for an increase in jaw adductor mass and bite force, this has never been tested experimentally. The skull of *Sphenodon punctatus* (Rhynchocephalia; tuatara) is different from that of other recent lepidosaurians in being fully diapsid. To test the hypothesis that the loss of the lower temporal bar resulted in an increased bite force we compared bite forces in *Sphenodon* with data of some basal squamates. Moreover, tuataras are unique in using translation to shear food rather than using the typical puncture-crushing of other lizards. Therefore, we also assessed the efficiency of the feeding system, by recording and comparing cycle durations and number of transport cycles used to transport standardized prey. *Sphenodon punctatus* had lower bite forces than basal lepidosaurian groups as predicted. Moreover, preliminary kinematic analysis of feeding events suggested a less efficient' (i.e. requiring more time) prey transport in *S. punctatus* compared to lizards. Whereas the increased cycle duration is likely due to the increased prominence of the slow closing phase in *S. punctatus*, the longer feeding bout duration and larger number of transport cycles employed are likely a consequence of the relatively low bite forces in *S. punctatus*.

S5.11 SCHIERWATER, Bernd*; DESALLE, Rob; JAKOB, Wolfgang; SCHROTH, Werner; HADRYS, Heike; DELLAPORTA, Stephen; ITZ, Ecology and Evolution; Dept. of Molecular Cellular and Developmental Biology, Yale University, American Museum of Natural History, ITZ, Ecology and Evolution, ITZ, Ecology and Evolution, Dept. of Molecular Cellular and Developmental Biology, Yale University; *bernd.schierwater@ecolevol.de*

Total Evidence Analysis Identifies Placozoa as Basal to Extant Metazoa

A more than a century old debate has focused on the origin of metazoan animals and the hypothetical urmetazoan bauplan. The morphologically most simply organized metazoan animal, the placozoan Trichoplax adhaerens, resembles the intriguing model for one out of several urmetazoan hypotheses, the placula hypothesis of metazoan origin. If there were clear support for a basal position of Placozoa all key issues of metazoan specific inventions (including for example head-foot axis, symmetry, coelom) would find a root for unraveling their evolution. Unfortunately, the phylogenetic relationships at the base of Metazoa have been unresolved. While morphological analyses have suggested a basal position for Placozoa, molecular studies revealed different and conflicting phylogenetic scenarios. Here we analyze the sum of morphological evidence, molecular sequence data from mitochondrial and nuclear genes, the secondary structure of a mitochondrial ribosomal gene, and Hox gene expression. Together with mtDNA genome structure and sequence analyses these data provide compelling evidence that Placozoa are basal relative to all other recent metazoan phyla.

1.10 SCHIZAS, Nikolaos*; RHYNE, Andrew; FIEDLER, Curt; University of Puerto Rico Mayagüez, Florida Institute of Technology, University of Maryland, University College Asia; *n_schizas@cima.uprm.edu*

Multidata phylogeny of the Western Atlantic Lysmata

Prior to recent revisions, only ten species of *Lysmata* were thought to occur in the Atlantic Ocean. From these ten species, six were known from the western Atlantic: *L. grabhami*, *L. intermedia*, *L. moorei*, *L. anchisteus*, *L. rathbunae*, and *L. wurdemanni*. In the western Atlantic, five more species have been recently added bringing the total to eleven. There is a need to decipher the phylogeny of this group in light of the rare reproductive mode in decapods, protandric simultaneous hermaphrodism, and their commercial importance in the marine reef aquarium industry. A powerful approach in assessing the relationships of species is a complete molecular phylogeny based on several genes, in conjunction with morphological and morphometric measurements of larvae and adults. Similar phylogenetic relationships of the western Atlantic *Lysmata* are supported by mitochondrial and nuclear genes, and morphological analysis of adult and larval characters. The data indicate further divisions within the genus.

S2-1.5 SCHLOSSER, Gerhard; University of Bremen; *gschloss@uni-bremen.de*

How old genes make a new head recent insights into development and evolution of neural crest and placodes in vertebrates

Two embryonic tissues - neural crest and cranial placodes - give rise to most evolutionary novelties of the vertebrate head. While many cellular and molecular components of neural crest and placodes predate the origin of vertebrates, the integration of these components into true neural crest and placodes appears to have evolved only in the vertebrate lineage. Both tissues develop similarly in several respects: they originate from ectoderm at the neural plate border; they undergo pronounced cell shape changes; and they give rise to multiple specialized cell fates. Due to these similarities and their joint appearance in the vertebrate lineage, it is often thought that neural crest and placodes have a common evolutionary origin from a specialized population of neural plate border cells. However, pronounced developmental differences between the two tissues make this scenario questionable. First, development of neural crest and placodes depends on largely non-overlapping sets of transcription factors. In addition, recent data show that each tissue is induced at a different time of development and relies on partly different inductive tissues and signals. Moreover, our own experiments in *Xenopus* suggest that competence to respond to placode induction is confined to non-neural ectoderm, while competence to respond to neural crest induction is confined to neural ectoderm. Taking these various lines of evidence together, I propose that both tissues evolved independent from each other, that they recruited different sets of genes encoding for transcription factors and signaling molecules, and that neural crest cells originated from cells on the neural side of the neural plate border in protochordates, while placodes originated from cells on the non-neural side of the neural plate border.

56.5 SCHNEIDER, Stephan Q.*; BOWERMAN, Bruce; Univ. of Oregon, Eugene; *schneider@molbio.uoregon.edu*

&beta-catenin mediated binary specification in the spiral-cleaving polychaete Platynereis dumerilii

&beta-catenin functions in the canonical Wnt-signaling pathway by activating target gene expression in the nucleus. Early roles for &beta-catenin signaling are surprisingly different among animal phyla. To gain insight into the ancestral role of &beta-catenin, we are using the polychaete *Platynereis dumerilii*. *Platynereis* embryos deploy a highly stereotypic cell division program called spiral cleavage that generates blastomeres of defined size and cell fate, in a series of animal-vegetal (a-v) oriented cell divisions. We observed a-v asymmetries in the levels of detectable &beta-catenin during embryonic cell divisions, from fertilization through the spiral cleavage stages and up to and beyond the emergence of bilateral symmetry. In each of these a-v oriented cell divisions nuclear &beta-catenin levels are increased in vegetal daughter cells and decreased in animal daughter cells. This asymmetry occurs independent of cell size, cell cycle, cell fate, and cell lineage. Interestingly, the asymmetry is lost only in transverse/bilateral cell divisions, and is reversed during the segregation of germ cell lineages. Furthermore, we demonstrate that treatment with GSK3 inhibitors causes nuclear accumulation of &beta-catenin in animal daughter cells and results in animal to vegetal cell fate transformations. These results are strikingly reminiscent of the anterior-posterior oriented divisions, Wnt pathway asymmetries and functions that occur throughout embryogenesis in *C.elegans*. We also find similarities to &beta-catenin signaling in early deuterostome and insect embryos. We propose that this a-v asymmetry of &beta-catenin in daughter cells constitutes an ancestral and versatile binary specification mechanism that has been deployed and modified throughout evolution in metazoan embryos.

56.1 SCHREIBER, A.M.; Carnegie Institution, Embryology; *schreiber@ciwemb.edu*

Swimming posture switches from visual to vestibular control in developing larval southern flounder

Flatfish transform from symmetric, upright-swimming larvae into asymmetric juveniles that swim on one side. Lateralized posture develops independent of eye position during metamorphosis, suggesting strong vestibular, as opposed to visual, involvement. This study used infrared videography to address visual and vestibular roles in larval swimming by measuring posture in light versus dark. Pre-metamorphic larvae (5-15 dph) in the dark swam to the surface and descended passively, head first with the body perpendicular to the bottom. Laterality was first observed during passive descent at 20 dph by inclination of the left side upwards. Left side bias continued with development, and by late pre-metamorphosis (23 dph) larvae were parallel to the ground during passive descent, like juveniles. By contrast, in the light pre-metamorphic through early-climax larvae switched from the passive descent posture to upright when feeding or actively swimming. After severing either left or right optic nerves larvae starting eye migration still swam upright in the light, suggesting each eye is capable of controlling posture. After early-climax, fish swam only on one side in both light and dark. These findings suggest alteration in larval swim posture is a continuous integration of visual and vestibular signaling, ultimately ending with vestibular control in juveniles.

4.5 SCHWANZ, L.E.*; BOWDEN, R.M.; SPENCER, R.-J.; JANZEN, F.J.; Iowa State University, Ames, Illinois State University, Normal, CRC for Invasive Animals, University of Canberra, Australia; *schwanz@unm.edu*

The influence of climate on offspring sex ratios in Painted turtles

In many reptiles, the sex of an individual is determined permanently early in embryonic development by the temperature at which the embryo is incubated. Temperature-dependent sex determination may have evolved in response to unique selective pressures and has marked consequences for population dynamics. We analyzed data collected over 19 years from a population of Painted turtles (Chrysemys picta) to examine the relationship between ambient air temperature and annual cohort sex ratios of hatchlings. We found that the strong relationship between air temperature during embryonic development and cohort sex ratios has been altered in recent years due to changes in climate. We discuss the importance of these results for population dynamics and population persistence in the face of potential climate change in the future.

19.4 SEARS, Michael W.; Southern Illinois University; *msears@zoology.siu.edu*

Proceed with caution: invalidating tests of the cost-benefit model of thermoregulation with spatially-explicit movement simulations

The Huey-Slatkin model of behavioral thermoregulation in lizards predicts that individuals should thermoregulate less effectively in costly environments. A recent test of this prediction (Blouin-Demers and Nadeau 2005) used published data of thermoregulatory indices for 22 lizard species, 4 snake species and one species of amphibian to suggest that this prediction is not upheld. Specifically, the test failed to show a positive correlation between an index of the accuracy of thermoregulation (d_b) and an index of thermal quality of available habitat (d_e). The authors then concluded that individuals can thermoregulate accurately regardless of the thermal quality of available habitat. One important cost that cannot be accounted for in such a test is the influence of explicit spatial configurations of operative temperatures in the environment. Using a constrained random walk simulation of animal movement that incorporates thermoregulatory decisions and thermal properties of individuals, I explored the spatial conditions under which such a test of the Huey-Slatkin model could be performed. Results of these simulations revealed that the true null model to be tested against cannot be known unless the spatially-explicit distribution of operative temperatures in the environment are specified. If the spatial configuration of operative temperatures is unknown (as with the test by Blouin-Demers and Nadeau), the consequence is that any potential slope for the relationship between the accuracy of thermoregulation and the thermal quality of available habitat cannot be distinguished from the expected null hypothesis. Therefore, it is suggested that future tests of the Huey-Slatkin model of thermoregulation should be performed among conspecific individuals under very specifically-defined spatial distributions of operative temperatures.

S1-1.15 SEBENS, Kenneth P.; Univ. of Washington, Seattle; *sebens@u.washington.edu*

Coral ensembles: their swan song, or a $CaCO_3$phony?

Corals have suffered unprecedented mortality during two decades of elevated sea surface temperature, and many more decades of human perturbation, on a global scale. The basic biology and functional morphology of corals is becoming better understood just as their populations are declining. What happens next, and is there any hope for the future of corals and coral reefs? Will there be widespread reduction in reef area, or chaotic species replacement in coral communities? Scleractinian corals use diverse resources to grow and calcify in habitats with scarce and potentially limiting resources. Species display a wide range of colony and polyp morphologies related to resource capture, water flow, and irradiance. On shallow reefs, zooxanthellae translocate more than enough photosynthate to meet metabolic demands, yet nutrients needed for tissue growth can still be scarce. In light limited reef locations, photosynthesis does not meet energetic needs. Zooplankton and other particulate material can be important sources of nutrients and energy to reef corals, and dissolved nutrient uptake can also be significant. Experimental results show that plankton capture rate can control calcification and tissue growth in several coral species; this effect is often greater than that of other known controls, such as available bicarbonate concentrations, aragonite saturation state, and water flow. Branch size and spacing, polyp size, tentacle size and shape, all affect light and particle capture and alter the local flow environment in coral aggregations. Understanding interspecific differences in morphology, and differential utilization of diverse resources, can help explain patterns of coral diversity, zonation, and abundance on reefs. Such information can be useful in interpreting changes in growth rate and survivorship, with predicted changes in habitat quality, temperature, and seawater chemistry over the next decades.

66.1 SECOR, S.M.*; BOBACK, S.M.; LIGNOT, J.-H.; University of Alabama, Louis Pasteur University; *ssecor@biology.as.ua.edu*

Spatial and temporal variation in the pH of the gastrointestinal tract of the Burmese python

Feeding triggers the rapid production of gastric acid for the Burmese python, lowering stomach pH from 7 to 2 within 24 hours. Unknown is the extent that the adjoining esophagus and small intestine are able to buffer this large flux in acid production. Therefore we measured luminal pH at 16 sites within the gastrointestinal tract of fasted pythons and of fed pythons at nine time points (0.25 15 days) following their consumption of a rodent meal equaling 25% of snake body mass. For all time periods, including fasting, there was significant variation in luminal pH throughout the GI tract. Even for fasted snakes, pH varied from 6.5 (stomach) to 7.6 (cecum). For fed snakes, pH was the lowest in the stomach (2 3), intermediate in the distal esophagus, proximal stomach, and distal large intestine (5 6.7) and highest in the esophagus, distal small intestine, cecum, and proximal large intestine (7 8). Across sampling periods, we detected no significant change in luminal pH for the proximal esophagus, middle and distal small intestine, cecum, and large intestine. In contrast, the distal esophagus, stomach, and proximal small intestine each varied in luminal pH among sampling times, a function of the postprandial production of gastric acid and the downregulation of acid production once gastric digestion had ceased. The very sharp gradient in pH (2 to 5-6) between the stomach and the distal esophagus and proximal small intestine demonstrates the tremendous buffering capacity of these latter two tissues. The high pH of cecal contents (> 7.4) suggests the absence of significant microbial fermentation occurring in the cecum.

S1-3.12 SEIPEL, J.*; FULL, R.J.; HOLMES, P.; Univ. of California, Berkeley, Princeton Univ.; *jseipel@princeton.edu*

Effects of Leg Number and Posture for a Class of Simple Three-dimensional Point-mass Running Models

Many legged animals produce similar net ground reaction forces during steady running - like an idealized point-mass pogo-stick. The simple pogo-stick analogy reduces the forces along a **steady**-gait to a single effective springy leg regardless of the system's complexities. Yet, morphology matters to the dynamics and energetics of such systems, even for a class of highly idealized zero-friction point-mass models. Morphological details of form, such as leg number and posture, make significant 'first order' contributions to the **dynamics** of running gaits, and thus to the stability of perturbations from steady-state periodic running. A phenomenological, single effective leg cannot reproduce these effects. Furthermore, while a simple passive monopod model can complete the task of running with no energy expenditure, the inclusion of sprawled postured legs requires actuation and thus energy expenditure significantly higher than what would seem necessary for an otherwise simple running gait. We present a laterally sprawled kangaroo model with bilateral symmetry and a tripod-sprawled cockroach model. We compared these animal models with the alternating tripod gait of the robotic hexapod RHex. We found that a sprawled posture can benefit dynamic stability. In particular, gaits of the cockroach-like model were quite robust even though they consumed energy. This result, along with work by Kubow and Full (1999) and Seipel et al. (2004) which modeled the tripod of the cockroach in the horizontal plane and where the body could yaw, supported the hypothesis that dynamic stability is an important factor governing cockroach morphology and gait selection, despite the consequence of higher energy expenditure. NSF FIBR grant and NSF Fellowship.

48.1 SFORMO, T*; BENNETT , VA; WALTERS , K; JEANNET, K; BARNES, B; DUMAN, J; Institute of Arctic Biology, University of Alaska, Fairbanks, Department of Biology Clarion University, Department of Biological Sciences, University of Notre Dame, Notre Dame, Department of Biological Sciences, University of Notre Dame, Notre Dame; *rfts@uaf.edu*

Overwintering Physiology of the Beetle Cucujus clavipes: Roles of Antifreeze Proteins, Polyols, and Dehydration

Insects that overwinter at high latitudes and under extreme environmental conditions should require, in comparison to populations from lower latitudes, tolerance to exceptionally low temperatures. The freeze-avoiding larvae of the coleopteran Cucujus clavipes found in sub-arctic and arctic Alaska (64 67 ºN latitude) populations produce antifreeze protein in August and may be cued by decreases in photoperiod, whereas polyol production (predominately glycerol) appears to be cued by decreases in temperature (~0 ºC). Alaska larvae undergo extreme dehydration from 63 65 % body water (1.7 1.8 g H2O g-1 dry weight) in summer to 28 40 % body water (0.40 0.68 g H2O g -1 dry weight) in winter. While the 2.5 4.6 fold reduction in body water and the increase in antifreeze and glycerol allow Alaska C. clavipes to supercool in winter between -35 to -42 ºC, we also present evidence that some Alaska larvae in winter do not freeze even when cooled to -80 ºC.

53.1 SHAPIRO, M.D.*; SUMMERS, B.R.; BALABHADRA, S.; BELL, M.A.; KINGSLEY, D.M.; Univ. of Utah, Stanford Univ., Stony Brook Univ.; *shapiro@biology.utah.edu*

Genetic origins of parallel evolution in threespine and ninespine stickleback fish

A longstanding question in the study of parallel evolution is whether the same gene or genes control similar adaptive phenotypes in different populations and species. Stickleback fish provide numerous opportunities to study the genetic basis of parallelisms. In particular, threespine (*Gasterosteus aculeatus*) and ninespine (*Pungitius pungitius*) sticklebacks show repeated evolution of similar adaptive traits among different populations within each genus, and these two genera also have evolved similar derived traits in parallel. Through intergeneric complementation tests, we demonstrated that at least one adaptive trait, pelvic reduction, likely evolved by changes at the *Pitx1* locus in specific populations of both genera. To examine the genetic architecture of other interesting traits in *Pungitius*, we generated the first genome-wide linkage map for the ninespine stickleback. By aligning the new ninespine map with an existing threespine map and genome sequence, we found broad synteny between the two genera, thereby allowing direct comparisons of trait-mapping results. Genetic mapping studies revealed that sex determination and lateral plate number in ninespine sticklebacks and threespine sticklebacks are controlled by different chromosome regions. We also identified a chromosome region in a second population of ninespine sticklebacks that plays a major role in pelvic reduction and is not linked to *Pitx1*. Further studies using genetic and genomic resources from both genera will allow us to directly compare the chromosomal location and genetic architecture of other interesting, adaptive traits that evolved in parallel in these taxa.

35.3 SHERRARD, K. M.; University of Washington; *kmsherra@u.washington.edu*

Invagination of ascidian endoderm is preceded by apical contraction, but driven by active shortening of cells

Invagination is a fundamental mode of morphogenesis whereby a sheet of cells autonomously generates forces causing itself to buckle inwards. Contraction of the apical (outer) cell cortex is the most commonly invoked mechanism; however, the means by which cells actively deform to drive invagination have not been fully documented in any system. I performed a detailed case-study of endoderm invagination in ascidians using time-lapse microscopy of intact embryos and explants, labeling of the cell surface with fluorescent microspheres, experimental manipulations of adhesivity and cortical contractility, and antibody labeling. The data reveal that ascidian invagination is a two-step process: apical contraction coinciding with placode formation followed by basolateral contraction that shortens the endoderm cells and actually generates the invagination. This mechanism is only possible because the apical cortex of endoderm cells and their adhesive connections are sufficiently strong to resist apical expansion. Because invaginations are typically preceded by placode formations and act on columnar cells which shorten during the invagination, apical-basal shortening by basolateral contraction may be a general mechanism of invagination.

BERN.1 SHERWOOD, NM; Univ. of Victoria, BC Canada; *nsherwoo@uvic.ca*

The Endocrine System just before the Backbone: Genomics of the Spineless

The nature of the endocrine system in animals that evolved just before the vertebrates has been difficult to study. Now, the release of the complete genome for two groups lacking a backbone, amphioxus and tunicates, has revealed the presence of a number of endocrine-related ligands, receptors, enzymes, transcription factors and signaling molecules that are homologous to those in vertebrates. The phylogenetic position of these basal chordates and the simplicity of their genomes before expansion by duplication in the vertebrates suggest that insight into the foundation of vertebrate endocrine-related genes is possible. In a tunicate (*Ciona intestinalis*), the major endocrine systems isolated and studied are those involved with metabolism and growth (insulin, IGF and their receptor), with reproduction (gonadotropin-releasing hormone, GnRH, and its four receptors), with feeding (CCK/gastrin and its receptor) and with brain-gut-thyroid function (tachykinin and its receptor). In amphioxus (*Branchiostoma floridae*) the genome is just released but insulin-like peptides, an insulin-IGF receptor and GnRH receptors have been isolated and studied. Although hormones are difficult to identify within the genome, a number of receptors including G-protein-coupled receptors, tyrosine kinase receptors and nuclear receptors have been annotated within the genome. Of equal interest are the endocrine molecules that are not present. One conundrum is the apparent lack of pituitary hormones, classical steroids and their receptors in tunicates, whereas the status of the pituitary and steroids is an open question in amphioxus. The presence of releasing factors such as GnRH in an animal lacking pituitary hormones provides an opportunity to study ancestral and peripheral actions of these neuropeptides.

71.4 SHINGLETON, A.W.; Michigan State University; *shingle9@msu.edu*

The developmental mechanism and evolution of allometry in Drosophila

The developmental mechanisms that control the relationship between final body size and organ size in animals are virtually unknown. This relationship, called static allometry, arises because variation in adult body size is accompanied by corresponding variation in organ size. Here we examine the static allometries created by rearing *Drosophila* under different environmental conditions. The male genitals show a hypoallometric relationship with body size when size variation is a consequence of variation in developmental nutrition, but a different allometric relationship when size variation is a consequence of variation in rearing temperature. Different sources of variation may therefore create different allometric relationship using different developmental mechanisms. We show that one such mechanism is likely to involve the insulin-signaling pathway, which is known to regulate growth with respect to nutrition in *Drosophila*, and most animals. Suppression of the insulin receptor has less of an effect on the size of the male genitals than it does on other organs. This and additional genetic data suggest that the nutritional hypoallometry' of the male genitals is explained by differential activity of insulin-pathway genes in the genitals relative to other body parts. Organ-specific regulation of the insulin-signaling pathway may therefore be a general method by which animals regulate nutritional static allometries, and suggests a potential mechanism by which allometries can evolve.

68.4 SIEG, A*; O\'CONNOR, M; SPOTILA, J; Drexel University; *aes48@drexel.edu*

Land Use Effects on Wood Frog (Rana sylvatica) Biophysical Ecology

Amphibians are important indicator species of ecosystem health but are declining worldwide at a faster rate than other vertebrate groups. Habitat loss is a major cause of this decline. As part of a broad-scale experimental study of effects of forestry techniques on amphibians, we measured microclimate variables in treated and control forest habitat and estimated potential rates of mass and energy exchange for wood frogs (*Rana sylvatica*) inhabiting each treated habitat. Daytime surface air temperatures (Mean &plusmn 2 SE; &deg C) were elevated in the clearcut treatment (21.8 &plusmn 0.2) as compared to control (17.4 &plusmn 0.1) and thinned canopy treatments (18.8 &plusmn 0.2). However, vapor densities (g/m3) in the clearcut treatment both at the surface (12.7 &plusmn 0.67) and under leaf litter (12.6 &plusmn 0.37) were not significantly different from leaf litter vapor densities in the control (12.4 &plusmn 0.22), thinned canopy (13.3 &plusmn 0.12), and a groundwater drainage site (12.4 &plusmn 0.22). Surface vapor densities were lower in the control (9.5 &plusmn 0.14), thinned canopy (8.4 &plusmn 0.37), and near the groundwater drainage site (10.1 &plusmn 0.14). Physical models of frogs in each treatment at the surface and under leaf litter were used to measure body temperatures and rates of evaporative water loss (EWL). Mannequin EWL rates (g/hr) were similar within the clearcut treatment (surface 0.50 &plusmn 0.05; leaf litter 0.51 &plusmn 0.05) and the surface thinned canopy mannequins were comparably elevated (0.79 &plusmn 0.15). Predicted surface EWL rates (g/hr) were consistent with the observed loss rates in each treatment (ranges: thinned 0.65 2.1; clearcut 0.31 0.97). We apply a new technique to the prediction of frog EWL under leaf litter and the application of frog mannequins to measuring field EWL over long time periods.

13.1 SIKES, James M.*; BELY, Alexa E.; University of Maryland; *jsikes@umd.edu*

Reversed polarity budding in the basal bilaterian Convolutriloba retrogemma (Acoelomorpha: Acoela)

The acoel *Convolutriloba retrogemma* reproduces by a remarkable budding process in which two posterior buds are formed that have a reversed A/P polarity relative to the parent. To investigate the evolution and development of this process, we have investigated the phylogenetic context of this mode of asexual reproduction, performed regeneration experiments on budding worms, and characterized patterns of cell division, muscle fiber dynamics, and gene expression during the budding process. 18S rDNA and COI gene sequence data reveal that *C. retrogemma* is most closely related to another *Convolutriloba* species (*C. longifissura*) that reproduces by two orthogonal divisions, a first one transverse and a second longitudinal. Interestingly, based on the phylogenetic placement of a recently discovered species that also reproduces by forming buds like *C. retrogemma*, it appears that reversed polarity budding has independently evolved at least twice within this group. Regeneration exeriments in which posterior buds are cut off from the parent at different axial positions demonstrate that the zone of A/P axis reversal occurs at the site of bud initiation. Studies of cell division (as revealed by BrdU labeling of S-phase cells) and muscle filaments (as revealed by phalloidin studies of F-actin) reveal that posterior buds extend via an anterior growth zone and that muscle fibers may be continuous across the parent and bud. To investigate gene expression during the budding process, we have cloned members of the anterior, central, and posterior classes of Hox genes as well as homologs of *orthodenticle*, an anterior patterning gene. RT-PCR results suggest that both anterior markers are upregulated during budding and attempts to characterize the spatio-temporal expression of these genes are currently underway.

