



**1<sup>st</sup> Great Lakes Student Paleoconference  
10 - 12 November 2017, Ann Arbor, MI**

**Abstract book and program**

## **ABOUT THE LOGO**

The logo of the 1<sup>st</sup> GLSP combines the iconic mitten-like silhouette of Michigan's lower peninsula with the texture of a Petoskey stone, the state stone of Michigan. Petoskey stones are in fact fossilized remains of the Devonian coral *Hexagonaria percarinata*, reworked by glaciers during the Quaternary. Common in the northwestern portion of the lower peninsula, they are often used as decorative or artistic objects.

# CONFERENCE SCHEDULE

|                  | Friday 10 <sup>th</sup>           | Saturday 11 <sup>th</sup>                                     | Sunday 12 <sup>th</sup>                               |
|------------------|-----------------------------------|---|---|
| <b>Morning</b>   |                                   | <b>9:30 am - 12:00 pm</b><br>Talk session                     | <b>9:30 am - 11:30 am</b><br>Visit to RMC collections |
| <b>Afternoon</b> |                                   | <b>12:00 pm - 1