25.1 SIMKINS, D.C.*; WHITENACK, L.B.; MOTTA, P.J.; University of South Florida; *dsimkins@eng.usf.edu*

A New Engineering Tool for What-If Finite Element Analysis In Biology

Finite element analysis is a common analytical tool in engineering and is seeing increased usage in biology. Often, the only geometry information available is from a diagnostic technique, such as CT scans, that provide a set of discrete points representing the object. From these points, a mesh must be developed to perform the analysis, and the mesh itself becomes the geometric representation. In order to model a different geometry, e.g. in morphological studies, a new mesh must be generated. This can be a difficult and time consuming task. The newly developed Reproducing Kernel Element Method (RKEM) provides a way to model discrete point sets in a smooth and highly accurate fashion, and at the same time allows a user to modify the geometry without any re-meshing. This has the potential to be a powerful tool for biologists interested in performing what-if mechanical analyses on CT models. In this talk, we present an introduction to the use of this new capability and explore some interesting applications in functional morphology of elasmobranch teeth. We will demonstrate how to exploit the RKEM method to greatly reduce the number of points and complexity of an FE model without loss of accuracy in a tooth from *Galeocerdo cuvier*. Further, using the simpler RKEM model, we will show how one can make significant modifications to the geometry without re-meshing.

50.7 SIMON, M.A.**; TRIMMER, B.A.; Tufts University, Medford, MA; *michael.simon@tufts.edu*

Movement and Body Stretch Encoding by Mechanosensors in Manduca sexta

Caterpillars are soft-bodied, terrestrial climbers capable of a wide variety of complex movements despite a relatively simple nervous system. To navigate successfully, they must adapt their movements in response to sensory information, in particular mechanical forces and deformations. Such mechanoreceptors must be attached to soft tissues, and it is unknown how they encode information or how that information is used to coordinate movement. In the soft-bodied crawler *Manduca sexta*, one potentially important sensory organ is the longitudinal stretch receptor organ (SRO), a muscle-like tissue anchored to the soft cuticle. Here, we discuss the output of an SRO undergoing stretching stimuli and show that its output includes multiple components. These responses include coding for receptor length and stretch velocity. The output also exhibits adaptation over longer duration stretches but does not appear to directly encode tension. We will also present new evidence regarding how the SRO might be dynamically adjusted by the activity of stretch receptor motoneurons (SRMs). Finally, we will discuss the implications that these results have for our understanding of proprioceptor function and what impact such feedback has on soft-bodied locomotion.

1.4 SIN, Y. W. *; CHU, K. H. ; NG, P. K. L.; The Chinese University of Hong Kong, National University of Singapore;
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Mitochondrial DNA Phylogeny of the Family Dorippidae (Decapoda, Brachyura)

Crabs of the family Dorippidae are unusual in that they have reduced fourth and fifth pairs of pereopods which are specially modified for carrying objects. There are two subfamilies of Dorippidae (Dorippinae and Ethusinae), with a total of 97 species from around the world. The affinities of the Dorippidae, between other brachyuran lineages and within the family, however, are very poorly known. In the present study, the phylogeny of the Dorippidae is investigated using three mitochondrial gene segments: 12S rRNA, 16S rRNA and COI. Fifteen species from nine of the 12 extant dorippid genera are included in the analysis. The result supports monophyly of each of the subfamilies, with *Ethusina* and *Ethusa* (Ethusinae) clearly distinct from the seven genera of Dorippinae studied. In the Dorippinae, *Dorippe*, *Medorippe* and *Dorippoides* always form a clade, while *Neodorippe*, *Heikea*, *Paradorippe* and *Philippidorippe* form another clade, with the former two genera being most closely related and *Philippidorippe* being the most distant taxon in the clade. This analysis provides insights into the evolutionary relationships within this family. Comparing the divergence among the Dorippidae and other related brachyuran families suggest a deep break between the two subfamilies.

53.2 SINCLAIR, Brent J.*; ROBERTS, Stephen P.; GIBBS, Allen G.; University of Western Ontario, University of Nevada - Las Vegas;
bsincla7@uwo.ca

Gene transcription during exposure to, and recovery from, cold and desiccation stress in Drosophila melanogaster

Tolerance to low temperature and desiccation are often thought to be linked in insects. However, while the responses to acclimation or exposure to these stresses has been oft-investigated, the processes that occur during recovery have received much less attention. We exposed adult *Drosophila melanogaster* to cold or desiccation, and examined the expression of several candidate genes during both exposure and recovery. We found that *Frost*, which has been implicated in responses to cold is, in fact, only expressed during recovery from cold, but that it is slightly upregulated during desiccation exposure. We found that both desiccation and starvation elicited increased expression of the senescence-related gene *smp-30*. These results will be discussed in the context of other studies that have purported to examine exposure to stress, but may be integrating recovery responses as well. This study highlights the importance of carefully controlling both exposure and recovery conditions, particularly in low temperature studies of insects.

29.7 SMALL, B.C.*; MURDOCK, C.A.; USDA-ARS Catfish Genetics Research Unit, MS, Jacksonville State University, AL;
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Seasonal Pituitary mRNA Expression of Steroidogenic Factor-1 and a Splice-Variant during Ovarian Steroidogenesis and Development in Channel Catfish, Ictalurus punctatus

Steroidogenic factor-1 (SF-1) is an orphan nuclear receptor that regulates steroidogenesis at multiple levels of the reproductive axis. Recently, channel catfish SF-1 (Genbank accession no: DQ000612) and a corresponding splice variant (SF-1b; DQ291133) were cloned in our laboratory. The spice variant has a 372 bp addition, resulting in the induction of an early termination codon into the open reading frame. In the present study, the seasonal regulation of channel catfish SF-1 and the SF-1b mRNA expression in the pituitaries of reproductively mature females was monitored via monthly sampling of pond-reared fish. Tissue collection began in April, prior to the natural spawning season, and continued on a monthly basis until May of the following year. Expression analyses were conducted using real-time quantitative RT-PCR to measure SF-1 and SF-1b mRNA levels in total RNA isolated from pituitaries. Concurrent measurements of estradiol, testosterone, and gonadosomatic index were also conducted. Gonadosomatic index decreased rapidly between June and August then increased steadily until the following May. No significant correlations between circulating estradiol or testosterone and SF-1 or SF1b were observed. Pituitary mRNA levels of SF-1 were approximately ten-fold higher than SF-1b levels; however, the seasonal patterns of expression were similar, with peak expression occurring at the start of the natural spawning season. A second increase in SF-1 and SF-1b expression was observed in September and August, respectively. Although, no correlations were observed between SF-1 or SF1-b levels and circulating steroid concentrations, the patterns of expression suggest roles for SF-1 and SF-1b at the start of seasonal ovarian development and again prior to final oocyte maturation.

49.8 SMART, T.I.; University of Oregon; *tsmart@uoregon.edu*

Tolerance of the Early Life History Stages of to Environmental Conditions: Possible Limits to Dispersal

Exposure to extreme environmental conditions has been shown to cause lethal and sub-lethal effects on survival and development in marine invertebrates, affecting both dispersal and abundance. is a tube-building polychaete found in mudflats and beaches both in temperate and tropical regions. Across its range, this species is exposed to a wide variety of environmental conditions that can be detrimental to the planktonic early life history stages. A description of the reproduction and early development of the Coos Bay, Oregon population will be presented. The effects of a range of temperatures and salinities on survival of embryos and larvae were investigated in the laboratory. Newly fertilized embryos and larvae were exposed to five temperatures from 5 to 30°C and survival and development success determined. Larvae were also exposed to four salinity treatments for 24 hours, after which survival was assessed. Temperate Oregon embryos and larvae did not survive high temperatures as well as expected, considering the geographic distribution of this species. However, these stages did survive temperatures comparable to those common during the reproductive season in this region. By comparison, both juveniles and adults showed much stronger tolerance to the extreme conditions possible in estuaries. Local adaptation of the planktonic stages of a marine species to environmental conditions may limit the dispersal capabilities of that species and its distribution and can serve to isolate populations, thus leading to speciation over time.

25.11 SMITH, A.M.*; WERNEKE, S.W.; SWANN, C.; FARQUHARSON, L.A.; HAMILTON, K.S.; Ithaca College; *asmith@ithaca.edu*

Gluing with an iron fist: crosslinking in molluscan adhesive gels

Many gastropod molluscs produce strong adhesion with soft, dilute gels. A major question is how such gels can become powerful adhesives. Previous research has identified specific glue proteins that appear to crosslink the gels and may be involved in interfacial adhesion, but the mechanism has not yet been identified. We studied the rapidly-setting defensive glue secreted by the slug *Arion subfuscus*. The proteins that constitute this gel are sensitive to the presence of iron. Atomic absorption spectroscopy on the dissolved glue and iron-specific stains on blots of the proteins show that the primary glue protein has iron bound at approximately a 1:1 molar ratio. This is the only protein in the glue that binds to iron strongly. Removal or binding of this iron with a high-affinity, iron-specific chelator shows that iron plays a major role in the function of the gel. Chelation of iron may inhibit the setting of the glue, as demonstrated by a marked increase in solubility when the chelator is added before the glue sets. Chelation also completely blocks the ability of the glue proteins to function in a gel-stiffening assay. This evidence suggests that iron associated with the glue proteins participates in crosslinking reactions that are essential for the mechanics and integrity of the gel. A mechanism involving iron could explain the ability to form strong, non-specific adhesion with dilute glues in an aqueous environment.

S4-1.3 SMITH, VAL H.*; SMITH, MARILYN S.; University of Kansas, University of Kansas Medical Center, Kansas City; *vsmith@ku.edu*

Effects of host nutrient supply on the outcome of infectious disease

In the context of human disease, nutrition is most commonly discussed primarily in terms of maintaining a proper diet and avoiding nutrient deficiencies. However, host nutrition can also be viewed from an ecological standpoint: plants, animals, and their associated pathogens share a wide range of resources that are required to support their metabolism, growth, and reproduction. After an infection occurs, all subsequent host-pathogen interactions in part depend upon the twin processes of resource acquisition and utilization, and competition for growth-limiting resources potentially can occur between pathogens and cellular components of the host ecosystem. Experimental studies of disease across a wide variety of host-pathogen systems confirm unambiguously that the supplies of both inorganic and organic nutrients to the host can have a profound effect on the outcome of infection by viral, fungal, and bacterial pathogens. It is argued that an ecological view of host nutrition potentially can help to inform biomedical, veterinary, and agricultural practices.

S4-1.1 SMITH, M.S.*; NIU, Y.; YANG, R.K.; TEFERA, P.; KELLY, J.K.; Univ. of Kansas Medical Center, Kansas City, Univ. of Kansas, Lawrence; *msmith6@kumc.edu*

Within-host evolution of non-pathogenic SHIV: positive selection of virus protein motifs coincides with CD4 loss.

We have used chimeric simian/human immunodeficiency virus infection of macaques for examining virus evolution within the host. Due to the rapid replication cycles and the total number of infected particles produced per day, and with a small genome size and an error-prone polymerase, this virus evolves very rapidly under selective pressures. Macaques were infected with a molecular clone of non-pathogenic SHIV virus to study within-host virus evolution. At 2.5 yr, we released in one animal the virus from immune control with anti-CD8 antibody. During virus rebound, blood from this animal was injected into two new macaques. Periodic plasma, biopsies, and blood cells were examined. We examined the sequence in these samples of the viral gene nef, important for disease progression. Clones of nef from early weeks from blood cells and plasma virus RNA were consistent with the rebound virus from the donor. Sequences from cerebrospinal fluid versus plasma showed evidence of distinct variants in the 2 compartments. Quantitative measures revealed higher viral expression in biopsies in one recipient, consistent with the higher plasma virus levels and greatly reduced CD4 cell counts, as in human HIV-1 infection. Both recipients lost CD4 cells to below 10, indicating onset of AIDS. We analyzed the nef sequences for positive selection using a maximum likelihood method, and compared the results with previous rapid-passage experiments using the same parental virus. We have examined the evolution of a clonal SHIV in the nef gene over time and in different compartments of the body, and found a correlation with an increase in pathogenicity.

30.6 SMITH, Moya M; KCL Dental Institute Guy\'s and St Thomas\' Hospitals; *moya.smith@kcl.ac.uk*

Building divergent dentitions by regulation of tooth addition

The dentition in each clade of gnathostomes is unique and shows great diversity in patterns for tooth addition and replacement, each adapted to a specific feeding niche. The formation of a sub-epithelial dental lamina promotes regulated tooth development with distinctive replacement patterns. The evolution of such a structure, judged essential to produce patterned teeth at the margins of the jaws, may have occurred independently in more than one gnathostome group and is not as classically thought, a conserved and plesiomorphic character of jawed vertebrates. This character teeth produced from a dental lamina' occurs more than once on a gnathostome phylogeny suggesting non-homologous developmental mechanisms. This may imply that the gene network necessary to regulate tooth patterning in mammals, assumed to be dependent on the dental lamina, could have evolved more that once. Teeth are capable of renewal in a specific spatial temporal pattern, reflected by an initial differential spatial temporal gene expression pattern. However, this pattern may also vary between dentate bones in the one dentition in bony fish, and tooth shape may also vary between upper and lower jaws in chondrichthyans. A universal developmental model has been suggested where all toothed fields start from a pioneer tooth on each bone or jaw, which autonomously regulates the pattern of tooth addition in the row and then subsequently for all successive replacement teeth in each family. Data on the development of tooth sites for succession of teeth either, without or from, a dental lamina in non-model animals from osteichthyans as well as chondrichthyans will be discussed. This may involve a mechanism for retaining a localised progenitor cell population for continuous tooth renewal deep to the oral surface and is considered essential to regulate tooth addition to each specific pattern.

52.6 SNELL-ROOD, Emilie C; Univ. of Arizona; *emilies@email.arizona.edu*

Phenotypic plasticity and the origin of novel traits: butterflies modify behavior and morphology in response to a novel environment

The origin of novel traits may allow organisms to expand into previously unfilled ecological space. Phenotypic plasticity, especially those forms occurring through somatic selection (trial-and-error) mechanisms, may facilitate the origin and stabilization of novel traits as organisms are exposed to novel environments. However, plasticity may come at a significant cost, specifically delays in reproduction associated with a learning-like developmental process. This research investigates why there is variation in the ability to express novel phenotypes to cope with novel environments. I test the prediction that more plastic genotypes will be more likely to produce appropriate behavior, physiology, and morphology in response to a novel resource, but this ability comes with reproductive costs. I present preliminary evidence that butterfly genotypes vary in their ability to learn to recognize a novel host plant, specifically, a red-colored host plant, which differs from their innate preference for green hosts. These genotypes also vary in developmental changes in neural and reproductive morphology associated with exposure to the novel resource. Understanding why organisms vary in their ability to cope with novel environments through the expression of novel traits is crucial to predicting how organisms will cope with rapid environmental change.

S1-3.16 SOCHA, J.J.**; WATERS, J.S.; WESTNEAT, M.W.; LABARBERA, M.; COOK, S.; FEZZAA, K.; LEE, W.K.; Argonne National Laboratory, Arizona State University, Field Museum, University of Chicago, University of Utah; *jjsocha@midway.uchicago.edu*

The Poise that refreshes: dynamics of internal food transport in a butterfly

Butterflies feed by sucking fluids through a long, cylindrical proboscis using a cibarial pump in the head. Although much is known about feeding rates and anatomy involved in digestion, little is known about the dynamics of food transport due to the previous inability to see inside the living animal. In this study, we use synchrotron x-rays to visualize internal food transport in living butterflies. Experiments were conducted at the 32-ID beamline at Argonne National Laboratory's Advanced Photon Source. Fasted cabbage white butterflies (*Pieris rapae*, N=40) were mounted by the wings and allowed to feed on a radio-opaque sugar water / iodine compound (Isovue) mixture. Effects of fluid viscosity were tested by varying the percentage of both solutions. To visualize the food, we used 33.3 keV monochromatic x-rays tuned for the K-edge absorption band of iodine. During feeding, butterflies moved food into the head using a two-stage pumping mechanism. In the first stage, food is drawn into the cibarium by suction, with the cibarial chamber expanding dorsally; in the second stage, the chamber contents are emptied into the esophagus by positive displacement. Fluid was transported in boluses that remained discrete, discontinuously filling the foregut. A typical bolus of 5 nl volume expanded the esophagus to a diameter of 90 µm and traveled at a speed of 2.8 mm/s through the thorax, implying that bolus transport was dominated by viscous forces (Re ~0.5). Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Office of Science, Basic Energy Sciences, under Contract No. W-31-109-Eng-38.

33.6 SOCKMAN, K.W.*; Univ. of North Carolina, Chapel Hill; *kws@unc.edu*

Growth and survival consequences of ovulation order among sibling Lincoln's sparrows

The asynchronous production of offspring may affect offspring viability, due to a potential sibling hierarchy established by competing siblings of unequal age and due to variation in parental provisioning relative to ovulation order. Using a population of free-living Lincoln's sparrows (*Melospiza lincolnii*) breeding in a subalpine meadow near Molas Pass, Colorado, USA, I examined the growth and survival consequences of ovulation order among sibling nestlings. Ovulation order almost perfectly predicted hatching order, thus enabling the use of hatching order to infer ovulation order. Although I found no evidence that either egg volume or hatchability were related to ovulation order, ovulation order strongly influenced nestling survival, with survival of late-ovulated offspring much lower than that of early-ovulated offspring. Late ovulated offspring that survived to approximately fledging were lighter than their earlier ovulated siblings, and this was due to differences in nestling growth rate and possibly hatching mass. Regardless of their adaptive significance for the parents, these growth and survival consequences of ovulation order would seem to have strong implications on the relationship between sibling ovulation order and fitness and raise the possibility that one major source of fitness variation among individuals may stem from ovulation order.

51.2 SOTO, W.*; NISHIGUCHI, M.K.; New Mexico State Univ., Las Cruces; *wisoto@nmsu.edu*

Microbial Experimental Evolution in the Bobtail Squid-Vibrio Model System

The mutualism between sepiolid squids (Cephalopoda: Sepiolidae) and their bioluminescent symbionts (Genus *Vibrio*) has become an experimentally tractable system for physiological, evolutionary, molecular, and ecological studies of symbiotic relationships. Since the squid host and their symbionts can be grown and maintained independently of each other in the laboratory, this association is feasible to empirical manipulation, including studies examining differences between closely related host-symbiont pairs. Previous research has shown that native strains of *Vibrio fischeri* will out-compete non-native ones isolated from different host species when competitive colonization experiments are conducted in the indigenous host. Since previous experimental evolution studies with microorganisms have revealed that adaptation can be observed relatively quickly, we propose a direct approach using experimental evolution to identify symbiotic and ecological loci by evolving non-native *V. fischeri* through a foreign *Euprymna* species for 500-750 generations. Since a frozen fossil record of symbionts can be generated, the evolving non-native clone has been monitored every 50-100 generations to determine if its competitive ability has improved relative to native strains of *V. fischeri*. In addition, the relative competitive ability of the derived non-native strain has been compared to the ancestral one to determine if fitness has improved through adaptation. This research addresses the potential of *V. fischeri* populations to expand into novel host ranges and whether non-native bacterial populations can displace native ones in a particular geographical area.

9.1 SPAGNA, J.C.*; PATEK, S.N.; VAKIS, A.I.; SUAREZ, A.V.; University of Illinois, Urbana-Champaign, University of California, Berkeley; *jspagna@uiuc.edu*

Extreme forces and jaw size variation in trap-jaw ants

The trap-jaw ant *Odontomachus bauri* (Formicidae: Ponerinae), produces the fastest self-propelled animal prey strikes known to science, averaging 38.4 m/s. The workers of this species use their mandibles for both trapping prey and propelling themselves into the air or away from danger. However, there is notable interspecific variation in workers' head, body, and mandible size and shape among the 64 species of this genus. Here we test the hypothesis that morphological variation across several *Odontomachus* species *O. bauri, O. haematodus, O. erythrocephalus, O. clarus and O. brunneus* is coupled with differences in jaw kinematics in terms of speed, acceleration, and force. We video recorded jaw-snaps of these species at 50,000-84,000 frames per second, and tracked the jaw movements to measure these parameters. Though speed might be thought to be a critical variable in such a high-speed system, differences in maximum tangential speed and maximum acceleration differed little between species (mean speed across all species = 38.9 m/s, S.D. 14.0 m/s, mean maximum acceleration $2*10^6$ m/s/s, S.D. $1*10^6$ m/s/s). However, given the nearly two-fold range of jaw mass and length between species (minimum 0.07 mg, 0.9 mm for *O. clarus*, maximum 0.17mg and 1.5 mm for *O. erythrocephalus*), with similar speeds and accelerations, the larger-jawed ants produce greater maximum jaw forces, ranging from 42 mN for *O. clarus* to 198mN for *O. erythrocephalus*. This increased force exceeds differences in body mass and predicts increases in jaw-performance during multiple behaviors, including escape jumps, prey-ejection, and predatory strikes in larger *Odontomachus* species.

26.5 SPEISER, D. I.*; SWEENEY, A. M.; JOHNSEN, S; Duke University; *dis4@duke.edu*

Scallops respond to simulated particles in flow

Scallops' eyes are abundant in number and positioned along the mantle at the edges of the valves. These eyes can form relatively high-resolution images, and their morphology and optics have been well-studied, but the function of scallop vision remains unknown. We tested whether scallops, which are filter feeders, use their eyes to detect suspended food particles. Specimens of the Common Bay Scallop *Argopecten irradians* were placed in an operating flow tank and shown videos of moving particles. Their mantle gapes were then observed at 24 second intervals over ten minute trials. We found that 25 *A. irradians* were open in 52% +/- 6% of observations when particles were shown, while 24 scallops viewing a blank screen were open in 29% +/- 5% of observations. The difference between these treatments was found to be significant (P

S1-3.13 SPENCE, Andrew J.*; REVZEN, Shai; YEATES, Kyle; MULLENS, Chris; FULL, Robert J.; Univ. of California, Berkeley; *aspence@nature.berkeley.edu*

Insects Running on Compliant Surfaces

Human runners and hoppers attempt to adjust their leg stiffness to maintain similar center of mass (COM) dynamics when confronted with a compliant substrate. Dynamic materials testing of cockroach legs shows that their behavior in the sagittal plane is largely determined by passive exoskeletal properties. We tested the hypothesis that rapid running cockroaches maintain their COM mechanics by compensating for a compliant substrate. Cockroaches *Blaberus discoidalis* ran from a rigid Plexiglas surface onto an elastic substrate of stiffness (8-13 N/m) equal to 2/3 its virtual leg spring stiffness (15 N/m for all three legs of a tripod). We directly measured the animal's COM dynamics using a novel 3-axis, MEMs accelerometer configured as a backpack placed near its COM. Vertical acceleration of the COM on the elastic surface had smaller peak-to-peak amplitudes (9.3 ± 0.012 m/s^2, n = 374 steps on elastic substrate, vs. 12 ± 0.007 m/s^2, n = 879 steps on rigid substrate; p

10.3 SPERLING, Erik/A*; PETERSON, Kevin/J; Yale University, Department of Geology and Geophysics, Dartmouth College, Department of Biological Sciences; *erik.sperling@yale.edu*

Poriferan paraphyly and its implications for Precambrian paleobiology

Well-supported molecular phylogenies combined with knowledge of modern biology can lead to new inferences about the sequence of character acquisition in early animal evolution, the taxonomic affinity of enigmatic Precambrian and Cambrian fossils, and the Proterozoic earth system in general. In this study we demonstrate, in accord with previous molecular studies, that sponges are paraphyletic with calcisponges more closely related to eumetazoans than they are to demosponges. In addition, our Bayesian analysis finds the Homoscleromorpha, previously grouped with the demosponges, to be even more closely related to eumetazoans than are the calcisponges. Hence there may be at least three separate extant poriferan lineages each with their own unique skeleton. Because spiculation is convergent within Porifera, differences between skeletonization processes in enigmatic Cambrian taxa such as *Chancelloria* and modern sponges does not mean that these Problematica are not organized around a poriferan body plan, namely a benthic, sessile organism feeding with a water canal system. The shift from an anoxic and sulfidic deep ocean that characterized the mid-Proterozoic to the well-ventilated Phanerozoic ocean occurs before the evolution of planktonic bilaterian predators, and cannot have been caused by the advent of fecal pellets. The evolution and ecological dominance of sponges provide an alternative mechanism for the drawdown and sequestration of dissolved organic carbon within the sediment.

S1-3.10 SPONBERG, S.*; SPENCE, A.; MULLENS, C.; FULL, R. J.; Univ. of California, Berkeley; *sponberg@berkeley.edu*

Effect of Rewriting the Neural Code to Muscles in Running and Stationary Insects.

While recent studies on isolated muscles discovered that single muscles can perform a variety of functions, we lack an understanding of how motor activation patterns are decoded through the musculo-skeletal system to affect animal locomotion. Here we define the control potential, termed **effective field** to parallel sensory neuron receptive fields, of individual muscles during two typical behaviors, station-keeping and running. We added direct muscle stimulation (spikes) in a phase-locked manner to muscles in behaving cockroaches, (*Blaberus discoidalis*) while measuring their dynamics using a 3-axis microaccelerometer backpack and videography. To modulate the neural code in behaving animals, we chose muscle 137, a femoral extensor of the middle leg because of its likely role as a control muscle. We measured the mechanical response to four naturally observed activation profiles. Activation of muscle 137 leads primarily to roll and lateral velocity responses with accelerations in the vertical and lateral directions (p

S1-3.15 SPRAYBERRY, Jordanna D. H.*; SUVER, Marie; Univ. of Arizona, Tucson, Univ. of Washington, Seattle; *jspray@neurobio.arizona.edu*

Innate preferences for flower motion dynamics in the hovering hawkmoth Manduca sexta

Hawkmoths are hovering feeders that meet the challenge of flower motions by exhibiting a compensatory tracking behavior. Previous work has shown this tracking behavior to have distinct tuning, with the hawkmoth *Manduca sexta* being best able to track flowers moving at 1 Hz in the horizontal and vertical axes. *M. sexta* were consistently poorer at tracking flowers in the looming axis (towards and away from the moth). Interestingly, when looking at how well *M. sexta* fed from moving flowers there was not a strong correlation between feeding and tracking performance. While *M. sexta* had the highest energy gain from stationary control flowers, there were minimal effects of frequency of flower motion on energy gain. However, *M. sexta* did have a much lower energy gain when feeding from flowers in the looming axis. To determine if there is a link between *M. sexta*'s innate flower-motion preferences and their energy gain, naïve moths were offered a choice between two flowers with different motion dynamics. Three different comparisons were made: 1) horizontal vs. looming flowers, 2) stationary vs. 1 Hz flowers, and 3) 0.5 Hz vs. 1 Hz flowers. *Manduca sexta* showed a distinct preference for horizontally moving flowers (p0.1) and a very weak preference for 0.5 Hz flowers (p=0.07). These data indicate that *M. sexta*'s feeding preferences do mimic their energetic performance.

S1-3.14 SRINIVASAN, Manoj; Princeton University, Princeton; *msriniva@princeton.edu*

Bipedal Running: "No muscle work and all tendon play" is energetically beneficial even with an energy cost for isometric force production.

Muscles consume energy whether or not they perform work, as long as they exert a force while active. An energy-economizing animal will presumably minimize its total metabolic expenditure during locomotion, rather than minimizing, say in particular, the mechanical work performed or the force exerted. However, the major muscles that produce forces during stance in running turkeys do little mechanical work --- most of the positive and negative work required to redirect the center of mass velocity seem to be provided by the passive stretch and recoil of elastic tendons. This strategy superficially seems coincident with minimizing stance work. However, it is not clear why an animal would prefer to minimize just the muscle work, while the close-to-isometric muscles do expend metabolic energy as they need to provide a force that is equal at all times to the force in the series tendons. Here we use a simple mathematical model of a bipedal animal: one consisting of a point-mass body and legs with a telescoping actuator (muscle) and a series spring (tendon), to study the overall energetic optimality or otherwise of this strategy. We set up a mathematical optimization problem to minimize a few simple models of energy expenditure (during stance) that penalize isometric force as well as mechanical work. For a range of parameters of these simple models, we find that the minimization of the overall cost is indistinguishable from minimizing mechanical work alone. That is, the optimal locomotion strategies in these idealized models involved little or no muscle work and only tendon work, as observed in real animals. As a result, in these optimal locomotor strategies, the total metabolic cost during stance seems to be dominated by the metabolic cost for the production of isometric force, as also suggested by various experiments.

39.5 STAAB, KL*; SUMMERS, AP; STROTHER, JA; VAN WASSENBERGH, S; George Washington University, UC Irvine, University of Antwerp, Belgium; *kstaab@gwu.edu*

The Scaling of Suction Feeding

We measured suction performance in a size series of great sculpin, *Myoxocephalus polyacanthocephalus*, to test hypotheses predicting the scaling of negative pressure. Two theoretical models of suction generation in fishes predict measured pressures with acceptable accuracy; however they differ in their prediction of the scaling of negative pressure in an isometrically growing fish. Maximal suction performance of 12 sculpins ranging from 164mm to 337mm standard length and 85 to 710 grams was used both as a metric of performance and to estimate timing variables needed as input for the theoretical models. We also measured buccal volume using silicone casts of both the relaxed and expanded buccal cavities in each fish. We compared the casting data to data inferred by modeling the buccal cavity as a series of truncated cones with diameters measured from the cast. Estimated volumes were consistently lower than actual volumes and just five joined truncated cones gave a volume within 10% of the volume estimated from 100 truncated cones. The pressure generated during feeding does not change significantly as this sculpin grows, however the buccal volume grows allometrically. We estimated the power generated during feeding events both by taking the product of pressure and volume over the feeding event and by multiplying the surface area of the buccal chamber, the change in pressure, and a calculated velocity of the feeding events. We found that power scales approximately with the square of length. Our data on suction pressure support the hypothesis that pressure is size invariant, which raises the prospect that for relatively isometric species, measurements from an individual can summarize performance of the ontogenetic series.

66.6 STAHLSCHMIDT, Z.R.**; DENARDO, D.F.; HOFFMAN, T.C.M.; Arizona State University; *zs@asu.edu*

Implications of brooding python postural changes on embryonic gas exchange and water loss

Female pythons typically coil tightly around their eggs throughout the incubation period (40-80 days). While this behavior has been shown to provide thermal and hydric benefits to the clutch, it may also restrict embryonic gas exchange. To address this possible trade-off, we hypothesized that brooding female pythons occasionally relax their posture to expose some of the clutch and thus promote embryonic gas exchange at a short-term cost to water conservation. Brooding Children's python (*Antaresia childreni*) underwent 24-hour trials during which we continually measured gas exchange and water loss while monitoring changes in brooding posture via an infrared digital camera. Trials were conducted during both early (mean = 16% of post-oviposition development) and late (mean = 73%) periods of incubation to elucidate the effect of embryonic metabolic rate on postural adjustments. After each trial, eggs were separated from the brooding female, and clutch and female gas exchange and water loss were measured independently. Results demonstrated that brooding reduced water loss from the clutch by 99%. Analysis of behavioral data indicates that a slight adjustments in posture, and thus minor exposures of the apex of the clutch, lead to significant bursts of CO2 release, O2 consumption, and H2O loss. Additionally, embryonic gas exchange increased nearly threefold between early and late measurements, while brooded clutch evaporative water loss was maintained at a relatively constant rate. Together, these findings imply that brooding pythons provide an adjustable diffusive barrier that leads to discontinuous gas exchange which minimizes clutch water loss.

S1-2.3 STANDEN, E.M.; Harvard University; *standen@fas.harvard.edu*

Finfull thoughts: does pelvic oscillation influence anal fin action in fishes?

Fish must balance torques around their centre of mass to control their body position. Recent kinematic and hydrodynamic studies on trout median fins show that dorsal and anal fins in trout appear to produce forces that balance rolling torques during swimming. Dorsal and anal fins oscillate with a large phase lag, yet the lateral jets produced by the fins have a small phase lag. This means fins release their jets at a similar time but at different points in their oscillation cycle. Dorsal fins release jets after they reach maximum excursion and anal fins before maximum excursion. Differences in incident flow experienced by each fin may contribute to different jet release timings between fins. Trout have two sets of paired fins located upstream of the median fins. The ventral location of paired fins means that the wake they produce could influence the flow surrounding the ventral anal fin. To date the kinematic or hydrodynamic function of the posterior paired pelvic fins has not been described. In this study I use particle imaging velocimetry and high-speed cameras to visualize the wake structures and kinematics of the pelvic fins in brook trout (*Salvelinus fontinalis*). I use a horizontal light sheet to visualize the entire fish belly and describe how the pelvic fin wake interacts with the anal fin during swimming. Trout oscillate their pelvic fins in phase with the tail beat cycle, one fin abducting while the contralateral fin adducts. The contralateral oscillation of the pelvic fins produces distinct lateral jets that appear to influence and contribute to the anal fin wake structure, possibly enhancing anal fin hydrodynamic function.

14.4 STARCK, J.M.; Univ. Munich, Germany; *starck@uni-muenchen.de*

Functional morphology of the python heart

Snakes, like all other ectotherm sauropsids, have a complicated heart anatomy, with five functional chambers: left and right atrium, the Cavum arteriosum, the C. venosum and the C. pulmonale. The C. venosum and C. pulmonale are connected by a wide opening, but, during ventricular systole, are functionally separated by a muscular ridge. The C. arteriosum has no arterial exit but ejects oxygenated blood through an intraventricular canal into the C. venosum and C. pulmonale. A current functional hypothesis suggests that the muscular ridge acts as central shunt that directs oxygenated blood from the C. arteriosum into the left and right aorta, and deoxygenated blood from the right atrium through the C. pulmonale into the pulmonary artery. The direction of the shunt supposedly is condition dependent (e.g., hypoxic vs normoxic; digesting vs fasting). I have studied the functioning of the heart of ball python (*Python regius;* N=6 adult individuals) by (I) investigating the specific heart anatomy by macroscopic dissections and microscopic anatomy, and (II) by using non-invasive Doppler-ultrasonography to record direction, velocity, and volume of the blood flow during the heart cycle, and in different physiological conditions of the snake, i.e., fasting vs. digesting. Oxygen consumption of the snakes was recorded simultaneously to the Doppler-ultrasonography by open flow respirometry. The dynamic functioning of the muscular ridge and the arterial valves, the pattern of blood flow in the heart, and the separation of the blood stream into the three major arteries are described using real time Doppler-ultrasonography records from live snakes. Quantitative measures of blood flow volume in the left and right aorta, and in the pulmonary artery are given for fasting and digesting snakes. The functional significance of the muscular ridge and concepts of central shunting are discussed.

30.4 STAYTON, C.T.; Bucknell University; *tstayton@bucknell.edu*

A combined analysis of variation in skull shape and feeding kinematics in five turtle species

Organismal morphology and kinematics interact to produce complex behaviors; however, morphological and kinematic data have traditionally been analyzed separately using different techniques. Here, I present a joint study of the morphology and kinematics of a relatively simple behavior: turtle biting during feeding. Skull morphology and biting kinematics were studied in 5 species of turtles: *Chrysemys picta, Sternotherus odoratus, Glyptemys guttata, Graptemys kohnii,* and *Trachemys scripta*. Each species overlaps with the others in some part of its geographic range save *G. guttata/G. kohnii*. Variation in skull morphology was studied using geometric morphometric techniques on a large data set of preserved skulls. High-speed video was taken of turtles feeding, and kinematic variation was studied using Procrustes motion analysis. These turtles show significant amounts of overlap in both morphology and kinematics, especially among the relatively closely related Emydids (i.e., it is difficult to discriminate the species based on skull shape or kinematics alone). However, when both morphological and kinematic data sets are combined, the observed overlap decreases. An integrated analysis of both types of data can provide valuable information about the evolution and integration of organismal form and function.

55.2 STEFFEN, John E*; MCBRAYER, Lance D; Auburn University, Georgia Southern University; *steffje@auburn.edu*

UV-based dewlap color correlates with bite force in the Brown Anole, Norops sagrei.

Weapon strength should be conveyed in correlated visual signals if they confer advantage to visual signal senders and receivers. This should especially be true in species that experience strong male-male competition. *Anolis* lizards are well known for their territorial behaviors in which males display visually striking and colorful dewlaps, and for which male-male competition is thought to be a very strong selective force. In many anoles, biting is used by males to pacify females during copulation, as well as inflict wounds on competing males. Biting is generally thought to be an important male behavior because it can create a painful wound that may ultimately affect the recipients fitness by causing death. We analyzed aspects of carotenoid and pterin based dewlap color in relation to male body size, dewlap size and bite force in the Brown Anole (*Norops sagrei*). We found that male body size positively related to ultra-violet (uv) dewlap color but did not relate to dewlap size or bite force. We assessed male dewlap colorfulness by creating a composite score that accounted for an individual's dewlap size, percent of dewlap area colored by pterins vs. carotenoids, and the saturation of color produced by each pigment in different dewlap regions. Our results showed that bite force related positively with dewlap uv color scores but did not relate to dewlap size. These results suggest that ultra-violet dewlap color may convey information about bite force, and that carotenoid pigments may advertise weapon strength in *Norops sagrei*.

S1-1.13 STEWART, W.J.*; BARTOL, I.K.; Old Dominion University, Norfolk, VA; *wstew003@odu.edu*

Locomotive fin function of brief squid Lolliguncula brevis

Although the pulsed jet is the foundation of a squid's locomotive system, the lateral fins also play an important role in swimming, potentially providing thrust, lift, and dynamic stability. Fin morphology and fin movement vary greatly among squid species, but direct data on the locomotive forces produced by complex fin motions are lacking. To begin to elucidate the locomotive role of the fins in squids, we examined fin dynamics and kinematics in the brief squid *Lolliguncula brevis* using digital particle image velocimetry (DPIV) and high-speed videography, respectively. During experimental runs, *L. brevis* swam freely against currents in a water tunnel, while a motorized traverse system was used to move the laser sheet and/or three cameras to keep pace with movements of the squid. Fin amplitude, beat frequency, and undulatory motions generally decreased with swimming speed, with the fins serving primarily as stabilizers at the highest speeds. Preliminary DPIV data indicate that both lift and thrust are produced by the fins, especially at low speeds, and vortex features generated during upstrokes and downstrokes correlate closely with swimming speed.

20.6 STRAND, C.R.*; DEVICHE, P.; Arizona State University, Tempe; *christy.strand@asu.edu*

Temporal effects of testosterone treatment on song control region growth in adult male House Finches

In adult male songbirds, increases in circulating testosterone (T) levels and singing behavior induce the growth of specific brain regions that control singing behavior (song control regions; SCRs). However, in some species this growth occurs early in the breeding season, before significant changes in singing behavior occur and before maximal T levels are reached. Furthermore, birds in captivity have shown maximal growth of one SCR, the HVC, after one week of T treatment. The growth of the HVC is partially due to an increase in neuron number. To investigate the timing of the effect of T on the growth of the SCRs and singing behavior in adult male House Finches (*Carpodacus mexicanus*), we divided the birds into three groups: (1) Control group no T; (2) 14 days of T treatment (14T); and (3) 21 days of T treatment (21T). To quantify singing behavior, birds were observed for 1 hour every other morning beginning on the fourth day of the experiment. Singing behavior was rare and was not influenced by T treatment. SCR volumes were larger than controls in the 21T group, while the 14T group was not different from either group. Similarly, there were more neurons in the HVC in the 21T group compared to controls, but not in the 14T group. SCR growth appears to occur slower in adult male House Finches in captivity, than in other species investigated. The rapid growth in other species is likely dependent on the combination of increased T and singing. The attenuated effect of T in the present experiment may be due to the lack of singing behavior. Thus, our results demonstrate effects of T on SCR growth independently of increases in singing behavior, which may help to identify the mechanisms of T alone on SCR growth.

S1-5.2 STROTHER, J.A.; Univ. of California, Irvine; *strother@uci.edu*

The effects of morphology on gill ventilation

The gills of teleost fish have often been described as a counter-current exchanger, where water flows through the gills in the opposite direction to that of blood flow within the gills. Such counter-current exchange depends strongly on the spatio-temporal pattern of flow through the branchial cavity. Surprisingly, the flow patterns that develop around and irrigate the gills are not well understood. Is the flow of water through the gills uniform along their length, or do different regions of the gills experience different levels of irrigation? How does gill morphology affect the uniformity of the pressure gradient or the shunting of water around the gills? I addressed these questions by developing a computational fluid dynamics model of the water flow around the gills of a teleost fish. The gills were modeled as orthotropic porous structures whose porosity was calculated using an analytical model of the flow through the secondary lamellae. The model geometry was based on measurements of morphological parameters in the killifish *Fundulus heteroclitis*. The computational model predicts that the pressure gradient across the gills, and thus the flow of water through the gills, decreases to near-zero at the distal tips of the primary lamellae. Additionally, model calculations show that morphological differences generate functionally significant heterogeneity in the pressure gradient and shunting of water around the gills.

1.3 STRUCK, Torsten H; University of Osnabrueck, Osnabrueck, Germany; *struck@biologie.uni-osnabrueck.de*

Nuclear Genes and Phylogeny of Lophotrochozoa

Well-corroborated hypotheses explaining the relationships within Lophotrochozoa are still lacking and thus their phylogeny can be regarded as unresolved. Lophotrochozoa comprises at least Mollusca, Annelida, Brachiopoda, Phoronida and Bryozoa and the taxon name refers to the possession of either a lophophorate or trochophore feeding apparatus. Several other taxa like Sipuncula, Nemertea, Kamptozoa, Rotatoria and Platyhelminthes are also discussed to belong to the taxon. For example, due to molecular phylogenetic analyses based on the nuclear small and large ribosomal genes the inclusion of Sipuncula within Annelida as well as of Phoronida within Brachiopoda appears to be likely, but is not significantly supported. Herein I assess the utility of nuclear protein coding genes like Aldolase, Myosin II Heavy Chain or Methionine Adenosyltransferase, which have been used to address metazoan phylogeny, but not lophotrochozoan relationships. In contrast to ribosomal genes, protein-coding genes are usually unambiguously to align and thus position homology is given with higher certainty. Besides the nucleic acid sequences amino acid sequences can be exploited for phylogenetic reconstructions. Together with the ribosomal genes larger combined data sets can be established to overcome the bad signal to noise ratio in single or few gene phylogenetic reconstructions of Lophotrochozoa.

S7-2.2 STUART, D.G.; University of Arizona, Tucson; *dgstuart@u.arizona.edu*

Reflections on integrative and comparative approaches in movement neuroscience

Integrative movement neuroscience involves blending "inside-out" and "outside-in" approaches in the study of posture and movement. The former is characterized by determining the properties of single cells within the central nervous system (CNS) and then testing for how these properties influence the operation of CNS microcircuits, single reflexes, groups of reflexes, and central pattern generators. This information is then used to theorize on CNS control of overt motor behavior. In contrast, the outside-in approach begins with analysis of the biomechanics of posture and movement and then uses this information to theorize on how the mechanics are solved by the CNS and its pathways, circuitry, and even single cells. Studies conducted in the 1960s on the locomotion of brain-stimulated decerebrate cats together with in-parallel advances in the study of locomotor pattern-generating CNS circuitry in several invertebrate and vertebrate species have led to a convergence of outside-in and inside-out understanding of the neural control of locomotion in invertebrates, non-mammalian vertebrates, and mammalian vertebrates, including even humans. This convergence of integrative and comparative approaches has been facilitated by modeling and simulation studies. These developments have important implications for PhD and postdoctoral training programs in movement neuroscience. They can profit greatly by use of a multidisciplinary university-wide faculty that places a strong emphasis on integrative and comparative biology. Furthermore, the next generation of movement neuroscientists will require more familiarity with modeling and simulation theory and techniques than are being provided in most current training programs.

9.4 SUSTAITA, Diego*; HERTEL, Fritz; University of Connecticut, California State University, Northridge; *diego.sustaita@uconn.edu*

Bite and grip performance in relation to killing behavior of North American accipiters and falcons

Raptors exhibit a wide diversity of attack strategies to disable and/or procure their prey, but ultimately kill using either their beaks or talons, or both. Thus, bite and grip forces are ecologically important parameters that have direct implications for their subsistence. Whereas falcons tend to rely heavily on their beaks for killing, most hawks primarily use their feet. Consequently, falcons are expected to achieve relatively greater bite forces, and conversely hawks are expected to generate relatively greater foot forces. The primary objective of this study was to complement results based on anatomical force estimates produced in a previous study, with direct measurements of actual bite and grip performance. To this end, captive and wild-caught accipiters and falcons were induced to bite and grasp modified electronic load cells. Our results indicate that falcons tend to bite significantly harder than accipiters, and accipiters grip significantly harder than falcons for any given body mass, but by a smaller margin. Furthermore, bite force tends to increase isometrically with body mass in both groups. Grip force, however, increases allometrically in accipiters, but does not differ from isometry in falcons. The anatomically-derived measurements of force tended to overestimate the actual performance measurements, but the two are correlated, and therefore these data provide an important link between morphology and killing behavior in these raptors.

39.7 SWANSON, B.O.*; HAYASHI, C.Y.; Gonzaga University, Univ. of California, Riverside; *swansonb@gonzaga.edu*

Stretchy, sticky and strong: evolution and ecology of spider capture fibers

Spider silk provides an excellent model for examining connections between the properties of biological materials and organismal ecology. Orb-weaving spiders spin sticky capture threads that are made of exceptionally extensible and strong materials, resulting in tough fibers thought to be adapted for arresting flying insects by dissipating their kinetic energy. Using tensile testing, we ask whether this material is variable across spider species and whether we can discern patterns in the evolution and ecology of spider capture silks. The material properties of the capture spiral vary greatly across species. Extensibility, strength and toughness all differ up to approximately 6-fold across species. These material differences, along with differences in fiber size, dictate that the mechanical performance (energy and force required to break the fiber) of capture threads varies by more than an order of magnitude across species. Material properties can also be evolutionarily correlated. Species with small diameter fibers tend to have tougher materials, suggesting compensation to maximize breaking energy. There is also a negative correlation between strength and extensibility, suggesting a trade-off between these properties. The different properties of these capture silks help define feeding niche by determining the range of prey that can be caught in an orb web.

S6-2.2 SWANSON, WJ*; AAGAARD, J; CLARK, N; University of Washington; *wswanson@gs.washington.edu*

Adaptive Evolution and Coevolution of Sperm - Egg Recognition Molecules

The molecular basis of speciation remains one of the outstanding questions in evolutionary biology. Recent studies have indicated that the rapid evolution of reproductive proteins may be involved in reproductive isolation and speciation. I will discuss characterizing egg coat proteins and interacting male-female reproductive proteins in abalone (genus Haliotis), a system for which many of the molecular details of fertilization are well established and one that serves as a model for the study of speciation by the rapid evolution of reproductive molecules. I will show that the rapid evolution of both sperm and egg gamete recognition molecules is promoted by positive selection, and provide statistical evidence of the co-evolution of the genes encoding these molecules.

S3-1.2 SWEENEY, A*; JOHNSEN, S; Duke University; *ams27@duke.edu*

Evolution of High-Acuity Vision in Coleoid Cephalopods

Spherical lenses with a graded refractive index design are required for camera-like vision in aquatic animals. In cephalopods, these lenses are made of a group of closely related proteins collectively called S-crystallins. Our earlier work has shown that an adaptive radiation these S-crystallin genes and positive selection on the electrostatic properties of S-crystallin proteins led to a graded refractive index lens capable of forming high-resolution images in the squid *Loligo opalescens*. In the *L. opalescens* lens, S-crystallins with high charge stabilize the optical properties of regions of low refractive index in peripheral layers, and S-crystallins with lower charge are tightly packed in the high refractive index cortex. The mechanistic link between S-crystallin sequence, biochemistry and refractive index allows us to understand in molecular detail the optical evolution of a camera-like eye in cephalopods. To understand the transition from ancestral cephalopod vision to extant camera-like vision in coleoid cephalopods, we used techniques from molecular evolution, biochemistry, molecular dynamics, optical modeling and image analysis. We sequenced 600 S-crystallin genes from most major coleoid taxa, constructed a gene tree from these sequences and analyzed it for patterns of charge evolution. We also measured the optical quality of these lenses by calculating their modulation transfer functions (MTFs). Our gene tree suggests that high-resolution lenses evolved from a low-resolution ancestor multiple times within the coleoid cephalopods. Consistent with our gene tree data, our MTF data show that there is taxonomic variation in lens quality within coleoid cephalopods. We will discuss the correlations between independent adaptive radiations of S-crystallin molecules, high acuity vision in cephalopods and possible evolutionary scenarios in which these changes in visual acuity may have been occurring during the Jurassic radiation of squid.

32.1 SZAFRANSKA, Paulina A.*; ZUB, Karol; KONARZEWSKI, Marek; SPEAKMAN, John R.; Mammal Research Institute Polish Academy of Sicences, Mammal Research Institute Polish Academy of Sicences and Univesity of Bialystok, University of Aberdeen; *pszafran@bison.zbs.bialowieza.pl*

Seasonal variation in Resting Metabolic Rates (RMR) and Daily Energy Expenditures (DEE)

The relationship (if any) between daily energy expenditures (DEE) and RMR is still open to debate. We measured seasonal variation of DEE and RMR in the same free-ranging individual weasel males - small predator characterized by a considerable variation in body mass (range 40g 150g). DEE and RMR varied in concert among seasons. They were lowest in winter and significantly higher in spring and summer. Most important predictor of DEE was daily activity time followed by body mass. Ambient temperature affected DEE indirectly through its positive correlation with daily activity time. On the other hand, body mass explained most of the variation in RMR, which was less affected by activity time and ambient temperature. In the whole annual cycle RMR was positively correlated with DEE. However, the correlation was not significant within seasons. We conclude that between-season variation in both RMR and DEE was high enough to resolve the correlation between them. However, within-season variation was insufficient to demonstrate the correlation.

25.9 SZARKO, M.J.**; BERTRAM, J.E.A.; University of Calgary; *mjszarko@ucalgary.ca*

Freeze-Thaw Treatment Alters Articular Cartilage Dynamic Behaviour

Recent development of new procedures aiming to combat osteoarthritis has placed an importance on articular cartilage for tissue transplant. The general assumption of freezing not altering the mechanical properties of cartilage has caused many protocols to involve freezing for storage convenience. However, evidence for this is derived from loading at relatively low loading rates. In this study we investigate mechanical property changes induced by the freeze-thaw process for both near-static (0-25 Hz) and dynamic (10-119 Hz) loading. Effects of different freezing protocols are also assessed. Osteochondral dowels (8mm dia.) from mature bovine tibiae were harvested and split into four freezing temperature groups: 4, -20, -80, and -196 degrees C. Specimens were hydrated with PBS, brought to storage temperature, then thawed (4 degrees C) before testing at 22 degrees C. Two spectra of compressive loading rates (0-200 Hz and 0-25 Hz) were applied as a sinusoid. Waveform frequencies utilized a chirp' function, comprising equal amplitude sine waves periodic in the time record over the full frequency spectrum. Loading was non-destructive and low amplitude (0.1 MPa). Complex moduli were determined from storage and loss moduli generated from transducer and force beam comparisons and were used to characterize the material behaviour. Freezing of articular cartilage does indeed produce a difference in material behaviour, most evident at higher loading rates. Frozen samples were significantly more elastic, having lost much of the viscous material properties inherent in fresh articular cartilage. This change in material properties may cause erroneous approximations between the biomechanical behaviours of frozen and *in vivo* articular cartilage.

57.1 TAFT, Natalia K.; University of Massachusetts Amherst; *natashak@bio.umass.edu*

Patterns of fin ray curvature of Myoxocephalus octodecimspinosus, the longhorn sculpin during substrate-contact and swimming

The pectoral fins of benthic fished are used for substrate contact behaviors as well as during swimming. Morphological specializations of the fin rays are correlated with this functional flexibility in several groups. For example, in benthic suckers, flatfishes and blennies, fin rays that routinely contact the substrate are generally shorter and thicker, lack distal branching and exhibit reduced webbing compared to rays that are not involved in substrate interactions. However, the specific contribution of individual fin rays during pectoral fin behaviors is not well understood. To characterize the role of different fin rays in a benthic species, I measured fin ray curvature during both substrate-contact and swimming behaviors in four individual longhorn sculpin. To calculate curvature, six equally spaced points along every other pectoral fin ray were digitized. The 3-D coordinates for each point were used to fit splines to each ray. Curvature data were then calculated from each spline at 10% increments along the length of each fin ray. In all groups, curvature of the rays was higher during substrate-contact than during swimming. During both behaviors, curvature was consistently highest in the two most ventral rays digitized, followed by the next two most ventral and the two most dorsal rays. The four middle rays showed the least absolute curvature and smallest difference in curvature between the two behaviors. In general, the regions of the fin ray in all rays with the highest curvature were the most proximal 15% of the ray and the most distal third. The potential structural underpinnings of the differences in bending among pectoral fin rays will be further explored using clearing and staining and CT scanning techniques.

9.5 TANNER, J. B.*; ZELDITCH, M. L.; LUNDRIGAN, B. L.; HOLEKAMP, K. E.; Michigan State University, East Lansing, University of Michigan, Ann Arbor; *tannerja@msu.edu*

Ontogeny of Feeding Performance and Skull Morphology in the Spotted Hyena

Ontogeny in the spotted hyena *Crocuta crocuta* is characterized by dramatic behavioral and morphological change. These large, social carnivores feed in intensely competitive environments in which the ability to quickly consume large quantities of food is highly advantageous. Spotted hyenas are also capable of cracking open and consuming large bones. Consequently, their skulls are highly specialized for durophagy, with enormous sagittal crests and wide zygomatic arches providing increased attachment area for muscles critical in bite force generation. In this study we used geometric morphometric techniques to quantify ontogenetic changes in skull size and shape. We analyzed the ventral and lateral views of 65 *Crocuta* skulls ranging in age from 1 day to 17 years. Additionally we conducted feeding performance tests using standardized objects such as dog biscuits and goat femurs to measure age-related changes in feeding speed. Lastly, we calculated bite force estimates from measurements of the skulls and performed partial least-squares analyses to investigate the relationship between specific changes in the skull and bite force. We find that *Crocuta* skulls continue to grow and change shape past 30 months of age although this is long after the average weaning age of 14 months. Likewise, feeding speed and bite force continue to increase significantly until 35 months of age. We thus conclude that the development of the feeding apparatus is significantly delayed although selection should favor rapid improvement in feeding performance in such competitive feeding environments. This delayed development in the feeding apparatus ultimately may provide insight into the adaptive significance of the unusual trait of female dominance in this species.

3.7 TAYLOR, S.M.; GRACE, M.S.*; Florida Institute of Technology, Melbourne, current: St. Matthew\'s University, British West Indies, Florida Institute of Technology, Melbourne; *mgrace@fit.edu*

Retinal Photoreceptor Arrays in Larval Tarpon (Megalops atlanticus) and Speckled Worm Eel (Myrophis punctatus)

The teleost subdivision Elopomorpha includes tarpon (*Megalops atlanticus), ladyfish (Elops saurus), bonefish (Albula vulpes) and an array of eels. Adult elopomorphs are remarkably diverse among species in morphology, ecology and behavior. However, their leptocephalus larvae are very similar- clear, ribbon-like fish with tiny heads, fang-like teeth, and unusual modes of nutrient acquisition. In a comprehensive study of elopomorph visual development, we characterized photoreceptor arrays in tarpon and speckled worm eel (Myrophis punctatus). Retinas labeled with rod opsin- or cone opsin-specific antisera showed that M. atlanticus anti-cone immunoreactivity (IR) was confined to the central/mid-temporal (forward-looking) retina while anti-rod IR occurred throughout the retina. In M. punctatus (and 12 other eel species), anti-cone IR was confined to the ventral retina, and anti-rod IR occurred throughout the retina. However, cone opsin-like IR co-localized with rod opsin-IR in eels, suggesting that either rod and cone opsins are coexpressed (at least briefly) in single cells, or the cone opsin antiserum cross-labels a non-cone opsin epitope. High-resolution transmission electron microscopy allowed clear distinction of rods and cones. In M. atlanticus, both rods and cones were observed, while in M. punctatus, all photoreceptors appeared morphologically rod-like. These results show that larval tarpon and eel retinas are highly rod-dominated. These rod-dominated larval retinas are in stark contrast to the cone-dominated retinas of most larval teleosts. This unusual and shared developmental pattern provides strong evidence for monophyly of the Elopomorpha despite contradictory conclusions from recent molecular data.*

28.10 THACKER, R.W.; Univ. of Alabama at Birmingham; *thacker@uab.edu*

Evolutionary Specialization of Sponge-Cyanobacteria Symbioses: Cospeciation vs. Colonization

Highly specific interactions between hosts and symbionts are often attributed to cospeciation; however, independent colonization events can generate similar patterns of host specificity. Symbiotic filamentous cyanobacteria (*Oscillatoria spongeliae*) have been reported from diverse marine sponges, with each sponge species hosting a unique clade of cyanobacteria. Initial phylogenetic analyses of Indo-Pacific sponges in the order Dictyoceratida supported the hypothesis of cospeciation between sponges and their symbiotic filamentous cyanobacteria. More recent investigations have examined the 16S ribosomal RNA gene sequences of filamentous cyanobacteria associated with three Caribbean sponges, including *Hyrtios violaceus* (Dictyoceratida) from Belize and two newly described species in the order Haplosclerida from the Bocas del Toro region of Panama, *Haliclona* n. sp. and *Xestospongia* n. sp. The addition of these three species to previous phylogenies reveals the presence of two major clades of *O. spongeliae*, with each clade represented in the Indo-Pacific and Caribbean regions. Although evidence for cospeciation can be found within sponge genera, the revised phylogenies suggest multiple independent colonization events among sponge genera. *O. spongeliae* appears to have initially colonized a dictyoceratid host, spreading to other species by a combination of cospeciation and colonization events, with independent colonizations of two haplosclerid hosts.

47.3 THAKER, M.*; HEWS, D.K.; LIMA, S.L.; Indiana State University; *mthaker@indstate.edu*

Corticosterone mediation of antipredator responses in male lizards with alternative reproductive tactics

Most vertebrates respond to acute and chronic stressors with increased plasma concentrations of glucocorticosteroids (CORT), yet few studies examine behavioral consequences of increases in CORT. Indeed, no study in any vertebrate species has examined the subsequent effects of elevated CORT on behavioral responses to predation risk. We examined the behavioral effects of acute exogenous CORT elevation in male tree lizards (*Urosaurus ornatus*) with alternative reproductive tactics (ART). In our study population, territorial males have a blue patch on an orange dewlap (OB males) and non-territorial males lack the blue (O males). Social behaviors of males with a mottled dewlap are uncharacterized but these males were included. Using noninvasive dermal patches, we acutely elevated CORT levels in all male morphs and recorded behavioral responses of these males when exposed to a collared lizard (*Crotaphytus nebrius*) predator in outdoor enclosures. When exposed to predation risk, males with CORT patches responded more quickly, hid longer, and displayed more than control-patched males. O males were more fearful than other male morphs and were most sensitive to elevations in CORT. Field measures of antipredator responses of all male morphs were consistent with our laboratory findings. In sum, the influences of CORT on antipredator behaviors of males with ART suggest differences in selective pressures faced by males, especially in the context of sensitivity to predation risk.

S1-1.8 THOMPSON, S.B.*; MOESER, G.M.; COUTTS, L; CARRINGTON, E; CSU Fresno, Univ. of Washington, Univ. of Richmond; *seans_aquarium@yahoo.com*

Flow Modification: Musseling Around the Flow

Mussels are an important species in many marine habitats, providing food, filtering water, and acting as a home for many species. Mussels attach to various substrates with byssal threads produced by the foot. Moeser et. al. (2006) observed that thread production is limited by the ability of the foot to protrude into flow, and placed this physiological threshold at ~18 cm/s for solitary *Mytilus edulis*. Given that flows on wave swept shores are routinely two orders of magnitude higher (e.g. 35 m/s), it is unclear when mussels can produce threads on exposed coasts. This study evaluates the extent to which mussel aggregations (or beds) reduce extreme flows, thereby facilitating thread production. An Acoustic Doppler Velocimeter (ADV) was used to measure water velocities in mussel beds of *M. galloprovincialis* and *M. trossulus* in a flume and in the field. Video was also used for particle tracking to calculate velocities within 1 cm of the bottom. Flow velocities found in the bed were greatly reduced, less than 6% of freestream velocity in lab trials, and 0.5% of freestream in the field. When examined lengthwise along the bed, velocities decreased dramatically with increasing distance from the front of the bed, plateauing at 20 cm and beyond. While an analysis of small gaps (3-12 cm diameter) in a mussel bed showed an increase in velocity with increasing gap size, flow reduction provided by the neighboring bed was nonetheless substantial (< 13% of freestream). Overall, the magnitude of the flow reduction observed in the bed is sufficient for individual mussels to produce new byssal threads at freestream velocities that exceed their physiological threshold, even on exposed wave-swept coasts.

35.4 TIBBETS, T. M.*; WHEELESS, L. A.; University of Wyoming; *ttibbets@uwyo.edu*

Trophic enrichment without change in diet: An ontogenetic shift in &delta^{15}N during insect metamorphosis

Analyses of nitrogen and carbon stable isotopes are widely used as tools in the study of food web structures and to estimate an animal's trophic position. Most food web studies assume that an enrichment in ^{15}N in an animal's tissues represents a shift in trophic level. We examined the effect of metamorphosis on the ^{15}N trophic enrichment between the tissues of several species of holometabolous insects and their diet. We measured the &delta^{15}N of larval, pupal, and adult stages of four Lepidoptera (*Bombyx mori*, *Galleria mollonella*, *Manduca sexta*, and *Vanessa cardui*), one Diptera (*Sarcophaga sp.*), and one Coleoptera (*Tenebrio molitor*). As expected, we found that the tissues of insect larvae were enriched in ^{15}N relative to their diet. The enrichment in ^{15}N between larvae and diet was explained by the production of frass significantly depleted in ^{15}N. Surprisingly, we found that the tissues of adult insects were significantly enriched in ^{15}N relative to larvae in all but one species (*T. molitor*). Because we measured the adult tissues immediately after they emerged from pupal cases, the enrichment was not due to a change in diet. Rather, it was due to the excretion of ^{15}N depleted metabolic waste (meconium) that resulted from protein metabolism during metamorphosis. Our results suggest that ^{15}N enrichment during metamorphosis is significant, that discrimination during metamorphosis is variable across taxa, and that one cannot assume adult holometabolous insects reflect larval or larval diet ^{15}N values.

14.5 TOIEN, O.*; BLAKE, J.; EFIMOV, I. R.; GRAHN, D.; HELLER, H. C.; BARNES, B. M.; Institute of Arctic Biology, University of Alaska Fairbanks; *oivind.toien@uaf.edu*

Circulatory and cardiac physiology of hibernating black bears

Black bears depress metabolic rate to about 25% of normal resting levels during hibernation with a decrease of core temperature by only 2-8°C. Along with the needs for reduced perfusion, mean heart rate is profoundly decreased. There is a strong sinus arrhythmia on the heart rate pattern. During breathing events HR is close to normal, while between breathing events inter-beat intervals can be prolonged to typically 8-12 seconds with the extreme recorded at 23 s. Therefore, can bears perfuse the tissues during the long inter-beat intervals, and how do they avoid uncontrolled arrhythmias? We present preliminary recordings of intra-arterial blood pressure in hibernating non-anesthetized bears recorded through a mesenteric artery in- or close to- abdominal aorta. Temperature loggers, a radio telemetry temperature transmitter and a transmitter for blood pressure, ECG and EMG were implanted into the peritoneal cavity or in the neck area (ECG /EMG only). Air was collected from the hibernaculum and passed to a respirometry system. Breathing was detected with a differential pressure transducer connected to the den. The periods of high heart rate during breathing episodes pushed blood pressure up to very high levels, often with a systolic pressure of 200 mmHg at the end of this period, representing a very high load. During long inter-beat intervals, blood pressure slowly decreased to about 60 mm Hg adequate for tissue perfusion and indicates a high degree of vasoconstriction. Observed changes of interrelationships in the ECG pattern during breathing cycles may indicate adaptations to avoid fibrillation. - Supported by the NSF Alaska EPSCoR program. We thank Alaska Department of Fish and Game for supplying bears.

29.9 TOOMEY, M.B.*; MCGRAW, K.J.; Arizona State University, Tempe, AZ; *matthew.toomey@asu.edu*

Carotenoid pigments in the tissues of zebra finches (Taeniopygia guttata): identity, distribution, and intercorrelations

Carotenoids serve a variety of functions in animals, including sexually selected coloration, photoprotection, antioxidant activity, and immune function. Carotenoids are distributed throughout the body and are likely to have different functions in different tissues. Carotenoids in the integument serve as sexual signals and photoprotectants, whereas carotenoids in internal fluids and tissues (e.g. plasma, liver, adipose tissue) serve as antioxidants and immunomodulators. Although animals cannot synthesize carotenoids *de novo*, dietary carotenoids are often metabolized into different forms with specific functions. However, the metabolic precursors and products and the relative allocation of carotenoids among various sites in the body are not well known. To explore these patterns, we used high performance liquid chromatography (HPLC) to identify, quantify, and compare the carotenoid composition of the diet, plasma, liver, adipose tissue, eye, beak, and legs of male and female Zebra Finches (*Taeniopygia guttata*). In the beak and the eye of both sexes, we identified red ketocarotenoids that are restricted to these tissues, indicating metabolism is occurring at the site of deposition. The concentration of astaxanthin (a ketocarotenoid) in the eye was correlated with plasma zeaxanthin levels, indicating that it may be a precursor for the production of this carotenoid. Analyses are ongoing and we will discuss the allocation of carotenoids among tissues and the functional implication of these patterns.

61.5 TREMBLAY, Yann*; ROBINSON, Patrick W; SHAFFER, Scott A; KAPPES, Michelle A; MCDONALD, Birgitte I; CROCKER, Dan E; COSTA, Dan P; Univ. of California, Santa Cruz, Sonoma State University; *tremblay@biology.ucsc.edu*

To what extent does life-history affect space utilization in marine top-predators?

Laysan albatrosses (*Phoebastria immutabilis*) and northern elephant seals (*Mirounga angustirostris*) are two top-predators that forage in the northern Pacific Ocean. Their diets overlap and both forage extensively within the transition zone. Tracking data from these species reveal that both exhibit area-restricted (ARS) patterns of movement, suggesting convergence in foraging strategies. However, these predators represent two extreme foraging modes. Albatrosses are fast moving, non-diving animals whereas elephant seals are slow but excellent divers. Using novel techniques for animal movement analysis, this work compares ARS behavior and spatial scale utilization between albatrosses and elephant seals to determine how space utilization is affected by fundamental life-history differences or limitations. Convergence in strategies was found for the smallest spatial scales whereas space utilization at large scales differed more. Duration and timing of the utilization of the different spatial scales were extremely different. Movements at small spatial scales are likely environment-dependant whereas movements' patterns at large scales and time-use are most affected by the predator's life-history.

S4-2.2 TRIDANE, A*; HADELER, K; KUANG, Y; Arizona State University; *tridane@math.asu.edu*

Comprehensive modelling of the immune response of cytotoxic T Lymphocytes in the influenza infection

The aim of this work is to investigate the mechanisms involved in the clearance of viral infection of the influenza virus at the epithelium level by analyzing the interaction of the influenza virus-specific cytotoxic T Lymphocytes (CTL) and the epithelial cells . In fact, the understanding of this interaction would provide us interesting tools for the evaluation of the potential protective cell-mediated immunity. Moreover, the induction of CTL-cells by vaccination is considered to be highly desirable, particularly in the context of viral infections, such as influenza, where the surface glycoproteins of the virus rapidly accumulate amino acid substitutions that allow the virus to escape from pre-existing antibody responses. By presenting different scenarios of interaction of CTL-cells and epithelial cells, we constructed models of CTL response to influenza infection. Our ultimate goal is to use these models to provide insight into the pathology and possible treatment of this disease.

65.7 TRUEBLOOD, Lloyd A.*; ROSA, Rui A.; BIRDEN, Leanne E.; SIEBEL, Brad A.; University of Rhode Island; *truell@mail.uri.edu*

Scaling of aerobic metabolism in epipelagic squid

Mass-specific rates of metabolism (B) typically decline with increasing body mass (M) according to $B = b_0 M^b$, where b_0 is a normalization constant independent of mass and b is a scaling coefficient that is often assumed to reflect geometrical constraints on exchange processes. The value of this scaling coefficient varies in the literature, but quarter power (-0.25) is common and is widely accepted as a biological law. Most studies examining this phenomenon have focused on vertebrates while much less is known about metabolic scaling in invertebrates. This study examines oxygen consumption rates and activities of mitochondrial enzymes in epipelagic squids, active Cephalopod Molluscs, over more than five orders magnitude size range (0.1 g 17 kg). Metabolism in the three families examined (Lolignidae, Ommastrephidae, and Gonatidae) scaled nearly isometrically, with coefficients ranging from 0.02 to 0.11. Small squid have mass-specific metabolic rates similar to shrews and hummingbirds at comparable temperatures. However, the shallow scaling slopes reflect a demand for energy in large squid higher than any reported organism in the same size class. This unusual scaling relationship may be the result of a unique tubular geometry and reliance cutaneous respiration, or cost-of-transport scaling for jet-propelled swimming.

15.5 TURMELLE, Amy/S*; ALLEN, Louise/C; JACKSON, Felix/R; MENDONCA, Mary/T; KUNZ, Thomas/H; RUPPRECHT, Charles/E; MCCRACKEN, Gary/F; Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN.; Rabies and Poxvirus Section, Centers for Disease Control and Prevention, Atlanta, GA., Center for Ecology and Conservation Biology, Boston University, Boston, MA., Rabies and Poxvirus Section, Centers for Disease Control and Prevention, Atlanta, GA.; Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN., Department of Biological Sciences, Auburn University, Auburn, AL., Rabies and Poxvirus Section, Centers for Disease Control and Prevention, Atlanta, GA., Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN.; *aturmell@utk.edu*

Ecology of Rabies and Immunity in Brazilian Free-tailed Bats (Tadarida brasiliensis).

Brazilian free-tailed bats (*Tadarida brasiliensis*) have extreme variation in their behavioral and roosting ecology, often forming especially large roosting aggregations in Texas. Among bats, they are one of the most frequently submitted species for rabies testing, suggestive of frequent contact with humans, particularly in Texas. The objective of this study was to investigate the role of ecological variation in predicting the prevalence of rabies in Brazilian free-tailed bats. We sampled wild-caught bats (N=709) at 6 sites in south-central Texas from May-October, 2005. Rabies antibody titers of blood plasma were determined using the MRFFIT, and the presence of viral RNA in the saliva was tested with RT-PCR. Viral isolations were attempted, for RT-PCR positives, to investigate the infective nature of the viral RNA present in the saliva. Of 534 bats, 40.3% tested seropositive. Mean seroprevalence was not significantly different at 5 of 6 sites (range 43.2%-53.8%), but one cave had exceptionally low mean seroprevalence (17.9%, &alpha=0.05). Seasonally, 3 of 6 sites showed significant variation in seroprevalence (p

28.8 TURNER, L.M.; WILSON, N.G.*; British Antarctic Survey, Cambridge, Scripps Insitute of Oceanography, University of California, San Diego; *wilsong@auburn.edu*

Paraphyly across oceans: a molecular phylogeny of the family Chromodorididae (Gastropoda: Nudibranchia) using three molecular markers

The Chromodorididae are a colourful, speciose family of nudibranchs (sea slugs), and are found in all of the five oceans on earth. Like many marine invertebrate groups, their greatest diversity occurs in the tropical Indo-west Pacific. There are seventeen known genera, but only six of these are found in multiple biogeographic provinces; the rest are restricted to a single province. The monophyly of the family, and its constituent genera has not been examined to date, and provides an interesting test of molecular concordance with traditionally recognized marine biogeographic provinces. There are also several genera that are monotypic, which cannot be linked easily with other genera. The lack of well-supported phylogenetic hypotheses means that existing evidence showing coloration patterns within a genus were the result of shared ancestry, rather than mimicry, could not be tested across genera. We used three genes with differing rates of evolution (18S, 16S and COI) to try to answer the questions outlined above. Is the family monophyletic? Are the genera monophyletic, (especially those that occur in multiple biogeographic regions)? Can we link monotypic genera to other groups? Is mimicry occurring? We used Maximum Parsimony and Bayesian analyses to generate phylogenetic hypotheses for this family of sea slugs. We discovered that the family was monophyletic after the exclusion of one genus. However, most of the genera that encompass more than one biogeographic province were paraphyletic (*Chromodoris, Hypselodoris, Glossodoris, Mexichromis*). The current classification for these nudibranchs does not reflect evolutionary relationships, and requires revision.

44.1 TURNER, B. E.; TOMANEK, L.*; California Polytechnic State Univ., San Luis Obispo; *ltomanek@calpoly.edu*

Nitrate stress in the Morro Bay Ecosystem: Utilizing 2D gel electrophoresis to characterize protein expression profiles in Mytilus californianus

Estuaries depend on effluents containing complex mixtures of numerous anthropogenic and naturally derived chemical compounds, e.g. nitrogen. Increased nitrate and ammonia concentrations are known to adversely affect adult and juvenile marine invertebrates, including oysters and mussels. Thus we used the filter-feeding intertidal mussel *Mytilus californianus* as an indicator species to investigate the toxic effects of nitrogen. In this study, *M. californianus* were placed in one of three subtidal test sites experiencing various levels of effluent exposure in and around Morro Bay, an ecologically important Central Californian estuary. Two test sites are within Morro Bay, the first is closer to the mouth of the bay and benefits from tidal flushing, the second, in a sheltered portion of the bay that experiences less tidal flushing and is thus exposed to anthropogenic influences. A third site is located in Avila Bay, an open bay with relatively low nutrient levels and low effluent exposure. *M. californianus* was sampled from the three sites over a period of time. Significant rainfall events and changes in nutrient levels were monitored and animals were collected before and after these events. Protein expression profiles were characterized by isoelectric focusing and gel electrophoresis (two-dimensional gel electrophoresis 2D GE). Gel images were analyzed and proteins showing significant differences in expression between test sites or before vs. after rain events are currently analyzed. Gill tissue from laboratory acclimated mussels was subjected to a gradient of nitrate concentrations *in vitro*. Proteins of interest from both studies will be identified using protein fingerprinting and *de novo* sequencing. These preliminary results are an example of using 2D GE to monitor estuarine environments for stress.

S1-2.1 TYTELL, E. D.; LAUDER, G. V.*; Harvard University; *glauder@oeb.harvard.edu*

Escaping fishes: experimental hydrodynamics of wake flow patterns

Despite a vast literature on the kinematics, mechanics, and neural control of c-start escape responses in fishes, no study has yet examined the hydrodynamic effect of fish body motion on the fluid environment. We thus have little idea of how power produced by body musculature is transmitted to the water, and what type of hydrodynamic wake is left by escaping fishes. We investigated the wake generated by bluegill sunfish, Lepomis macrochirus, executing c-start escape responses. We used two laser light sheets in orthogonal horizontal orientation to eliminate shadows and allow full field resolution of flow structures, and imaged the light sheet and fish with two synchronized high-speed cameras in ventral and lateral view respectively at 1000 Hz. C-starts were obtained from five fish at three distinct horizontal planes: mid-body, mid-dorsal fin, and mid-anal fin positions. Body mass distribution and body and fin areas were also measured. Three distinct vortex rings with fluid jets, nearly orthogonal to each other, are formed during the c-start response. Jet #1 is the first ring formed by the tail during Stage 1, and moves in the same direction as Stage 2 fish movement, reducing final escape velocity but also rotating the fish. Jet #2, in contrast, moves approximately opposite to the final direction of fish motion and contains the bulk of the total fluid momentum. It forms during Stage 1 primarily as a result of suction on the inside of the c-bend. Jet #3 forms during Stage 2 in the mid-body region and moves in a direction approximately perpendicular to both jets 1 and 2, across the direction of body movement. The c-start escape response thus involves a complex pattern of fluid movement, with effectively all momentum contributing to the escape generated during Stage 1 by suction on the concave body surface.

23.1 TYTELL, E.D.*; COHEN, A.H.; University of Maryland;
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Variation in entrainment of fictive swimming in lampreys due to bending stimuli at successive longitudinal positions

In fishes, undulatory swimming is produced by sets of spinal interneurons constituting central pattern generators (CPGs). Coupling among successive oscillators in spinal cord produces in a consistent longitudinal phase lag that results in the traveling wave for swimming. Sensory input can modulate the wave; for example, bending the body entrains it to the stimulus frequency. Swimming bends the body along its entire length, but most previous studies of mechanical entrainment in fishes have examined bending at single points close to the spinal cord's ends. It is not known whether different portions of the cord respond to bending stimuli differently. If they do, the variation may contribute to both hydrodynamic and mechanical performance. First, it may affect the final form and speed of the neural traveling wave, which in turn affects the body's swimming wave, an important feature for hydrodynamic performance. It may also contribute to the phase lag between muscle activation and body bending. In many fishes, anterior muscle turns on during shortening, producing energy for locomotion, while posterior muscle is active during lengthening, absorbing energy and potentially reducing the mechanical performance. Entrainment by sinusoidal bending was examined at successive points along the spinal cord of fictively swimming lampreys while recording from ventral roots. A gradient in entrainment phase was observed. Caudal ventral root bursts occurred around the time of maximum stretch on the same side as the nerve, while central segments tended to burst later in the stimulus cycle, similar to the pattern observed *in vivo*. Entrainment was examined in spinal cord sections with different numbers of segments to determine how much of this gradient resulted from coupling among segments, in comparison to variation in responses to sensory stimuli.

6.5 ULRICH, PN*; MARSH, AG; Univ. of Delaware;
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Cell volume stress and respiration of the Antarctic clam Laternula elliptica: implementation of a high-throughput, optical assay of multiple parameters of mitochondrial physiology

Few data are available to describe the sensitivity of Antarctic biota to cell volume stress. We investigated the impact of reduced osmolality on respiration of the Antarctic clam *Laternula elliptica* at three levels: mitochondria, tissue, and organism. To address mitochondrial respiration, we developed a microplate respirometry technique that can be adapted for measurement of multiple physiological parameters (membrane potential, reactive oxygen production, pH) simultaneously in high throughput with a single fluorometer. Relative to controls (1150 mOsm), low osmolality (635 mOsm) stimulated phosphorylating (state 3) and nonphosphorylating (states 2 and 4) respiration of gill and hepatopancreas mitochondria 1.5 to 3-fold. In contrast to euryhaline bivalves, state 4 respiration was more sensitive to cell volume stress than state 3 respiraiton, depressing the respiratory control ratio (RCR) of gill mitochondria significantly ($p = 0.025$). Costs of ATP production in *L. elliptica* gill mitochondria were elevated under low osmolality, as indicated in reduction of ADP:O from 5.62 to 1.99 ($p = 0.0012$). In low osmolality, membrane potential of gill mitochondria was significantly related to state 2 oxygen consumption. Organismal respiration remained constant when salinity was reduced from 35 to 26 ppt. While isolated gill mitochondria increase respiration in response to lower osmolality, gill tissue respiration dropped threefold at low salinity ($p = 0.025$). This suggests that *L. elliptica* gill exerts strong top-down control of mitochondrial respiration. Salinity does not perturb whole organism respiration on the short term, but further research is needed to determine the threshold at which *L. elliptica* physiology is adversely affected as well as the capacity of the clam to acclimate to reduced salinity.

8.7 USHERWOOD, J.R.; The Royal Veterinary College, London;
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Mechanics of dog walking compared with a passive, stiff-limbed, 4-bar linkage model, and their collisional implications

This study presents a simple stiff-limbed passive model of quadrupedal walking, compares mechanics predicted from the model with those observed from forceplate measurements of walking dogs, and considers the implications of deviation from model predictions, especially with reference to collision mechanics. The model is based on the geometry of a 4-bar linkage consisting of a stiff hind leg, back, fore leg and the ground between the hind and front feet. It uses empirical morphological and kinematic inputs to determine the fluctuations in potential and kinetic energy, vertical and horizontal forces, and energy losses associated with inelastic collisions at each foot placement. Using forceplate measurements to calculate centre of mass motions of walking dogs, we find that 1) dogs may, but are not required to, spend periods of double support (one hind and one forefoot) agreeing with the passive model; 2) legs are somewhat compliant, and mechanical energy fluctuates during triple support, with mechanical energy being lost directly after hindfoot placement, and recovered following forefoot placement. Footfall timings and timing of mechanical energy fluctuations are consistent with strategies to reduce collisional forces and losses, analogous to the suggested role of ankle extension as an efficient powering mechanism in human walking.

S1-4.8 USHERWOOD, J.R.; The Royal Veterinary College;
jusherwood@rvc.ac.uk

Slow pigeon flight shows a compromise between aerodynamic and inertial power minimisation

When most birds fly slowly or hover, they do not use a horizontal stroke plane: the analogy of a hovering helicopter is limited. Pigeons, like many birds but unlike hawkmoths and hummingbirds, are capable of hovering for only brief periods, presumably achieving this anaerobically. This behaviour may therefore be considered, to a large extent, power limited, and the kinematic strategy adopted would be expected to minimise the required muscle power. I describe a new experimental set-up with which to measure the lift-drag polars of revolving bird wings, and show that, from purely aerodynamic considerations, the wings 'should' operate at a near-horizontal stroke plane, with low angles of attack and high wingbeat frequency. However, hovering pigeons use high aerodynamic angles of attack and high stroke-plane angles: they do not minimise aerodynamic power. A second power requirement for flapping wings is the inertial power - that associated with repeatedly accelerating massive wings. This power is minimised with low wingbeat frequency, and so is in conflict with the requirements of aerodynamic power minimisation. I suggest that understanding the kinematics of slow bird flight is impossible using aerodynamic considerations alone, and requires an appreciation of the balance between aerodynamic and inertial powers. Further, I consider the possibility of using the relatively easily measured inertial power as an indicator of aerodynamic and total power for slow flight.

S1-1.1 UYENO, T.A.*; KIER, W.M.; University of North Carolina at Chapel Hill; *uyeno@bio.unc.edu*

The structure and function of the hooks of a turbellarian flatworm: A vermetically sealed muscle articulation

This study investigates the functional morphology of the grasping hooks of the proboscis of an interstitial turbellarian flatworm (Suborder Kalyptorhynchia). The hooks, which are used in predation, do not articulate with one another and instead are embedded in muscle and connective tissue. Thus, they resemble the muscle articulations of the beaks of octopus and the jaws of polychaetes where solid muscle blocks composed of multiple fiber orientations allow the joint flexibility, move the beaks or jaws, and bear bite reaction forces. Confocal and conventional light microscopy was used to investigate the arrangement of the muscle and connective tissue fibers. In contrast to previously described muscle articulations, the muscles that support and move the hooks appear to include parallel muscle fiber arrays of a single orientation. Also observed were several connective tissue bands that may control and limit deformations along one axis. The hooks may be rotated open by the co-activation of transversely arranged muscle fibers that push the hook base forward and longitudinal muscle fibers that draw the hook tips back. The hooks may be closed by activation of a transverse muscle fiber layer in conjunction with medially/longitudinally arranged connective tissue bands. Muscle articulations may therefore be more widespread and diverse in structure and function than previously recognized.

44.7 VAJDA, A.M.*; LOPEZ, E.M.; GRAY, J.L.; BARBER, L.B.; WOODLING, J.D.; NORRIS, D.O.; University of Colorado, University of Colorado , U.S. Geological Survey, U.S. Geological Survey ; *alan.vajda@colorado.edu*

Reproductive Disruption of Fishes by an Endocrine-active Wastewater Effluent

The city of Boulder discharges its wastewater treatment plant (WWTP) effluent into Boulder Creek. This effluent contains detectable levels of biogenic steroidal estrogens, synthetic steroidal estrogens, and synthetic non-steroidal estrogens. White suckers (*Catostomus commersoni*) were collected from the WWTP outfall and from upstream reference sites. Gonadal intersex was identified in downstream white suckers but not in reference white suckers. The sex ratio was skewed in favor of females at downstream sites, with males half as abundant than at reference sites. Downstream male white suckers had decreased testicular sperm abundance and significantly elevated plasma vitellogenin; downstream females had a smaller GSI and an asynchronous pattern of ovarian follicular development. To determine whether this reproductive disruption was attributable to endocrine-active wastewater contaminants, we exposed adult male fathead minnows (*Pimephales promelas*) to either Boulder Creek water (Reference), 100% Effluent, or a 50/50 mixture of Reference and 100% Effluent (50% Effluent). Fish were maintained under stimulatory environmental conditions for up to 28 days on-site within a mobile flow-through exposure laboratory. Primary and secondary sex characters were rapidly demasculinized upon exposure to 50%- and 100%-effluent. Within 14-days of exposure, males exposed to 50%- and 100%-effluent had significantly fewer and less prominent nuptial tubercles, significantly less prominent dorsal fat pads, and decreased abundance of sperm within the testes. Vitellogenin was maximally elevated in both 50%- and 100%-effluent treatments within 7 days, consistent with the hypothesis that the reproductive disruption observed is likely due to endocrine-active wastewater contaminants.

58.4 VALENCAK, T.G.**; RUF, T.; Veterinary Univ. Vienna; *Teresa.valencak@vu-wien.ac.at*

Lactating hares are limited by the capacity of the alimentary tract

Traditionally, animals were considered to be mainly limited by food availability in their environment. However, studies on mammals and birds over the past two decades have clearly demonstrated that, even when food is abundant, animals may encounter endogenous physiological limitations of energy turnover during periods of high nutrient demands, such as lactation. It is still not fully understood whether these metabolic constraints are imposed peripherally , by the capacity of energy expending organs (skeletal muscles, mammary glands) or centrally , by the capacity of the alimentary tract. We investigated sustainable energy turnover in a herbivorous mammal, the European brown hare to address the question of central vs. peripheral limitation during lactation in this species. During lactation, our experimental animals were fed two diets of different energy content. We found that lactating females were unable to fully compensate for a low energy content of their diet by increasing their food intake and/or gastrointestinal tract. Specifically, time courses of food intake, assimilated energy, and milk transfer to young were significantly different between the two feeding groups. We conclude that, limits to energy turnover may have different reasons in different mammalian species, and central limits may play an important role for herbivorous animals, such as hares. This study was funded by the Austrian Science Fund (P17794-B06).

S1-2.9 VAN TRUMP, W.J.; Univ. of California, Irvine; *wvantrum@uci.edu*

Going with the flow: rheotaxis and station holding in the shiner surfperch (Cymatogaster aggregata).

Shiner surfperch (*Cymatogaster aggregata*) contend with the fast and rapidly changing currents of an intertidal environment. The aim of the present study was to determine the functional role of the lateral line in the rheotaxis and station holding ability of *C. aggregata*. The kinematics of swimming were measured in fish in a flume under illuminated, and darkened conditions with both the lateral line intact and blocked with ototoxic antibiotics. I found that *C. aggregata* is capable of rheotaxis at very slow speeds (C. aggregata may be achieved by utilizing sensory systems other than vision or lateral line hydroreception, such as olfaction or the vestibular response.

S9-2.4 VAN VALKENBURGH, Blaire; Univ. of California, Los Angeles; *bvanval@ucla.edu*

Evolution of Feeding Morphologies in the Carnivora

The fossil record of the order Carnivora extends back at least 56 million years, and documents a remarkable history of adaptive radiation, characterized by the repeated, independent evolution of similar feeding morphologies in distinct clades. Within the order, convergence is apparent in the iterative appearance of a variety of ecomorphs, including short-faced cats (felids, canids, mustelids, herpestids), bone-cracking hypercarnivores (canids, hyaenids), sabertooth cats (nimravids, felids) and frugivorous omnivores (procyonids, canids, viverrids). The iteration of similar forms has multiple causes. First, there are a limited number of ways to ecologically partition the predominant resource, vertebrate prey. Moreover, the material properties of animal tissues have not changed over the Cenozoic, and consequently, similar craniodental adaptations for processing skin, muscle, and bone evolve again and again. The extent of convergence in craniodental form can be striking, affecting skull proportions and overall shape, as well as dental morphology. This tendency to evolve highly convergent ecomorphs is most apparent among feeding extremes, such as sabertooths and bone-crackers where performance requirements tend to be more acute. Finally, the iterative evolution of large-bodied, highly carnivorous species in multiple families results from a combination of ecological (intra- and interspecific competition) and physiological (foraging energetics) constraints that ultimately lead to increased vulnerability to extinction of formerly successful clades. Thus, large hypercarnivores have evolved in rough succession with the decline of one clade followed by the rise of another, contributing to the overall pattern of repeated convergence within the order.

18.4 VAN WASSENBERGH, S.*; HERREL, A.; ADRIAENS, D.; AERTS, P.; Universiteit Antwerpen, Ghent University; *sam.vanwassenbergh@ua.ac.be*

Does biting performance trades off with suction feeding performance in clariid catfish?

It is generally assumed that biting performance trades off with suction feeding performance in fish because both feeding types may place conflicting demands on the cranial musculo-skeletal system. However, the functional consequences of morphological adaptations enhancing biting on the mechanics and performance of suction feeding in fish remain obscure. In this study, suction feeding performance was compared between three clariid catfish species differing considerably in their biting capacity, by measuring the velocity of a standardized prey being sucked into the buccal cavity using high-speed cineradiogaphy. In addition, buccal volume changes during prey capture were quantified by ellipse modelling. As all species were able to accelerate the prey to similar peak velocities, our results demonstrate the possibility for catfishes to increase bite performance considerably without compromising in suction performance. The amount of buccal expansion in the ventral direction is approximately equal for all species. Consequently, the system generating expansion through ventral rotation of the lower jaw, hyoid and pectoral girdle is apparently not constrained (mechanically or architectonically) by the hypertrophy of the jaw adductors. As the effect of a reduced magnitude of lateral expansion (suspensorium abduction) on suction performance in Clariidae appears to be negligible (for example in *Gymnallabes typus*), these data demonstrate the dominant role of ventral expansion for producing suction in these fish.

39.4 VANCE, JT*; WILLIAMS, JB; ELEKONICH, MM; ROBERTS, SP; Univ. of Nevada, Las Vegas; *jason.vance@unlv.edu*

Affects of age and behavioral development on honey bee flight performance

During the transition from hive work to foraging, honey bees undergo numerous physiological changes, including a large increase in aerobic capacity, presumably to support the intense flight demands of foraging behavior. In this study we addressed whether kinematic and aerodynamic performance/capacity increases as honey bees age and transition from hive work to foraging. The flight performance of age-matched hive bees (age = 13±0 days; mass = 127±13 mg) and foragers (age = 14±1 days; mass = 92±12 mg), as well as typical foragers (age > 21 days; mass = 92±21 mg), was assayed by allowing them to hover in variable-density gas mixtures ranging from air (21% O_2, 79% N_2; 1.21 kg m^{-3}) to heliox (21% O_2, 79% He; 0.41 kg m^{-3}). Wingbeat frequency and wing stroke amplitude were determined from high-speed (4000 fps) digital video recordings of these trials. Typical honey bee foragers were able to hover in pure heliox and did so by increasing wing stroke amplitude 24% while maintaining a relatively constant wingbeat frequency, which greatly increased wingtip velocity and lift during translation. Hive bees and young foragers could not hover in pure heliox but were restricted to hovering in gases of intermediate density. In response to hypodense gas, hive bees and young foragers increased stroke amplitude by 20%, but decreased wingbeat frequency by 9%, which in turn only moderately increased wingtip velocity. Young foragers were capable of hovering in lower density gases than hive bees (0.76 kg m^{-3} vs. 0.95 kg m^{-3}, respectively). However, while their kinematics at maximal capacity were similar, heavier hive bees had 15% greater stroke amplitude than lighter young foragers during hovering in air. These results suggest that the increased flight performance of foragers is a function of both reduced body mass and physiological/biomechanical enhancement of kinematics relative to younger bees.

21.2 VANDEN BROOKS, J. M.; Arizona State University; *john.vandenbrooks@asu.edu*

New Insights into Phanerozoic Oxygen Levels and their Impact on Evolution

Variation in atmospheric oxygen levels has the potential to be one of the main drivers of long-term vertebrate evolution through the Phanerozoic. Recent models of the evolution of atmospheric oxygen through time have hypothesized a large spike in oxygen from below modern day levels in the Devonian to upwards of 30% of the total atmospheric composition in the Permian, followed by a drop to as low as 12% in the early Triassic. Such large changes in oxygen would have had significant impacts on vertebrate development and evolution. Previous research by the author has shown that varying oxygen levels have a large impact on the development of *Alligator mississippiensis*. These effects include changes in growth rate, the timing of developmental events, bone density, phosphate concentration within the bones, and mortality rates. Additionally, oxygen has been shown by other research groups to have an effect on the development and short-term evolution of various insect groups (e.g. body size and tracheal diameter in *Drosophila melanogaster*). This modern data is reviewed here and then used to critically examine changes and trends observed in both the vertebrate and insect fossil record. It has long been known that some giant insects existed during the time of hyperoxia, but here we look past the outliers for a more in depth analysis of changes through time. In the vertebrate record, the results demonstrate strong correlation between changes in allometric relationships (e.g. head/body size ratios) in both reptilimorphs and temnospondyls and the modeled variation in atmospheric pO_2. Patterns of origination and extinction are also shown to be correlative with changing pO_2. The fossil data is presented here and discussed with respect to the modern analyses.

S8-1.3 VANHOOYDONCK, Bieke*; HERREL, Anthony; IRSCHICK, Duncan J; University of Antwerp, Wilrijk, University of Massachusetts, Amherst ; *bieke.vanhooydonck@ua.ac.be*

Evolution of sexual dimorphism in habitat use and escape behaviour in Anolis lizards.

Evolutionary biologists have long been fascinated by intersexual differences. In most cases, quantification of sexual dimorphism has remained limited to measures of intersexual differences in morphology. Yet, it currently remains largely unclear whether and how differences in morphology relate to ecological and/or behavioural differences between the sexes. In this study, we investigate the evolution of sexual dimorphism in escape behaviour among *Anolis* lizards and test if variation in escape behaviour is determined by variation in microhabitat use and morphology. We use *Anolis* lizards because they have evolved independently into a series of ecologically, behaviourally and morphologically distinct forms or ecomorphs. In addition, males and females typically differ in size, and the degree to which they do varies among species. Here, we quantify snout-vent length, microhabitat use and escape behaviour in males and females of 12 species of *Anolis* lizards. Our data indicate that both species and sexes show a marked difference in behavioural responses when confronted with predators. For example, whereas twig anoles have the shortest approach distance and seem to rely heavily on crypsis, grass-bush and trunk-ground anoles appear to evade predators by running. In addition, females generally have shorter approach distances and flee over smaller distances than males. Since the behavioural strategy of males seems to be determined by other morphological and ecological factors than that of females, the interspecific variation in sexual dimorphism in escape behaviour cannot be explained by interspecific differences in sexual size dimorphism or microhabitat use.

12.2 VELEZ, A*; AMEZQUITA, A; University of Minnesota, Universidad de Los Andes; *velez011@umn.edu*

The role of temporal properties of the advertisement calls in the phonotactic response of territorial Allobates femoralis (Anura: Dendrobatidae) males

Among anuran amphibians advertisement calls are used to attract females and repel other males. Territorial species most commonly defend their territories with advertisement calls and overt aggression. Different physical properties of the advertisement calls are used by different species during species recognition. Here I test if two temporal properties of the advertisement call - note duration and inter-note interval - are used by *Allobates femoralis* for species recognition. Males *A. femoralis* showed positive phonotactic response to synthetic 4 note-stimuli with supernormal note duration and supernormal inter-note interval. Furthermore, this species showed a high probability of responding to synthetic sounds presenting typical values of note duration and inter-call interval of a syntopic population of *Ameerega trivittata*, typically producing series of 1 note-calls. Thus, *A. femoralis* would be a species in which only one trait of the advertisement call might not be enough for species recognition.

49.3 VAUGHN, Dawn ; Univ. of Washington, Friday Harbor Laboratories; *dvaughn@u.washington.edu*

Predator-Induced Morphological Defenses In Marine Zooplankton: A Larval Case Study

While there are numerous reports of predator-induced morphological defenses for benthic marine animals, freshwater zooplankton and freshwater larvae, at present there is an absence of studies demonstrating similar phenomena in adult marine zooplankton, and the planktonic larvae of marine organisms. Rarity of predator-induced morphological defenses in marine zooplankton would imply a difference in predation risks, whereas the presence of such plasticity in defenses would imply that risks are modified by developmental responses. This study reports a predator-induced change in defenses and vulnerability of a marine planktonic larva. Specifically, when reared in the presence of zoea larvae of Cancer spp., veliger larvae of the intertidal snail Littorina scutulata developed significantly smaller shell apertures and rounder shells than did cohort veligers reared in the absence of predator cues. Pair-wise predation trials demonstrated that veligers reared with caged zoeas throughout development had greater survival than predator-naive veligers during short-term exposure to zoeas. The results indicate that some marine larvae develop predator-induced morphological defenses and suggest that predators on marine larvae and other zooplankton are not so diverse as to preclude plasticity in development of defensive structures. This result introduces a range of testable hypotheses on developmental plasticity that reduces vulnerability of planktonic larvae and other marine zooplankton to predators.

58.1 VÉZINA, F.*; JALVINGH, K.M.; DEKINGA, A.; PIERSMA, T.; NIOZ, NIOZ, University of Groningen; *fvezina@nioz.nl*

Thermogenic capacity in wintering and migratory shorebirds is driven by body mass-related changes in organ size

Cold acclimatization in birds involves an array of metabolic adjustments resulting in increased shivering endurance and improved cold tolerance. These adjustments often result in elevated summit metabolic rate (Msum), a measure of maximal thermogenic capacity and an indicator of sustainable heat production. However, several aspects of this phenomenon are poorly understood. Contradictory findings with regard to variations in basal metabolic rate (BMR) raise the question whether an increase in BMR contributes to improved cold tolerance or only reflects the physiological upregulation necessary to tolerate cold. Furthermore, few avian studies have examined individual flexibility in organ size in response to life in the cold. Here, we investigated physiological adjustments associated with thermal acclimation, in long-distance migrant Red Knots (Calidris canutus). Compared to birds acclimated to thermoneutrality, cold-acclimated (4-5°C) captive red knots were 15% heavier and exhibited a BMR and Msum 26% and 13% higher, respectively. Although the improvement in thermogenic capacity was directly related to the difference in body mass, likely through larger heat producing pectoral muscles (measured by ultrasonography), body mass-independent BMR remained 15% higher in cold acclimated birds. During the premigratory fattening period, all birds increased their body mass (up to 31%) and pectoral muscle size (up to 14%). This gain of mass was associated with improved thermogenic capacity (up to 16%), independent of thermal treatment. We suggests that in cold acclimated red knots, increase in thermogenic capacity is achieved via modulation of body mass and muscle size and that changes in size of other internal organs, such as the liver, are responsible for variations in BMR.

7.10 VICKNAIR, K.E,; PEARSE, J.S.**; MCCLINTOCK, J.B.; FEDER, H.M.; Univ. of California, Santa Cruz, Univ. of Alabama,Birmingham, Univ. of Alaska, Fairbanks; *pearse@biology.ucsc.edu*

When keystones meet: sea stars and sea otters in central California

Ochre sea stars (*Pisaster ochraceus*) and sea otters (*Enhydra lutris*) are both recognized keystone species that profoundly influence community structure. However, there are no data on whether the two species influence each other. Sizes, densities, and prey of ochre sea stars were documented at three sites adjacent to Hopkins Marine Station in Monterey Bay, California in the mid-1950s, a decade before sea otters returned to the area. Data were collected again from the same sites 2, 3, and 4 decades after the sea otters returned. Sea-star mean size was reduced more than 50% at the exposed, mussel-dominated site in the mid-1980s, remained low in the mid-1990s, then slowly increased. However, density changes were reciprocal to size changes so biomass at the mussel-dominated site remained about half what it was in the 1950s. Mussels at the site increased in size and the bed expanded into the low zone until it was torn out by storms or sea otters in 2004. Heavy recruitment in 2005 resulted in extensive mussel cover throughout the intertidal in 2006 when sea-star density was very low. Sea-star densities declined steadily at the two more protected sites, and patches of mussels now occur at one of those sites. We propose that sea-otter predation on sea stars, particularly larger individuals, allows mussels to increase in size and mussel beds to extend into the low zone, becoming more susceptible to storms. The decline in sea-star abundance at the more protected sites probably is related to other factors, perhaps the development of a major harbor-seal haul out in the area, gull predation, or climate change.

S8-1.1 VINCENT, S.E.*; HERREL, A; Stony Brook University; *svincent@ethol.zool.kyoto-u.ac.jp*

Functional and ecological correlates of ecologically-based dimorphisms in squamate reptiles

Sexual dimorphism in phenotypic traits associated with resource use is a widespread phenomenon throughout the animal kingdom. Ecological dimorphisms can be generated initially by sexual selection on body or head size, but are typically maintained by natural selection acting to reduce intrasexual resource competition. The trophic apparatus of ophidian squamates (snakes) has attracted a significant amount of research in this regard because head size is not known to be under sexual selection, enabling researchers to make straightforward hypotheses regarding the evolution of ecological dimorphisms. However, significantly less attention has been paid to the evolution of ecological dimorphisms in lizards. This lack of research is likely due to the fact that the feeding apparatus of lizards can be under both sexual and natural selection simultaneously, making it difficult to distinguish between natural and sexual selection pressures. In order to tease apart the respective influences of natural and sexual selection on the feeding apparatus of squamates, we take a functional morphological approach here to formulate two straightforward hypotheses for snakes and lizards, respectively: 1) For gape-limited predators such as snakes we predict that natural selection will act to generate differences in maximum gape, which will translate into ecological differences in maximum ingestible prey size between the sexes. 2) For lizards which mechanically reduce their prey, we predict that the sexes will differ in maximum bite force, which will be correlated with differences in maximum consumed prey size and hardness. Finally, we predict that functional differences in the feeding apparatus of both lizards and snakes will result in differences in sex-based prey selection in the wild.

26.3 VINCENT, S.E.*; HASEGAWA, M.; MORI, A.; Stony Brook University , Toho University, Kyoto University; *svincent@ethol.zool.kyoto-u.ac.jp*

Ecomorphological diversification among snake populations on the Izu islands

A recent review showed that insular snake body sizes are bimodal in their distribution, with giants evolving on islands with large prey sizes and dwarfs on islands with small prey sizes. Nonetheless, body size itself plays no direct role during ingestion in gape-limited snakes, and exhibits a strong plastic response to the amount of food consumed over ontogeny. Thus, the adaptive nature of these insular snake body size trends remains largely unclear. To address this issue, I first compared the relationships between maximum head and body size and consumed prey size among three insular populations of a dietary generalist snake (*Elaphe quadrivirgata*) from the Izu Islands off the central coast of Japan. I predicted that due to the markedly different prey fauna amongst islands, maximum head dimensions of adult snakes would closely match consumed prey size. A multivariate analysis of size revealed that adult snakes on Tadanae-jima have evolved gigantic head and body sizes compared to adult snakes from from Kozu-shima and Nii-jima. Coupled with this morphological divergence, Tadanae-jima adult snakes primarily consume large nestling seabird prey and seabird eggs, whereas Kozu-shima and Nii-jima adult snakes primarily consume smaller lizard prey. To test for environmental versus genetic effects, I compared head and body dimensions among hatchling snakes from these three islands born under standardized laboratory conditions. Hatchling data revealed a significant genotype-environment interaction for both head width and snout-vent length. Specifically, Tadanae-jima snakes are born with wider heads and larger body sizes, and their heads and bodies grow faster than other populations as well. This study further supports the hypothesis that head width has been a major axis of diversification among gape-limited snakes.

59.2 VINTHER, Jakob; Yale University; *jakob.vinther@yale.edu*

The esthetal canal system in chitons (Mollusca: Polyplacophora) and homologous structures in Lower Cambrian small shelly fossils.

The esthetal canal system in chitons is one of the most complex canal systems within a mineralized matrix with both a sensory and secretory function. The esthete system is regarded as a distinct feature of the shell-plates in chitons, but it may have already been present in the aculiferan stemgroup. The Sachitida He, 1980 (Lower to Middle Cambrian), where forms like *Halkieria* Poulsen, 1967 belong, are common constituents of early Cambrian small shelly fossil assemblages. They sometimes exhibit a similar canal system within their sclerites. The significance and function of this canal system, as well as the systematic position of the sachitids within the Metazoa have been debated for some time. A reinvestigation of Halkieria revealed morphological evidence relating sachitids to the molluscs, especially the chitons. This assignment is opposed to earlier suggestions relating the sachitids to the brachiopods, annelids or lophotrochozoans. The morphology of the esthetal canal system in modern chitons is constrained by a number of factors. Acid macerated material of *Sinosachites* (=*Thambetolepis*) *delicatus* from the Lower Cambrian of Australia, which is abundant and preserved in great detail, reveals evidence that the canal system functioned in a similar manner to that in modern chitons. There are a number of remarkable similarities between these two canal systems in external morphology and ontogeny, which further supports the relationship of *Halkieria* and other sachitids to the molluscs.

S10.6 VOGEL, S; Duke University; *svogel@duke.edu*
Academic Scientists Involved in Education - A Need for the SICB Digital Library
In most areas represented in SICB, people doing research also teach. We routinely disseminate results of our research; we rarely do the same with innovations in our teaching. And we neither carry out nor report on research without plumbing the literature; in teaching we only occasionally look much beyond selection of a textbook. The inevitable results are reinvention of some wheels and unawareness of the utility of others. Perhaps the major barrier to an equivalently critical literature for teaching is the inappropriateness of the conventional journal- or book-based format. A dedicated, peer-reviewed digital resource base can transcend that barrier. It creates an instantly accessible archive of material derived from the immediate experience of people whose courses cover the particular subject. It can be searched by topic, intended level of use, type of resource, and so forth. Contributions can vary widely in scope and type, including overall course designs, questions for homework and tests, audiovisual and computational items, demonstrations, suggestions for projects, and laboratory protocols. Even research tools with potential for course use can be made available. Material can be downloaded for direct use or easy modification. And both contributors and users can update material previously posted. And fortunately, the system of peer review evolved for research journals and now commonly done on-line will work without modification for such digitally-based teaching resources.

S1-1.11 VOLTZOW, J.; Univ. of Scranton, Pennsylvania; *voltzowj2@scranton.edu*
Induced flow in gastropods: Filling in the holes
Many organisms can take advantage of an induced flow by exploiting pressure gradients caused by their shape or the shape of their burrow to enhance flow through or around them. The shells of the marine gastropods of the families Fissurellidae, Haliotidae, and Pleurotomariidae (keyhole limpets, abalone, and slit shells) have openings or slits that may permit them to passively induce the flow of seawater through their mantle cavities. Fissurellids have an induced flow that appears to enhance the efficiency of their respiration in moving water. Some species of fissurellids that lack apical openings in their shells form siphons with their mantles that elevate the excurrent window above the rest of the body. The elevated series of openings, or tremata, of haliotids, especially of those that live in subtidal areas marked by strong currents, permit a passively induced flow through the mantle cavity. Pleurotomariids line the slit with the edges of the mantle and elevate one portion into an excurrent siphon. The position of this siphon, as indicated by a scar on the inside of the shell, would make it possible for these animals also to take advantage of a passively induced flow.

15.1 VON BIELA, V.R.**; BURNS, J.M.; GILL, V.A.; University of Alaska Anchorage, U.S. Fish and Wildlife Service, Anchorage, AK; *vanessavb@gmail.com*
Differences in age at first reproduction of northern sea otters (Enhydra lutris kenyoni) in Alaska
Life history theory predicts that populations experiencing different environmental conditions such as resource availability and/or predation rates will have different reproduction and survival rates. Age at first reproduction (AFR) is expected to be older if populations are stable or declining due to bottom up constraints and younger if populations are increasing or declining due to top-down factors. In southwest Alaska (SW), where northern sea otter (*Enhydra lutris kenyoni*) populations have declined over 75% since 1992, changes in AFR may shed light into the causes of the decline. In this study we compared AFR, determined from analysis of reproductive tracts or cementum annuli, between three sea otter populations in Alaska: southcentral (SC, 1994-2005, n=25) where the population is are stable, southeast (SE, 1994-2005, n=39) where the population is stable or increasing, and southwest (SW) during a period when population was stable (1967-71, n = 692) and during the rapid decline (1994-2005, n=42). Otters in SC had the highest AFR of all groups (t-test with Bonferroni correction, $p>0.05$), as expected for a stable population at carrying capacity. In addition, the AFR for SW sea otters during the decline was significantly lower than when the population was stable (t-test, $p>0.05$), supporting the hypothesis that top-down forces are driving the current population decline. These findings support the use of AFR as a cost-effective indicator of the underlying causes of population change in large marine vertebrates.

S2-1.7 WAGNER, G. P. ; Yale University; *gunter.wagner@yale.edu*
Linking the Evolution of Genes with the Evolution of Morphological Characters
There are two types of questions implied by the title of our symposium: Linking Genes and Morphology. At the one hand there is the question what role a certain gene plays in the development of a morphological feature. This is the question of developmental genetics and there is a well developed paradigm of how to answer this question. On the other hand there is the question, what genetic changes led to specific morphological changes in evolution. The paradigm of how to address the latter issue is much less mature than that of developmental genetics. The challenge of elucidating how the evolution of genes have caused the evolution of morphological phenotypes has many levels. In this contribution I want to focus on one specific problem, namely the difficulty to identify which changes have caused the morphological change of interest and which are incidental. I will be discussing a strategy which consists of combining a careful analysis of the molecular evolution of genes involved in the development of a derived morphological character with experimental validation of candidate genetic changes. The objective is to associate un-expected patterns of sequence evolution with the inferred morphological change. This approach assumes that relevant genetic changes happened under directional selection. It also requires sufficient knowledge of the developmental biology of the derived morphology and a hypothesis about what genetic elements are likely to have caused the morphological change (coding sequence evolution of transcription factors, cis-regulatory elements, mi-RNA). Finally it needs an experimental handle on testing the functional consequences of the inferred genetic changes. I will propose a set of minimal set of evidential criteria to validate a specific hypothesis about a link between a genetic and a morphological change in evolution.

S5.4 WAGNER, G. P. *; CROW, K. ; LYNCH, V. ; Yale University; *gunter.wagner@yale.edu*

Do Genome Duplications Play a Role in Key Transitions?

A survey of gene duplications in early metazoan, vertebrate and plant phylogenies suggests an association between major transitions and gene duplication events. The evidence for a causal connection between genome duplication and major innovations and/or radiations, however, is weak on several grounds. First, evidence for an association between a genomic event and innovations or cladogenetic events is not strong, with a few exceptions including the origin of teleosts and the higher flowering plants. Second, major transitions can happen without genome duplications, like the origins of birds, and mammals. Third, genome duplications occur quite frequently in plants, fishes, and amphibians. Hence the apparent association between genome and gene duplications and major transitions could either be a perceptual artifact or caused by another mechanism than genome duplications causing innovations. We note that genome duplications, which coincide with an adaptive radiation may have a higher probability of leading to the permanent integration of paralog genes, than genome duplications, which are not associated with adaptive radiations. We propose that adaptive radiations may increase the chance for the retention of duplicated genes by adaptive processes which take advantage of the genetic material offered by the duplication event. Hence the chance that two paralogs can be traced back to a major radiation event is higher than by chance. We provide molecular evidence from Hox gene evolution that ancient paralogs tend to be differentiated by divergent selection immediately following the duplication event, while those paralogs which originated independent of a radiation tend to evolve under strong purifying selection, with little evidence of adaptive changes occurring after speciation events. Hence it may be that adaptive radiations drive the evolution of genome structure and not vice versa.

63.1 WAGNER, E.C.*; PREVOLSEK, J.S.; WYNNE-EDWARDS, K.E.; WILLIAMS, T.D.; Simon Fraser University, Queen\\\'s University; *ewagner@sfu.ca*

Anemia associated with egg production is estrogen-dependent: a basis for the cost of reproduction?

The cost of reproduction' (i.e. trade-offs between current reproduction and future fecundity and/or survival) is a central concept in life history theory, yet we still know very little about the physiological mechanisms underlying such costs. Recently it has been recognised that reproduction itself or the regulatory (physiological) mechanisms underlying reproduction might result in costs' (cf. the more traditional resource-allocation based mechanisms). The antagonistic pleiotropic effects of hormones represent such a mechanism, where the endocrine networks regulating reproduction have multiple effects in other body systems, with negative non-reproductive effects considered resource-independent costs. Previously we have proposed a specific mechanism, the development of anemia (decreased hematocrit) during egg production in birds, which may play a role in associated costs of egg production via reductions in oxygen carrying capacity, aerobic capacity, and thus negatively impacting parental care. Here we demonstrate that anemia during egg-laying is dependent on endogenous estrogens: blocking estrogen receptors using the anti-estrogen tamoxifen completely inhibits development of anemia in female zebra finches (*Taeniopygia guttata*) such that hematocrit of tamoxifen-treated laying females is not significantly different from pre-breeding or non-breeding values, and is significantly higher than control laying values. Thus, this mechanism is a good candidate for a regulatory-network based trade-off involving antagonistic pleiotropic effects of estrogens, which otherwise have essential reproductive functions during egg production.

S9-1.4 WAINWRIGHT, P.C.; Univ. of California, Davis; *pcwainwright@ucdavis.edu*

Suction feeding mechanics and diversity in fishes

Suction feeding is the most widely used mechanism of prey capture among fishes, so any attempt to understand trophic diversity in this group must be rooted in an understanding of how suction feeding works. I focus on a series of recent insights on the nature of suction feeding performance and the forces that suction feeders exert on their prey as a foundation for a reinterpretation of some classical axes of trophic diversity in fishes. A model of the musculoskeletal basis of suction pressure points to a set of features that underlie variation in the capacity of fishes to generate suction and therefore provides a framework for interpreting the consequences of diversity in skull form. This work indicates that there are a variety of ways to build a fish that can generate high suction flow velocities. Researchers have focused mostly on drag as the dominant force that suction feeders exert on their prey, but physical modeling indicates that under most conditions the pressure gradient is the dominant force experienced by prey. An insight that emerges here is that the force exerted on a prey item increases with reduction of mouth diameter, even when peak suction velocity is held constant. Mapping of morphology onto prey-use patterns reveals that (1) a few highly demanding prey types tend to generate easily recognized patterns of convergence (e.g. mollusk crushing, zooplanktivory), but (2) most prey types exhibit many-to-one mapping in which multiple forms feed on the same thing. This is partly because the performance requirements of many prey are modest, but also because the complexity of the feeding mechanism means that many morphologies can have the same feeding performance. Supported by NSF IOB-0610310 and 0444554.

29.4 WALLACE, B.P.*; SOTHERLAND, P.R.; SANTIDRIAN TOMILLO, P; BOUCHARD, S.S.; REINA, R.D.; SPOTILA, J.R.; PALADINO, F.V.; Duke University Marine Lab, Kalamazoo College, Drexel University, Otterbein College, Monash University, Drexel University, Indiana-Purdue University, Ft Wayne; *bwallace@duke.edu*

Egg components, egg size, and hatchling size in leatherback turtles Dermochelys coriacea

Relationships between egg size, egg components, and neonate size have been investigated across a wide range of oviparous taxa. Differences in egg traits among taxa reflect not only phylogenetic differences, but also interactions between biotic (i.e., maternal resource allocation) and abiotic (i.e. nest environment conditions) factors. We examined relationships between egg mass, egg composition, and hatchling size in leatherback turtles (*Dermochelys coriacea*) because of the unique egg and reproductive characteristics of this species and of sea turtles in general. Albumen comprised approximately two-thirds of egg mass and explained most of the variation in egg mass, whereas yolk comprised only about one-third of egg mass. Additionally, leatherback albumen dry mass was ~16% of albumen wet mass. Whereas hatchling mass increased significantly with egg mass (n = 218 clutches), hatchling mass increased by only approximately 2 g for each 10 g increase in egg mass and was approximately 10-20 g greater than yolk mass. Taken together, our results indicate that albumen might play a particularly significant role in leatherback embryonic development, and that leatherback eggs are both capable of water uptake from the nest substrate and also possess a large reservoir of water in the albumen. Relationships between egg mass and egg components, such as variation in egg mass being largely explained by variation in albumen mass and egg mass containing a relatively high proportion of albumen solids, are more similar to bird eggs than to eggs of other non-avian reptiles. However, hatchling mass correlates more with yolk mass than with albumen mass, unlike patterns observed in bird eggs of similar composition.

58.6 WALSH, PJ*; BARIMO, JF; MCDONALD, MD; University of Ottawa, Portland State University, University of Miami; *pwalsh@uottawa.ca*

The influence of photoperiod on pulsatile urea excretion in the gulf toadfish Opsanus beta

The gulf toadfish Opsanus beta (Batrachoididae) is one of the few teleosts to maintain a functional ornithine-urea cycle (O-UC) during adult life and to possess the capability to change from ammonotely to ureotely within 24 hours in the laboratory. Captive O. beta excrete most nitrogenous waste across the gill membrane. In the lab, urea is generally excreted in daily pulses of 1.5 hrs in duration while ammonia is eliminated continually. At present, the mechanism of O-UC activation is putatively due to an elevation of plasma cortisol (stress response) which promotes the up regulation of the key O-UC enzyme glutamine synthetase. Experiments in this study examine the diel pattern of nitrogen excretion in the laboratory and in mesocosms. Under both experimental conditions toadfish were exposed to natural photoperiod, samples were collected hourly from toadfish in shelters fabricated with PVC pipe, and assayed for urea and ammonia with standard chemical techniques. In laboratory trials, conducted in 2 L containers with static seawater changed daily, urea pulses occurred at random with no correlation to light or dark cycles. In mesocosm experiments, toadfish were unrestrained in 8000 L tanks with the seagrass Thalassia testudinum planted on carbonate substrate effectively simulating their natural habitat. Shelters were outfitted with an underwater IR camera connected to a time-lapse video recorder to document toadfish behavior. As in prior field studies, in mesocosms urea and ammonia were excreted simultaneously in approximately a 50:50 ratio and occurred predominately during daylight hours with peak levels near dawn or dusk, and these excretion patterns were also reflected in appropriate and pronounced declines in plasma levels of urea. Differing results between experimental regimes are believed to reflect the degree of stress encountered by toadfish and to represent two ends of the spectrum of natural physiological responses. The results will be discussed in the context of a hypothesis of chemical crypsis and predator avoidance. Supported by NSF (IOB-0455904)

27.5 WALSH, B.M.*; BERTA, A.B.; San Diego State University; *bredamckay@yahoo.com*

Cranial ossification and growth patterns of balaenopteroid mysticetes

The sequence of ossification of sutures in the skull of baleen whales (mysticetes) can be used to characterize the relative age of these animals. We examined occipital suture closure in four neonate mysticete species and determined that gray whale calves have open occipital sutures until approximately 6 mos. of age and are born at a more developmentally juvenilized stage than closely related fin, minke and humpback whales. In examination of the cranial growth over the life span of these species, we computed allometric cranial growth patterns of the different ontogenetic stages (calf, juvenile, mature) with log linear regression analysis of eight cranial measurements. Previous studies found that juvenile mysticetes grow slower than calves attributed to their adjustment to different nutritional supplies, but differences in cranial growth patterns has not been described. This study uses a larger data set than previously available for comparison and description of cranial growth and classification of ontogenetic stages among a group of closely related balaenopteroid mysticetes (Balaenopteridae + Eschrichtiidae). The results of this investigation suggest that the dimensions of the skull grow at different rates depending on ontogenetic stage and species. This analysis indicates that the skulls of balaenopteroids develop at a rapid rate during the first year, along with total body length; however, each species has its own cranial growth pattern that cannot be generalized for all mysticetes, as has been done in previous studies.

31.6 WANG, Gang*; RICHARDSON, Matthew I.; MOORE, Ignacio T.; SOMA, Kiran K.; LI, Dong-Ming; LEI, Fu-Min; WINGFIELD, John C.; Univ. of Washington, Seattle, Virginia Tech, Blacksburg, Univ. of California, Los Angels, Inst. of Zoology, Chinese Academy of Sciences; *gangw@u.washington.edu*

Seasonal regulation of adrenocortical response to stress in two species of snowfinches on the Tibet Plateau

The Arctic tundra and Tibet Plateau are considered extreme environments but they differ in latitude and altitude respectively. Many studies have addressed adaptations of hormone-behavior interactions to unpredictable environments in Arctic birds, especially regulation of the hypothalamic-pituitary-adrenal (HPA) axis. These modulations are thought to enhance reproductive success under severe conditions. Whether similar modulations of the HPA axis occur in major high altitude environments is less well known. In this study, we investigated the baseline and stress induced levels of corticosterone in relation to season and year in two species of snowfinch: white-rumped snowfinch (WRSF), *Onychostruthus taczanowskii* and rufous-necked snowfinch (RNSF), *Pyrgilauda ruficollis*, which are endemic to the Tibet Plateau from 3000 5000 meters elevation. Baseline and stress-induced levels of corticosterone were significantly higher during spring than autumn in WRSF, but not in RNSF. An abnormal cold spring in 2005 delayed onset of breeding in WRSF. In contrast, RNSF were already mated and were building nests at this time. It is unclear whether this is due to RNSF being more resistant to low temperature or whether regulation of breeding seasons is different between these two snowfinch species. WRSF did show seasonal regulation of both baseline and stress induced level of corticosterone, similar to Arctic birds. However, RNSF, often breeding alongside WRSF, did not modulate. Whether this represents a species difference or is related to differences in breeding phenology is currently under investigation.

3.2 WANG, JH*; LOHMANN, CMF; LOHMANN, KJ; University of Hawaii, Manoa, University of North Carolina, Chapel Hill; *john.wang@noaa.gov*

THE MAGNETIC MAP OF SEA TURTLES: EVIDENCE FOR MULTIPLE MAGNETIC ELEMENTS

Juvenile sea turtles take up residence in specific coastal feeding sites and return to these sites after displacement. Previous work has established that such turtles use magnetic map information when navigating to specific destinations. Because newly hatched turtles can detect the intensity and the inclination angle of the field, the magnetic map used by the juvenile turtles might be based on one or both of these parameters. To investigate the organization of their magnetic map system, juvenile green turtles were captured and tethered inside a large magnetic coil system used to reproduce the magnetic field of specific geographic locations. One group was exposed to a field that exists approximately 325 km north of the test site. The second group was exposed to an experimental field; this field paired the intensity of the northern site with an inclination angle 325 km to the south. Turtles exposed to the first field oriented southward as if navigating to their feeding site, whereas turtles exposed to the second field oriented randomly. These results imply that turtles do not rely exclusively on magnetic field intensity; if they did, then turtles tested in the second field should have oriented south. Similarly, turtles do not rely on inclination alone; if they did, then the second field should have elicited northward orientation. The results are consistent with the hypothesis that turtles detect both field parameters and are unable to navigate under unnatural conditions in which the two provide conflicting positional information. Thus, both inclination and intensity appear to play important roles in the ability of turtles to determine geographic position.

52.1 WANG, G*; FRAZIER, MR; Univ of Washington, Seattle; *gw0@u.washington.edu*

Increased variation in extreme environmental conditions: Adaptive response or sampling artifact?

Trait variation is greater in stressful environments than in non-stressful environments. For example, the confidence interval of fitness in *C. elegans* is greatest at high temperatures. Several authors have hypothesized that increased variation in extreme environments is the result of selection. Proposed mechanisms include: 1. Direct effects of stress on recombination and mutation rates. 2. Breakdown of canalization in extreme environments. 3. Increased variability is an adaptive response which exposes underlying genetic variability to selection in extreme environments. However, these hypotheses ignore the fact that increased variation is the null expectation in steep areas of non-linear reaction norms when there is either measurement error or small lateral shifts in underlying reaction norms. We explore the effects of measurement error and changes in reaction norm shape on observed variation using both Monte Carlo simulation and published experimental datasets. We suggest analytical and experimental methods for separating the underlying causes of variation.

7.2 WARNE, R.W.*; PERSHALL, A.D.; WOLF, B.O.; University of New Mexico; *rwarne@unm.edu*

Quantifying the resource dynamics of a lizard community: Coupling abiotic drivers and ecosystem productivity to reproduction in lizards

Desert animals must integrate unpredictable and often ephemeral pulses of resources, yet how these animals allocate limited resources to survival and reproduction in the face of climate extremes has not been directly quantified. During 2005 and 2006 precipitation in New Mexico alternated between one of the wettest recorded winters to the driest; while summer monsoons in 2006 produced the most summer rain in recorded history. In this study we examine how these extreme climate patterns drive the seasonal and inter-annual resource dynamics within a lizard community in the Chihuahuan Desert of New Mexico. Through the use of naturally occurring carbon and nitrogen stable isotopes we quantify the relative importance of C_3 and C_4 plant productivity to the nutritional and reproductive ecology of lizard consumers at the Sevilleta LTER in New Mexico. The summer monsoonal rains characteristic to our site support the abundant growth of C_4 plants, a functional plant group with a unique form of photosynthesis that produces carbon isotope values (-14 VPDB) distinct from spring dominant C_3 plants (-26 VPDB). Because the carbon isotope values of animal consumers reflect those of their diet we show that with an increased summer abundance of C_4 plants, the resources used by insectivorous lizard consumer's shift from 21% C_4 derived plant sources in June 2005 to 38% by August 2005. In comparison resource patterns for 2006 reflect the importance of rain as an abiotic driver of this arid ecosystem. Further isotope analysis of these lizard's fat stores, eggs and muscle provides insight into the allocation strategies these lizards use to meet the demands of survival and reproduction in the face of extreme climate patterns.

6.2 WEAKLEY, J.C.; CLAIBORNE, J.B.; EDWARDS, S.L.**; James Cook University, Georgia Southern University; *susan.edwards@jcu.edu.au*

Molecular identification and expression of a V-type H^+-ATPase in the gills of euryhaline barramundi (Lates calcarifer).

In fishes, most acid-base imbalances in the short term are moderated by blood and tissue buffering to lessen the impact of acid/base fluctuations. Limitations to buffering require that the final compensation for alterations in pH is by the transepithelial excretion of the excess acid or base from the fish to the ambient water. Euryhaline fishes and moderately euryhaline species such as the barramundi *(Lates calcarifer)*, have the physiological ability to move between waters of various salinities and are often exposed to rapid changes in ionic gradients that impact acid-base exchanges. It has recently been proposed that euryhaline fishes may utilize both V-type H^+ATPase and Na^+/H^+ exchanger mechanisms located in the branchial epithelium to regulate systemic pH, and that the differential expression of the acid/base relevant transporters is governed by environmental salinity. This study has used molecular and immunohistochemical approaches to identify of the presence of a V-type H^+ATPase in the gill of the euryhaline barramundi. The barramundi V-type H^+ATPase shares a 97% amino acid identity with other known vertebrate V-type H^+ATPase cDNAs and is localised to a subpopulation of mitochondrial rich cells in the gill epithelium. In addition, results from H^+ efflux analysis on animals acclimated to a range of environmental salinities and exposed to 1% CO2, demonstrated that barramundi placed in higher salinities displayed the greatest net H^+ excretion overall, highlighting the importance of external counter ion (Na^+) availability and the absolute rate of H^+ excretion. Initial analysis on terminal gill samples collected during H^+ efflux studies, show a pattern of increased V-type H^+ATPase and Na^+/K^+-ATPase protein expression correlated to an increased environmental salinity and increased rate of net H^+ efflux.

65.2 WEGNER, N.C.*; SEPULVEDA, C.A.; GRAHAM, J.B.; Scripps Institution of Oceanography, Pfleger Institute of Environmental Research; *nwegner@ucsd.edu*

Specializations for gill rigidity in ram ventilating teleosts

For ram-gill ventilators such as tunas (family Scombridae) and marlins (family Istiophoridae), a rigid gill structure prevents filament and lamellar deformation by the fast, continuous ventilatory flow stream. Comparative studies of water-flow resistance imposed by fusions binding the gill filaments and lamellae are in progress. In tunas, lamellar fusions bind adjacent lamellae on the same filament to opposing lamellae of the neighboring filament. Examination of other scombroid genera reveals lamellar fusions in the bonitos and a previously undescribed inter-lamellar fusion in the wahoo (*Acanthocybium solandri*), striped marlin (*Tetrapturus audax*), and sailfish (*Istiophorus platypterus*). Unlike lamellar fusions, the inter-lamellar fusion binds juxtaposed lamellae on the same filament, but does not connect to the opposing lamellae of the adjacent filament. This shared character in the wahoo, striped marlin, and sailfish supports the phylogenic hypothesis of Johnson (1986) who proposed that the billfishes are sister group to *Acanthocybium*.

6.7 WEIHRAUCH, Dirk; University of Osnabrueck, Osnabrueck, Germany; *weihrauchblues@gmx.net*

Active ammonia uptake in the midgut of the tobacco hornworm Manduca sexta.

In Ussing chamber experiments the mid- and hindgut of *Manduca sexta* larvae were tested for their ammonia transport properties. In the presence of 0.1 mM ammonia on both sides of the isolated epithelium, active transepithelial ammonia absorption (aTEPA) was observed in all midgut sections, with greatest transport rates (140 $nmol*cm^{-2}*h^{-1}$) detected in the median midgut. The hindgut showed no aTEPA. In the median midgut inhibition of energy metabolism by azide blocked aTEPA completely, whereas inhibition of the V-ATPase by bafilomycin A1 reduced the active transport by 50%. The imposition of a luminal directed NH_3-gradient (pH 6.5 apical, pH 8.5 basal) lowered the aTEPA by approximately 50% but did not reverse its direction. Apical addition of amiloride reduced aTEPA by 90%, suggesting a role of carrier-mediated ammonia transport across the apical membrane via a member of the NHE family. Inhibition of the microtubule network by colchicine reduced aTEPA by ca. 50%. In contrast, blocking basal K^+ channels by Barium ions had no effect on aTEPA. Using molecular methods, full cDNA sequence of a Rhesus-like ammonia transporter (RhMS) was found with low mRNA expression levels in midgut tissues, but high expression levels in the hindgut, Malpighian tublules and ganglia. Due to its low expression in the midgut, it is likely that RhMS plays no major role in the transport process. However, presumable excess hemolymph ammonia is secreted in a regulatory mode into the Malpighian tubules, where high tissue ammonia concentrations (ca. 30 µmol/g fresh weight) but also high levels of RhMS mRNA were detected. Ammonia is then finally released for excretion into the hindgut where, in contrast to the midgut sections (ca. 1 mM), very high ammonia concentrations (ca. 60 mM) were measured.

61.6 WEISE, M.J.*; COSTA, D.P.; UC Santa Cruz; *weise@biology.ucsc.edu*

***Individual-based foraging strategies in male California Sea Lions* (Zalophus californianus)**

Historically conspecifics were often treated as ecological equivalents in studies of foraging theory, but more recently the variation among individuals is no longer considered as irrelevant noise, but a focus of interest. California sea lions are one of the most abundant apex predators along the West Coast of North America and likely affect the dynamics and community structure of coastal ecosystems, yet we know little about their foraging behavior. In this study satellite-linked dive recorders were used to investigate the foraging strategies of sub-adult and adult male California sea lions following the breeding season during 2003-04 and 2004-05. Multivariate analyses were used to reduce the number of behavioral variables used to characterize foraging strategies, identify individually based foraging strategies in multidimensional space, and classify each individual into a cluster or foraging strategy. Approximately 81.1% of the variation among individuals in diving behavior could be explained by three factors; diving patterns, foraging effort, and surface behavior. Individuals could be classified into three distinct groups based on their diving behavior (shallow, mixed depth, and deeper divers), and jack-knife re-sampling of the data resulted in correct group assignment 86% of the time. Differences among individual strategies were partially explained by size dimorphism, in that, larger animals dove deeper and longer and likely reflected differences in the distribution of targeted prey. Individual-based foraging strategies in sea lions have broad ramifications for models of intraspecific competition, predator-prey dynamics, and food web structure in the coastal ecosystem.

S1-1.16 WEISSBURG, M*; JACKSON, J; RAHMAN, S; WEBSTER, DR; GA Tech; *marc.weissburg@biology.gatech.edu*

The effects of vertical odor plume structure on navigation and foraging performance in blue crabs

Large marine invertebrate predators (e.g., blue crabs) navigate using odor plumes in turbulent boundary layers. Unfortunately, we know little about the vertical distribution of odors and how it affects navigation. This study used laser-induced fluorescence to examine the information content of plumes at several locations sampled by crab chemosensors. In parallel, we studied crab foraging to link odorant distributions and olfactory search performance, and altered the bed substrate to generate a large range of turbulence levels (u*=3-6; Re*= 0-350). Foraging success declined markedly over the first 2 roughness conditions then remained constant. Increased turbulence decreased odor burst concentration, which disrupted upstream movement and lowered walking speed. Path linearity was unaffected. The steering ability of animals depends on sensors located close to the bed, and is less affected by turbulence because mixing peaks close to the bed to create homogenous odor distributions even when turbulence is low. Odor is transported to the substrate better in rough than in smooth beds. This is advantageous for animals with sensors located close to the substrate, such as whelks, which forage well in turbulent conditions. Close to the source, odor concentration and concentration variance had sharp maxima near the source height, but become almost uniform across depth ca. 80 cm downstream. Profiles were more homogenous with increased roughness. Thus, 3D information may be used for near source decisions (e.g. local search, stopping) but is more limited when turbulence is increased. The ecological impact of fluid flow on foraging decisions and performance may be limited to distances relatively close to the source since plumes converge to similar structures regardless of turbulence level.

65.6 WELCH, KC*; SUAREZ, RK; Univ. of California, Santa Barbara; *k_welch@lifesci.ucsb.edu*

Biochemical stoichiometry affects whole-animal oxygen consumption rate in vivo

The stoichiometric relationship of molecular oxygen consumption to ATP production is known to vary as a function of the metabolic substrate used. The P/O ratio of isolated mitochondria oxidizing fatty acids is lower than when pyruvate is oxidized while perfused hearts using fat consume more O_2 than when using carbohydrate. Whether this matters at the level of the whole animal is not known. In the present study, we hypothesized that VO_2 should decline as RQ increases from 0.7 to 1.0 to reflect these stoichiometric relationships in hovering hummingbirds (*Selasphorus rufus* and *Calypte anna*) as they transition from fasted to fed states. Under controlled conditions in which metabolic power input requirements are expected to be constant, we show that oxygen consumption is significantly greater when fats are metabolized compared to when carbohydrates are metabolized. The effect of metabolic substrate on oxygen consumption rate remains robust after accounting for small changes in hummingbird mass over the course of the experiment. The average difference in oxygen consumption rate between states in which individuals are oxidizing fats versus carbohydrates is remarkably similar to the differences observed at the mitochondrial level and as predicted by current estimates of substrate-dependent P/O ratios. This study highlights the importance of knowledge of oxidized substrates whenever respirometry is employed as a means of inferring whole-animal metabolic power input.

1.6 WEST, Donnelly/A*; AYERS, Tina/J; Rollins College, Northern Arizona University; *DAWest@Rollins.edu*

Systematics of Lysipomia based on Chloroplast and Nuclear Sequence Data

The plant genus *Lysipomia* Kunth (*Campanulaceae*) is comprised of two subgenera and approximately forty species that grow exclusively in the Andes at 3000-5000 m elevation. Recent work using molecular markers has revealed more species than previously known from earlier morphological data. In this study, using sequences of the nuclear marker ITS and the chloroplast spacer region between the atpB-rbcL genes, we expand upon recent results to examine phylogenetic relationships within the subgenus *Rhizocephalum*. From our analyses, we confirmed that the genus *Lysipomia* is monophyletic. A consensus tree using both markers generated three well supported clades within the subgenus and unequivocally placed *L. caespitosa* as a sister species to the clade containing *L. biliniata*, *L. lehmannii*, and *L.cylindrocarpa*. We also discovered a cryptic species lying within the morphospecies now known as *L. sparrei*.

48.5 WESTERMAN, E.L.*; HARRIS, L.G. ; BOLKER, J.A.; DIJKSTRA, J; University of New Hampshire; *erica.westerman@unh.edu*

Timing of colonial ascidian life cycle offset by warmer winter water temperatures in the Gulf of Maine

Temperature and its effects on life cycles in organisms particularly those of invasive species have received great attention in recent times due to heightened awareness of global warming. To compare effects of rising ocean temperatures on native vs. recently arrived species, we monitored the relative growth and reproductive development in two dominant species of ascidians from the Gulf of Maine: *Botrylloides violaceus*, a recent invader; and *Botryllus schlosseri*, an established non-native species. Panels deployed at three sites with different temperature regimes (Damariscotta, ME, Newcastle, NH, and Salem, MA) allowed us to monitor growth and reproductive development for two years. Settlement panels deployed at the same sites supported a recruitment study from May through December, 2006. Average water temperatures were highest in Salem, Mass and lowest in Newcastle, NH, with those of Damariscotta, ME lying in the middle. Winter water temperatures were warmer during 2005-2006 than 2004-2005; spring and early summer temperatures were comparable. Earlier growth and settlement was exhibited by both species at all sites during the spring of 2006, which may be a result of warmer winter water temperatures. Similar temporal patterns of growth were found for both species throughout the sites, however those of the northern, colder sites were offset from those at Salem. During 2006, both species recruited to panels in MA over a month earlier than those in ME and NH. These results suggest that though temperature may not shape ascidian life cycles, it may be a driving force behind their annual starting time.

50.4 WESTHOFF, Guido*; BOETIG, Melissa; YOUNG, Bruce/A.; University of Bonn, Washburn University; *bruce.young@washburn.edu*

The spatial distribution of venom spat by cobras

Venom spitting has evolved independently in multiple lineages of cobras. Within the spitting cobras this defensive behavior spans a considerable range; some species expulse strong streams of venom capable of traveling well over a meter through the air, while other species produce a mist of venom that is limited in both volume and distance covered. Previous studies have shown that the same specimen can produce different spatial distributions or patterns of spat venom. Given that the corneal surface is the only external body area affected by contact with the venom, and that these distribution patterns impact the likelihood of spat venom contacting the cornea, the spatial distribution of the venom could be under selective pressure. We explored three competing hypotheses for the determinant of the spatial distribution of spat venom: 1) morphological specializations within the venom fang; 2) physiological performance of the propulsive muscle, and 3) kinematic displacement of the head during venom expulsion. To explore the morphological hypothesis we examined the fangs of several species of spitting and non-spitting cobras using SEM. The other two hypotheses were explored experimentally. Bipolar EMG leads were implanted into the skeletal muscle surrounding the venom gland. Standard and high-speed digital videography was used to document the distance between the cobra and the target (one of the authors) as well as the kinematic displacement of the cobra's head during venom expulsion.

S1-5.1 WESTNEAT, M. W.; Field Museum of Natural History; *mwestneat@fieldmuseum.org*

Role Models Play in Biomechanics

Biomechanics is rich in models: mathematical models, physical models, and role models. Using biomechanical models is one way that role models such as Steve Vogel make a complex subject accessible and fun, and help the rest of us achieve a contemptuous familiarity with biomechanics. In addition to celebrating how one of our best role models plays in biomechanics, I will discuss the role models play in biomechanics. Using several different kinds of biomechanical models: (mathematical, physical, and integrated computer models), this study will explore the utility of modeling in research and teaching. Most models start out simple but they can become complex, potentially limiting their use by others. How can we make complex models accessible? Models can play a central role in studies of basic functional morphology, developmental change in a system, and phylogenetic change in function among related forms. Examples from fishes are used to answer questions such as, how can we use models to test for functional convergence in biomechanics? How do we define functional characters and determine when they are convergent or redundant? When is a physical model better than the same idea written out as equations? The primary conclusions of this study are that (1) most biomechanical models are equations written on a page that present hurdles for easy deployment by others, (2) physical models, when possible, are the best for teaching, (3) integrated computer models that are easy to use and come with a user manual are the best for getting others to use your model. Roll that model!

68.3 WETHEY, David*; WOODIN, Sarah; Univ. of South Carolina; *wethey@biol.sc.edu*

Feeding and burrowing mechanics of lugworms, Arenicola marina and Abarenicola pacifica

Lugworms are subsurface deposit feeding polychaete annelids, who feed head-down in marine muddy-sands. These animals use hydraulic mechanisms to create and irrigate their burrows and to feed. We used simultaneous time-lapse photography and recordings of porewater pressure fluctuations to determine the mechanics of feeding. During feeding, lugworms generate positive pressure transients in the porewater of up to 800 pascals, which cause the sediment to crack in the region of the feeding zone. These cracks propagate to the sediment surface, and when pressurized, they allow sediment grains to fall from the surface down to the feeding zone of the animal. Repeated action of this sort creates a pit on the surface of the sediment. Burrowing generates porewater pressure fluctuations of up to 1200 pascals, as the animals fluidize the sediment in front of their heads in order to penetrate it. Defecation generates pressure fluctuations up to 1000 pascals, as the animals fluidize sediment in the tail shaft of their burrow. The European species *Arenicola marina* and the US west coast species *Abarenicola pacifica* use very similar hydraulic mechanisms in their activities. Laboratory and field measurements with pressure sensors indicate that unrestrained animals in the field carry out these activities at the same rates and using the same mechanisms as animals in the lab.

25.3 WHITENACK, L.B.*; SIMKINS, D.C.; MOTTA, P.J.; Univ. of South Florida, Tampa, FL; *whitenac@mail.usf.edu*

Biology Meets Engineering: Finite Element Analysis of Selachian Teeth

Applying engineering principles to biological studies can reveal novel functional insights into performance and evolution. This study explores the link between form, function and performance of shark teeth using finite element analysis. FE models of select shark species were fixed at the base and loaded at the tip for puncture and on the lateral cutting edges for unidirectional draw. Loadings were taken from puncture and draw material testing of shark teeth on teleost prey, from theoretical estimates in the literature, and finally loaded to an ultimate load of 10 kN. Initial results indicate that in puncture, regardless of the load magnitude, the tooth experiences stresses concentrated at the tip and along the lateral edge, rapidly diminishing away from these areas. When loaded laterally in draw, teeth with non-serrated thin cusps, such as those in *Carcharhinus limbatus*, show stress patterns that are similar to those predicted by beam theory. As cusps become broader and notched, such as teeth of *C. leucas* and *Galeocerdo cuvier*, stress concentrations occur along the cutting edge and at the notch. Consequently, notches could possibly be a site of crack formation and eventual failure. Notches, which also concentrate force on the prey, permitting cutting of durable material, may therefore be restricted to sharks that cut through tough prey. Furthermore, flexible attachment of teeth may serve to modify the stress distribution in live sharks in a way that reduces the chances of breakage.

28.7 WHITTAKER, D.J.; Indiana University, Bloomington; *djwhitta@indiana.edu*

Evolution of gibbons: resolving the Hylobates phylogeny with multiple datasets

The lar group of gibbons or small apes (genus *Hylobates*) has long represented a phylogenetic puzzle, with different datasets producing very different results. Most likely, this radiation represents a true polytomy. Rising sea levels in southeast Asia during the Pleistocene simultaneously isolated populations of gibbons which subsequently diverged into the six species present today. Nonetheless, molecular and vocal data have indicated variation in the degree of divergence among the species and a comparison of datasets reveals a biogeographic pattern. As the more slowly evolving genes typically used for phylogenetic analysis proved uninformative for this genus, I sequenced the hypervariable region I (HV-I) of the mitochondrial control region, or D-loop, and constructed a phylogenetic tree of the lar group. I then compared this phylogeny to published datasets (the ND3-4 locus, vocalizations, and morphological traits) by testing for congruence. The Kloss's gibbon (*H. klossii*), which was long considered a primitive representative of the genus based on morphological characteristics, shares many molecular and vocal characteristics with the Javan gibbon (*H. moloch*), and these two taxa, along with the agile gibbon (*H. agilis*) appear to be the most recently derived species. Meanwhile, the northernmost species (*H. lar* and *H. pileatus*) appear at the base of the radiation. No significant incongruence was found between the D-loop data and the other datasets. Together these data suggest that ancestral gibbons radiated from north to south. They also have important implications for understanding the evolution of other species in the region. Unlike the other markers, the HV-I region can accurately identify members of different gibbon species much like a DNA barcode, which should have applications in conservation efforts.

S9-1.1 WILGA, C.D*; MOTTA, P.J.; SANFORD, C.P.; Univ. Rhode Island, Univ. South Florida, Hofstra Univ.; *cwilga@uri.edu*

Feeding Mechanisms in Cartilaginous Fishes

Early chondrichthyans had limited cranial kinesis and a non-suspensory hyoid, suggesting a ram dominated capture mechanism. Modern sharks are characterized by a kinetic upper jaw braced by a suspensory hyoid arch that is highly kinetic. The ventral hyoid arch in batoids is dissociated from the jaws, permitting extensive cranial kinesis. The evolution of kinetic jaws is thought to be responsible for the extensive radiation of feeding modes in actinopterygians, particularly that of suction, as well as that of chondrichthyan fishes. Modern elasmobranchs possess a remarkable variety of feeding modes for a group containing so few species. Ram, suction, bite or filter feeding may be used to capture prey, with most species able to use a combination of two modes during a strike. Suction feeding, which has repeatedly arisen within all major elasmobranch clades, is associated with a suite of morphological and behavioral specializations similar to that of actinopterygians. We investigate prey capture performance in a diverse assemblage of purported suction feeding elasmobranchs. Drop in water pressure measured at the prey shows that suction inflow drops off rapidly with distance from the mouth. Maximum suction pressure in the buccal cavity is 8 and 44 times greater than at a distance of half gape width from the mouth in ram and suction feeders respectively. Consequently, prey capture by suction alone is only successful at close range. Indeed, the strongest and most specialized suction feeders, such as bamboo and nurse sharks, are primarily benthic and thus are able to closely approach or lie-in-wait for potential prey. Generalist feeders like spiny dogfish use ram coupled with moderate suction to pursue and catch prey. Benthic batoids such as Little skates and Atlantic guitarfish use primarily ram with very little suction to capture prey.

47.2 WILLIAMS, J.B.*; ROBERTS, S.P.; ELEKONICH, M.M.; Univ. of Nevada, Las Vegas; *jason.williams@unlv.edu*

Flight induced oxidative stress and Hsp70 expression in aging honey bees, Apis mellifera

As honey bees age they switch from in-colony tasks, such as nursing, to foraging for nectar and pollen outside the colony. Nurses rarely fly, have a relatively low metabolic rate, and experience a homogeneous colony environment. By contrast, foragers have the highest measured mass specific metabolic rates and produce thoracic temperatures that are 6-7ºC higher than heads during frequent foraging trips. Consequently, foragers have a six-fold higher concentration of the stress protein Hsp70 in their thoraces than their heads, as well as two-fold and six-fold higher Hsp70 levels than nurse thoraces and heads. Interestingly, temperature does not induce Hsp70 expression in forager thoraces at typical flight temperatures or even after exposure to 50ºC for 1h. In this ongoing study, we used the metabolic differences between nurse and forager honey bees to test the hypothesis that oxidative stress, rather than temperature stress, induces Hsp70 expression in forager thoraces. We measured carbonyl content (a measure of protein oxidative damage), total antioxidant activity, and expression of Hsp70 and the antioxidant enzymes, superoxide dismutase and catalase, in thoraces and heads of 9 to11 day-old foragers and nurses collected as foraging activity begins (8-10am) or at end of the foraging day (3-4pm). To determine the effect of a single foraging flight on tissue oxidative damage and Hsp70 expression, we measured the above parameters on thoraces and heads of foragers that were collected while leaving or returning from flights at each collection period. To assess the effect of age on accrued oxidative damage and Hsp70 expression we repeated the above experiments on bees aged 30 to 32 days.

S1-2.8 WINDSOR, S.P.**; MALLINSON, G.D.; MONTGOMERY, J.C.; Univ. of Auckland; *s.windsor@auckland.ac.nz*

Hydrodynamic imaging by blind cave fish

The hypogean (cave-dwelling) form of the fresh water teleost *Astyanax fasciatus*, commonly known as the blind Mexican cave fish, occurs in deep subterranean caves where there is no light. In the absence of visual information they rely on other cues for navigation and obstacle avoidance. They predominately use hydrodynamic signals processed by their mechanosensory lateral line sensory system to obtain hydrodynamic images of their environment. This ability depends on the fish monitoring the flow field created by its own movement and the distortions in this flow field created by nearby objects. Video analysis of fish behavior, and quantitative measurements of the flow field around swimming fish were made using digital particle image velocimetry (DPIV) and have been compared with computational fluid dynamic (CFD) models to help understand the precise stimulus and signal processing requirements for hydrodynamic imaging. The fish show a distinctive burst/glide form of swimming and during the tail beating phase there is a greatly increased chance of collision with stationary objects. In comparison during the glide phase they are capable of avoiding head-on obstacles at a distance of up to 17% of their body length. Results from DPIV and CFD both show that the flow field around a fish is strongly influenced by viscous effects and that the boundary layer that forms around a gliding fish will have a significant influence on the stimulus to the lateral line system. The combination of these techniques allows the exploration of the complex relationship between fish swimming kinematics, the induced flow field and the hydrodynamic stimulus to the lateral line.

68.9 WOLCOTT, T.G.*; KAMYKOWSKI, D.; WOLCOTT, D.L.; WATERS, L.; NC State Univ., Raleigh; *tom_wolcott@ncsu.edu*

Control of vertical migration in harmful algal blooms (HABs): field-testing a model using a robot "Plankton Mimic".

Red Tide dinoflagellates (*Karenia brevis*) undertake diel vertical migrations (DVM) but not simply as coherent swarms. At cell division, daughter cells may receive different resources, hence have different needs. Many of the field observations can be explained by a fairly simple model of migration control: photosynthate (C) deficiency increases speed upward, and nutrient (N) deficiency increases speed downward. The model's consequences in a dynamic field situation are being explored with the "Plankton Mimic", an autonomous vertically-migrating Lagrangian drifter. It measures *in-situ* depth, temperature, salinity, and photosynthetically-active radiation (PAR). Based on these measurements, it calculates photosynthesis, photodamage and light inhibition, respiration, and nutrient uptake (using depth and water temperature as surrogates for nutrient concentration.) Velocities of DVM are modulated by fullness of the cellular C and N pools. Each new depth presents different physical conditions, which feed back into swimming behavior. Data logged during a week-long deployment will be presented to show various consequences of behaviors in a context of continuous, dynamic interaction between [pseudo]organism and environment. Migration velocities that were modulated by C and N pools affected amplitude and average depth of DVM, which could lead to vertical distributions and dispersion similar to those exhibited by algae in the field. These adaptive behaviors maximized accumulation in the cellular pool (C or N) that was deficient, leading to "cell division" within biologically realistic times despite differences in initial conditions. (Funded by EPA.)

S6-2.1 WOLFNER, M.F.*; RAVI RAM, K.; MUELLER, J.M.; WONG, A.; MCGRAW, L.A.; ALBRIGHT, S.N.; SIROT, L.K.; PAGE, J.L.; Cornell University; *mfw5@cornell.edu*

Functions of seminal proteins in reproductive interactions between the sexes in Drosophila

The seminal proteins that females receive during mating play roles in sperm storage and utilization, and in changes to the female's physiology that can enhance fertility. Though the primary sequences (and even the presence of) some particular seminal protein genes vary among animals, the conservation of biochemical classes in seminal fluid suggests a conservation of functions. To address these functions, we have carried out genetic, RNAi, physiological and biochemical experiments in *Drosophila melanogaster*. We have identified seminal proteins that modulate the female's ability to store sperm, to mount an immune response, to ovulate large numbers of eggs, and that affect her viability and aspects of her transcriptome. We are particularly interested in seminal proteins as agents of chemical communication, mediating interactions between individuals. An example illustrating these interactions at the biochemical level will be presented. This example concerns a seminal protease that is made in a precursor form in males. As the protein transits through the male, on its way to the female, it is modified in a manner consistent with activation. However, the protease does not act until it is within the female! There, it mediates the processing of at least two other seminal proteins that affect sperm storage or ovulation, respectively. Molecular cooperation between the sexes may regulate male-derived modulators' effects on females.

55.3 WOOD, Jessica A.*; MEYERS, Jay; IRSCHICK, Duncan J.; Tulane University, University of Massachusetts, Amherst; *jwood@tulane.edu*

Display behavior, sexual signal size, and performance in Anolis sagrei

The theory of honest signaling posits several predictions; (1) There will be variation in quality among males, particularly within a polygynous mating system, and (2) high-quality males will exhibit displays or indicators of their status. The primary problem with this paradigm has been in determining how to define quality . Our approach has been to examine organismal performance as a key indicator of male quality in a polygynous mating system. Specifically, we examined if links exist between display behavior, sexual signal size (in this case dewlap size), and two kinds of organismal performance (bite force and sprint speed). We examined the lizard *Anolis sagrei* because this species is ubiquitous, possesses an enlarged sexual signal, and readily uses its performance capacities during social interactions. We filmed the display behavior of 64 male *Anolis sagrei* and analyzed each individual's quality in Bimini, Bahamas in July 2006. We also measured the dewlap size of all individuals filmed to determine if this characteristic is related to display behavior. Our results reveal intricate relationships among male sexual signal size, performance, and display behavior, and point towards performance as a key player in sexual selection.

49.11 WOODS, H.A.**; MORAN, A.L.; Univ. of Montana, Missoula, Clemson University, Clemson, SC; *art.woods@mso.umt.edu*

Egg mass physiology: Interactive effects of morphology, temperature, and embryonic age on oxygen gradients in invertebrate egg masses

Embryos of many marine invertebrates are encased in gelatinous masses for part or all of development. Because gel retards oxygen flux, this life-history mode profoundly affects partial pressures of metabolic gases surrounding embryos. We examined the effects of four factors (temperature, embryo age, embryo density, and egg-mass size) on the metabolism of egg masses using both natural egg masses of a nudibranch and artificial egg masses made using sand dollar embryos and agarose. Both temperature and embryo age strongly affected metabolic rates of nudibranch embryos. Rates of oxygen consumption roughly doubled between 12 and 21 degrees C and increased 2-4 fold from early cleavage to the veliger stage. Advanced embryonic age and higher temperature both led to steeper oxygen gradients into egg masses. Small artificial masses (2 mm diameter) had virtually no internal oxygen gradients regardless of embryo density or temperature, while oxygen profiles in medium (4 mm) and large (10 mm) artificial masses depended strongly and interactively on embryo density and temperature. Our data suggest that temperature, through its effects on embryonic metabolism, interacts with embryo age, embryo density, and egg-mass size in important ways bearing on egg mass design. These findings allowed us to make specific predictions about egg mass physiology within and among species distributed across steep marine temperature gradients in nature. We test these predictions by comparing temperature sensitivity of metabolism of nudibranch embryos from temperate versus Antarctic sites.

45.6 WOODS, W. A. Jr.*; HENDRICKSON, H.; MASON, J.; LEWIS, S. M.; Tufts University; *william.woods@tufts.edu*

Energy and predation costs of firefly courtship signals

A courtship signal may impose more than one cost, and despite the acknowledged theoretical importance of these multiple costs, little is known about their relative importance. In addition, although bioluminescent signals are widespread in the animal kingdom, the costs associated with light production have never been measured. We quantified separately the energy and predation costs associated with the bioluminescent courtship signals of fireflies. We made respirometry measurements of the energy required to generate bioluminescent flashes, and found that energy expenditure during periods of flash production averaged a nominal 37 ±6% (mean ± SEM, n = 13) higher than when the same beetles were measured when not flashing (paired t = 5.83, 12 df, P < 0.0001). Percent elevation of metabolic rates above resting values increased as a direct function of bioluminescent pulse rates recorded by time-synchronized video imaging (regression r^2 = 0.60, $F_{1,10}$ = 13.47, P < 0.01). We also conducted field experiments in which light emitting diodes (LEDs) were used to accurately simulate courtship flashes of *Photinus greeni* females. Predatory *Photuris* fireflies were attracted significantly more often to traps with LEDs than to control traps (paired t = 12.04, 30 df, P < 0.0001). Furthermore, higher rates of signaling significantly increased the risk of *Photuris* predation (logistic regression likelihood ratio chi-square = 8.57, n = 31, P < 0.01). These results demonstrate that while energy expenditure of flashing is small, predation cost can be considerable, and suggest the importance of thinking beyond dyadic interactions toward a broader framework of communication networks involving multiple categories of receivers.

31.4 WU, L.*; CHU, K. H.; The Chinese University of Hong Kong; *kahouchu@cuhk.edu.hk*

Molecular Cloning and Expression of Heat Shock Protein 90 and Heat Shock Factor from the Shrimp Metapenaeus ensis

During vitellogenesis of oviparous animals, the transcription of vitellogenin, the major source of nutrients during embryogenesis, is under the regulation of heat shock protein 90 (Hsp90), which is regulated by the heat shock factor (Hsf). In vertebrates, Hsp90 competes with estrogen hormones for estrogen receptor, the main transcription activator of vitellogenin, but the regulatory role of Hsp and Hsf in vitellogenesis of invertebrates is largely unknown. In a recent study on shrimp vitellogenin, multiple binding elements of Hsf have been identified in the promoter of the gene, suggesting the participation of Hsf in regulating vitellogenin transcription in crustaceans. To study the possible regulatory role of Hsp90 and Hsf, we cloned the full length mRNA of Hsp90 and Hsf from the ovary of the shrimp *Metapenaeus ensis*. Amino acid sequences of Hsp90 show 87% and 70-80% homology with homologs in a crab and insects, respectively. Hsp90 shows consistently high level expression in ovary, gut, muscle and central nerve system of shrimps at different ovarian maturation stages, but is differentially expressed in eyestalk and hepatopancreas. While Hsp90 expression in the eyestalk increases during ovarian development, it shows an opposite trend in the hepatopancreas. The decrease of Hsp90 expression is accompanied by the up-regulation of vitellogenin transcription in the hepatopancreas, indicating the possible inhibitory action of Hsp90 on vitellogenesis. Further studies on the functioning of Hsp90 and Hsf in shrimp are in progress. The result would provide insights on the control of vitellogenesis in invertebrates.

3.6 WYETH, R.C.*; CROLL, R.P.; Dalhousie University; *Russell.Wyeth@dal.ca*

Peripheral sensory pathways in the pond snail Lymnaea stagnalis

Sensory systems are integral to the neural control of behavior. However, despite extensive neuroethological study of gastropod molluscs, there is only patchy understanding of their sensory pathways. For example, previous work has identified nitrergic chemosensory neurons, glutamatergic mechanosensory neurons, and an extensive population of catecholaminergic sensory neurons of unknown modality. Other observations suggest a histaminergic sensory innervation may be present, and peptidergic sensory neurons have been identified in some species. However, these observations are collated from different species and different studies. There has been no comprehensive study in a single species of all transmitters in both peripheral and central locations, making it difficult to match modality, morphology and neurotransmitter content. Consequently, our goal is to create a thorough map of the sensory neuroanatomy of the gastropod *Lymnaea stagnalis*. Using a combination of backfills, vital stains, and immunocytochemistry, we are cataloguing the different components of the nervous system in the lips and tentacles and their connections to the central nervous system. In addition to confirming the existence of previously identified nervous system components, we have found previously undescribed peripheral sensory neurons that we hypothesize are mechanosensory. In further physiological experiments, we plan to identify the different modalities of these and other populations identified in the map. When finished, the sensory map will provide a basis for targeted studies of sensory contributions to the neural control of specific gastropod behaviours. Furthermore, these results will improve our understanding of both mechanosensation and the peripheral nervous system, both neglected areas of study in gastropods.

16.5 XIANG, Y*; SANTOS, S.R.; Auburn University; *santos@auburn.edu*

A nuclear genome perspective on species boundaries and population structure in the sea anemone Aiptasia spp.

Many marine invertebrates form mutualistic symbioses with dinoflagellates belonging to the genus *Symbiodinium*. To better understand these symbiotic associations, there is a need to develop model systems that are well characterized for both the symbiont as well as their host. One potential model system involves the symbiosis between the common sea anemone *Aiptasia* and their *Symbiodinium* partner. However, genes from the mitochondrial genome of many cnidarians have been found to evolve relatively slowly when compared to other animals, hindering their use as species and/or population level genetic markers. In order to define potential species boundaries and fine-scale genetic structure within *Aiptasia* spp., random nuclear genomic fragments were isolated via inter-simple sequence repeat (ISSR) techniques from aposymbiotic hosts. Following characterization of common and private fragments obtained from *A. pulchella* (Hawaii) and *A. pallida* (Florida Keys), seven sequence characterized amplified region (SCAR) markers were developed which are genetically variable between and within species and/or populations. Currently, these markers allow differentiation between homozygote and heterozygote individuals, as well as provide information regarding the genetic structure of *Aiptasia* spp. Surprisingly, no fixed genetic differences have been identified between *A. pulchella* and *A. pallida*, suggesting that they may belong to a single, panmictic, species. These genetic markers will not only serve as a powerful tool in this model cnidarian-dinoflagellate symbiosis, but also in developing a better understanding of genetic structure and connectivity in marine invertebrate species and populations.

23.2 YAKOVENKO, Sergiy*; PROCHAZKA, Arthur; Université de Montréal, University of Alberta; *sergiy.yakovenko@umontreal.ca*

Integration of the pattern generation and multiple feedback pathways for the control of locomotion. A neuromusculoskeletal model.

Though not essential for the generation of locomotor activity, multiple sensory pathways participate in the locomotor control. In this study we investigated how stretch reflexes and multisensory If-Then rules interact with the output from the pattern generator and the intrinsic stabilizing properties of muscles during gait on level and variable terrain. We constructed a two-legged planar model with 9 segments, driven by 12 musculotendon actuators with Hill-type force-velocity and monotonic force-length properties. The locomotor pattern generator provided a stereotyped rhythmical pattern of activity to drive the simulated muscle groups with the patterns based on EMG profiles of the corresponding muscles during slow level locomotion. Muscle spindle Ia and tendon organ Ib afferent inputs were represented by transfer functions with a reflex latency of 35 ms, contributing a preset amount of the net EMG profile and gated to be active only when the receptor-bearing muscles were contracting. If-Then rules triggered swing-stance and stance-swing transitions in the activity of the pattern generator when multisensory conditions, based on muscle length and force, were met. We found that a wide range of combinations of the relative muscle strengths in a model with and without stretch reflexes may result in stable locomotion. The model demonstrated that the decrease in the pattern generator drive can be rescued by the stretch reflex pathway, potentiated by interactions with intrinsic muscle properties. Furthermore, we found that the gain of stretch reflexes is inversely related to the amount of the central drive from the pattern generator during locomotion. Finally, multisensory If-Then rules provided a robust mechanism for the regulation of phase duration for stable locomotion at a wide range of model velocities.

S2-1.4 YAMAMOTO, Yoshiyuki*; JEFFERY, William; University College London, London, UK, University of Maryland, College Park, Maryland, USA; *yoshiyuki.yamamoto@ucl.ac.uk*

Why cavefish lost their eyes? Natural Selection or Neutral Theory"

The question of why cave animals have lost their eyes is currently unresolved. There are two possible hypotheses: Neutral Theory and Selection hypothesis. Neutral Theory explains that eye degeneration is caused by accumulation of mutations in eye forming genes that has no advantageous or disadvantageous effects for living in completely darkness cave. Selection hypothesis suggests that eye degeneration could have some advantageous effects for surviving in a cave based on Darwin's Natural Selection Hypothesis However, Darwin, himself, could not explain how blindness would get any benefit living in a cave. We study this problem in the blind cavefish, *Astyanax mexicanus*. Cavefish have evolved regressive characters, such as a degenerate eye and less pigment, and constructive characters, such as a large jaw and additional teeth, cranial neuromasts, and taste buds. Although functional eyes are lacking in adults, cavefish embryos form a small eye primordium, which later arrests in development and degenerates. Lens apoptosis plays a major role in eye degeneration. Signaling molecule, Shh controls eye separation from a single embryonic optic field and jaw development in vertebrates. In *Astyanax*, *shh* has an expanded expression pattern in the presumptive head region of the cavefish embryo. The expansion correlates with programmed cell death in the lens, increased jaw size, and more numerous taste buds in the cavefish compared to surface fish. Our hypothesis is that Shh controls all three traits, and that a developmental trade-off occurred whereby functional eyes were sacrificed to allow the development of extra taste buds and a larger jaw that would help to survive in a complete darkness cave. This could only happen, of course, in the cave environment, where selection for sight is relaxed.

S3-1.4 YEN, J; Georgia Institute of Technology; *jeannette.yen@biology.gatech.edu*

Small-scale biological-physical-chemical cues of plankton.

Plankton operate at low Reynolds numbers, generating water-borne cues that can be attenuated by viscosity and confused with small-scale turbulence. Yet messages are created, transmitted, perceived and recognized. These messages guide essential survival tasks of aquatic micro crustaceans. Cues created include those of escaping prey, lunging predators, attractive mates, and appropriate hosts. In this presentation, I describe some unusual and typical examples of small-scale biological-physical-chemical signals in the sea that help to maintain the integrity of our aquatic ecosystems.

8.5 YOO*, E. H.*; LEE, D. V.; BIEWENER, A. A.; Harvard University, Concord Field Station; *edwinyoo@eecs.harvard.edu*

External joint work modulation in goats during climbing jumps

We wish to understand how multi-jointed legs are able to meet different terrain conditions and mechanical demands during vertical climbing jumps. We recorded ground reaction forces and hindlimb kinematics during three different climbing conditions in sub-adult male goats (N=3, 32.8±1.6 kg): a horizontal running approach jump (BJ) onto a box platform, a horizontal approach jump (CJ1) onto a climbing wall (64° slope), and a vertical approach jump from the climbing wall up onto a horizontal ledge (CJ2). Jump heights were 2.4, 2.1, and 2.0 times standing hip height for BJ, CJ1, and CJ2 respectively. Joint power (joint moment X joint angular velocity) was integrated to calculate net joint work. In accordance with these predictions, we hypothesized that joint work would be minimized in BJ by transferring horizontal kinetic energy during running approach to raise the center of mass (CoM) during the jump. In contrast, we hypothesized that in CJ2, the limited horizontal velocity and limb constraints due to the steepness of the climbing wall would necessitate increased net joint work while CJ1 would show intermediate net joint work. Total net work for a single hindlimb were 19.7±1.461 N-m in BJ, 26.3±1.603 N-m in CJ1, and 43.6±1.417 N-m in CJ2. Ankle net work ratio (ankle net work/total joint work) was 16.8±1.7% in BXJ, 39.2±1.9% in CJ1 and 56.2±1.9% in CJ2, which matched total joint net work patterns in the hind limb indicating significant work modulation at the ankle in CJ1 and even greater work modulation in CJ2 (p

17.6 YOUNG, JW; Stony Brook University; *jwyoung@ic.sunysb.edu*

Small-bodied primates adapt asymmetrical gait dynamics to locomotion on arboreal substrates

Whereas the dynamics of symmetrical gaits (i.e., walking and running) in primates have been well researched, their use of asymmetrical gaits (i.e., galloping and bounding) remains understudied. Asymmetrical gaits are usually associated with greater peak vertical forces, potentially causing branch sway when traveling arboreally and therefore compromising stability. I predicted that primates would attempt to mitigate peak vertical forces during arboreal locomotion by reducing the vertical displacement of the center of mass, increasing stride length, decreasing stride frequency and using gaits that permit the limbs to remain on the substrate for a longer period of time (i.e., gallops and half-bounds rather than bounds). Two juvenile (mean body mass=180g) and two adult (mean body mass=330g) marmosets (*Callithrix jacchus*) were filmed traversing a 3m runway (T) or elevated pole (A) into which two force transducers were incorporated. A total of 76 complete strides over the force transducers were selected for analysis. As predicted, peak vertical forces (scaled to body weight) were significantly lower during arboreal trials, even when controlling for speed (T: 2.4bw; A: 2.0bw). Decreases in peak forces were accomplished through decreased vertical displacements of the center of mass (T: 1.7cm; A: 0.9cm) and a greater use of half-bounds and gallops (T: 53% of strides; A: 93% of strides). Contradicting my predictions, stride length decreased (T: 0.39m; A: 0.31m) and stride frequency increased (T: 4.3Hz; A: 4.9Hz) during arboreal locomotion, perhaps due to the decreased use of more powerful bounding gaits. These results may have implications for interpreting the locomotor behavior of the ancestral primate, often reconstructed as a small-bodied arboreal taxon. Supported by the L.S.B. Leakey Foundation.

50.3 YOUNG, Bruce/A.*; BOETIG, Melissa; WESTHOFF, Guido; Washburn University, University of Bonn; *bruce.young@washburn.edu*

Target tracking and behavioral release of venom spitting in cobras

Multiple species of African and Asiatic cobras can expel (or spit) their venom during defensive encounters. Previous studies have shown that this spitting behavior is consistently associated with angular displacement of the cobra's head about it's neck. We hypothesized that these cranial movements of the cobra were a way of tracking the movements of a predator and, in that way, allow the cobra to more accurately target the spit. As a corollary we hypothesized that there is likely a particular movement, or suite of movements, of the predator that serves as a behavioral release for the spitting behavior. To explore these hypotheses one of the authors, serving as predator, wore a faceshield incorporating custom-made accelerometer chips and circuit boards that accurately tracked the movement of the author's head in all directions. Multiple standard and high speed digital video cameras recorded both the movement of the predator and the cephalic displacements of the cobra during the spitting behavior. Bipolar EMG leads were implanted into the cobra's neck muscles responsible for rotary displacement of the head in the sagittal and frontal planes. A laser pulse generated by the data acquisition system and visible on the video records enabled a 2 msec temporal resolution of the integrated data set. Our data suggest that spitting cobras have a reaction time of approximately 20 msecs and that their ability to track a target varies, at least in part, on the direction and magnitude of the target's movements.

S8-1.6 YOUNG, Rebecca L*; BADYAEV, Alexander V; University of Arizona; *rlyoung@email.arizona.edu*

Developmental evolution of BMPs: from postnatal epigenetic remodeling to adaptive genetic divergence

Evolutionary studies of ecomorphological adaptations in vertebrates have revealed a common role for bone morphogenetic proteins (BMPs) in inducing developmental changes in skeletal morphology. Whereas the importance of BMPs for adaptive evolution is widely documented, the ultimate mechanism behind the ubiquity of their involvement is not known. Here we propose two hypotheses for the origins of BMP-mediated mechanisms in ecomorphological adaptations that capitalize on the strong epigenetic regulation of BMP pathways. First, high mutability of regulatory elements of BMPs (e.g., transcription factors or promoter regions) can result in changes in spatiotemporal expression of BMP such as ectopic expression and changes in receptivity. Such modifications should lead to increases in morphological variants available to natural selection and, thus, facilitate rapid adaptation of BMP regulatory pathways and corresponding skeletal structures to novel or fluctuating environments. Alternatively, the ubiquity of BMP-mediated mechanisms in ecomorphology can be due to sensitivity of BMP pathways to external stimulation, such as muscle loading or postnatal bone remodeling. Such responsiveness might enable the development of locally adaptive plasticity in bone growth and remodeling throughout postnatal ontogeny. In turn, when a particular environment consistently induces a morph and exerts selection favoring the morph, it should favor reliable developmental incorporation of environmentally-induced pathways. We review recent empirical and experimental studies examining genetic, epigenetic, and biomechanical regulation of cartilage and bone formation, remodeling, and repair to test these alternative hypotheses.

50.6 YOUNG, Bruce A.; FAHEY, Anna; KROCHMAL, Aaron R.*; Washburn University, University of Houston - Downtown; *krochmala@uhd.edu*

On the structure and function of the inner chamber of the facial pits of pitvipers (Viperidae: Crotalinae)

Pitvipers (Viperidae: Crotalinae) are named for their paired, thermally-sensitive facial pits located midway between the eye and nostril on either side of the head. Empirical studies of these organs have traditionally focused on their functional utility and neurophysiology, leaving certain anatomical aspects unexamined. The facial pit membrane, a ca. 15 micron thick sensory membrane, is suspended across the pit cavity, dividing the pit into an inner and outer chamber. The inner chamber is connected to the external environment by means of a narrow duct that terminates in a pore located beneath the posterior edge of the lower preocular scale. Lynn (1931) claimed that this pore was surrounded by a sphincter muscle, but provided no anatomical or histological evidence in support of this. We used standard microdissection and histological techniques to survey the anatomy of the inner facial pit chamber and the associated duct and pore in a representative sample of pitvipers. The duct, exit pore, and surrounding sphincter are a consistent feature of this sensory organ in all species examined. Further, the sphincter muscle surrounding the pore is under direct neurological control. The function of the inner chamber and duct remains unclear, but our anatomical evidence is consistent with its utility as a heat disperser as first conjectured by Klauber (1972), or as a means to vent pressure built up in the inner chamber as a result of heating the facial pit membrane. Future studies focusing on the causes and consequences of the contraction of this sphincter muscle are needed to fully address its function.

S2-1.6 YU, J-K.; ONAI, T.; HOLLAND, L. Z.*; California Institute of Technology , Univ. California, San Diego, Univ. California, San Diego, Univ. of California, San Diego; *lzholland@ucsd.edu*

Heads or tails? Amphioxus and the evolution of axial patterning in chordates

Within the vertebrates, the mode of gastrulation is highly variable. Consequently, the evolutionary origin of the gastrula organizer, which induces the head and patterns the embryo along the anterior/posterior axis, remains unclear. In contrast to vertebrate embryos, the amphioxus embryo gastrulates by simple invagination. As a result, the relative positions of the ectoderm and mesendoderm remain constant throughout the gastrula stage, facilitating an understanding of embryonic patterning. We have found that the amphioxus gastrula expresses orthologs of organizer genes in patterns reminiscent of their deployment in vertebrates. Genes involved in dorso/ventral (D/V) patterning include a dorsally expressed group of secreted proteins (*Nodal*, *Lefty*, *Chordin*, and *ADMP*) and transcription factors (e.g. *Goosecoid* and *Lim-1*) as well as a ventrally expressed group of secreted proteins (including the BMP-signaling modulators *BAMBI* and *Tolloid-like*) and transcription factors (*Vent* and *Evx*). Genes involved in anterior/posterior (A/P) patterning (e.g. several *Wnts*, *Wnt* antagonists and the anterior endodermal marker Hex) are also expressed in comparable patterns as their vertebrate orthologs, consistent with a role for Wnt-signaling in A/P patterning. These results together with those from functional experiments suggest that amphioxus and vertebrates use homologous gene networks for both D/V and A/P patterning. In light of recent phylogenetic analyses placing cephalochordates basal in the chordate lineage, we conclude that separate D/V and A/P signaling centers, as proposed for chick and mouse, may already have been present in ancestral chordates.

71.2 ZACHOS, Louis G.; The University of Texas at Austin; *zachos@mail.utexas.edu*

Implementation of a developmental model for growth of the post-metamorphic echinoid skeleton

The changes in shape of an echinoid skeleton or test during post-metamorphic ontogeny result from a precise interrelationship between growth of individual plates (accretion), introduction of new plates at the apical system (insertion), movement of plates towards the mouth (migration), and suturing of plates (annealing). The actual developmental mechanisms involved are unknown, but a heuristic model of echinoid growth can represent these interrelationships via realistic developmental pathways. I present a computer program of a model based on hypothetical signaling pathways represented by a set of functions describing nutrient diffusion, growth factor induction, lateral growth inhibition, and morphogen thresholds and gradients. The computer program applies these growth functions incrementally to produce a series of static models, each representing the growth state of every plate in the test at each time step. The test is modeled over a spherical coordinate system using Delaunay triangulation to create and maintain a plate reference system and a corresponding data structure to store individual plate geometries. Overall test growth (plate accommodation) is wholly dependent on insertion, accretion, migration, and annealing of the individual plates. Final test shape is derived from affine deformations applied to the spherical model. Varying the signaling parameters and rules of interaction results in a range of realistic models and suggests a basis for a phylogenetic hierarchy of growth mechanisms. Program results can be visualized as animations of growing model echinoids, which can be compared with actual ontogenetic series of representative species.

39.11 ZARDUS, J.D.*; BALAZS, G.H.; The Citadel, Charleston, SC, NOAA, National Marine Fisheries Service, Pacific Islands Fisheries Science Center, Honolulu, HI; *john.zardus@citadel.edu*

Form Follows Function In Mode Of Attachment For Barnacles Commensal With Sea Turtles

Approximately one dozen species of barnacles live attached exclusively to sea turtles. Yet, despite similarity of habitat they vary considerably in form owing to differences in attachment mode. Specialized for particular locations on their hosts, some species fasten themselves to turtle shell by way of adhesives, others mechanically clamp onto host skin, and a few embed or even burrow into epidermis. Being associated with elusive and highly migratory hosts, turtle barnacles have not been well documented. Morphological descriptions are incomplete for a number of species and there is uncertainty about their geographical distribution and occurrence with the world's various sea turtles. Using light and electron microscopy, we demonstrate the attachment mechanism of various turtle barnacle species and highlight their diagnostic features. In addition, we report new records of occurrence for two species in Hawaii and one in the Atlantic. Aspects of turtle barnacle biology and enigmas concerning their life-histories are also discussed.

35.5 ZELLER, Robert W.; San Diego State University; *rzeller@sciences.sdsu.edu*

Peripheral nervous system development in the ascidian Ciona intestinalis

Current hypotheses postulate that the ancestral bilaterian nervous originated as a basiepidermal nerve net that was interspersed with sensory neurons. During bilaterian evolution, this nerve net was independently centralized in both protostomes and in the chordate lineage. In the ascidian embryo, the larval peripheral nervous system (PNS) consists of a series of ciliated cells, called epidermal sensory neurons (ESNs), which are located only along the dorsal and ventral midlines of the larval tail and on the dorsal and anterior trunk. We have discovered that a key transcriptional factor important for sensory neuron development in other organisms, a Pou IV class gene CiPouIV, is specifically expressed in the *Ciona* PNS sensory neurons. This gene is a target of Notch-Delta mediated lateral inhibition. When Notch-Delta signaling is disrupted throughout the epidermis in transgenic embryos, the domain of sensory neurons expands, but only along the dorsal and ventral midlines of the embryo. In addition, expansion of CiPouIV expression is also observed in these ectopic sensory neurons, however ectopic sensory neurons are never formed laterally, only along the embryonic midlines. When CiPouIV is ectopically expressed in all of the epidermis, ectopic sensory neurons are formed throughout the epidermis, both in the embryonic midlines and in lateral territories. We observe that nearly any epidermal cell that expressed CiPouIV may be transformed into a PNS sensory neuron. Our observations suggest that cell-signaling pathways have restricted the developmental fate of the potential PNS neurons, but that bypassing Notch-Delta signaling may abrogate this restriction. The resulting ectopic sensory neurons may represent what might have been present in the expansive nerve-net of a common tunicate-vertebrate ancestor.

S4-2.1 ZHANG, Pei; SANDLAND, Gregory; FENG, Zhilan*; XU, Dashun; MINCHELLA, Dennis; Purdue University; *zfeng@math.purdue.edu*

Evolutionary implications for interactions between multiple strains of hosts and parasites

The interaction between multiple parasite strains within different host types may influence the evolutionary trajectories of parasites. We formulate a deterministic model with two strains of parasites and two host types in order to investigate how heterogeneities in parasite virulence and host life-history may affect the persistence and spread of diseases in natural systems.The reproductive number for each strain of parasites ($mathcal R_i$) as well as the ``invasion'' reproductive number for strains i (R_i^j, $jneq i$) are computed and shown to determine the stability of various equilibria. We show that strain i can invade strain j when $mathcal R_i^j>1$. Subthreshold coexistence driven by co-infection is possible even when ${mathcal R}_i$ of one strain is below 1. Conditions are identified that determine the evolution of parasite specialism or generalism based on the life-history strategies employed by hosts, and investigate how host strains may influence parasite persistence.

53.5 ZHANG, Ziping*; LI, Weiming; Michigan State University; *zipingcn@msu.edu*

Identification of a potential ancient skin calmodulin gene from the sea lamprey

The development and structure of integument systems differ significantly between vertebrates and invertebrates. In vertebrates, keratinocytes undergo a complex and Ca2+ dependent differentiation to form a real skin. This process is absent in invertebrates. Calmodulin (CaM) is a calcium binding protein that is involved in the regulation of multiple calcium-mediated functions. Generally, CaMs which contain four calcium-binding domains (EF-hand) are derived from an ancestral one-domain precursor by two gene duplications. Recently, two skin CaM related factor genes (scrfs) have been identified and proposed to play some roles in the epidermal differentiation. Skin related calmodulin genes have not been identified from non-mammalian vertebrates or invertebrates. Using a custom-made cDNA microarray, we identified a potential ancient skin CaM gene from a jawless vertebrate, the sea lamprey (Petromyzon marinus) termed as slcam4 which showed 66% similarity to mouse cam 4 (scarf) at amino acid sequence level. Slcam 4 encodes a protein of 73 amino acids which is only a half of the size of most CaM. And more interestingly, SLCaM 4 contains only two EF-hand domains. Furthermore, SLCaM 4 is an alkaline protein, as apposed to most of the other CaMs that are acidic. Like mouse CaM 4, SLCaM 4 does not have myristoylation sites. In situ hybridization showed epidermis-specific expression of slcam4 in sea lamprey embryo. To shed light on the origin of skin related CaM and its contribution to evolution of skin, further investigation to study the origination and characterization of this gene and its potential role in skin formation is being carried out. *This work is funded by the Great Lakes Fishery Commission.

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Development of the facultatively planktotrophic echinoid Clypeaster rosaceus

We studied the cell lineage and egg energetics of *Clypeaster rosaceus*, a facultatively planktotrophic echinoid from the Caribbean. We also compared *C. rosaceus* egg energy with its sympatric congener *C. subdepressus*, an obligate planktotroph, estimated when the two species diverged, and determined whether the two species are gametically compatible.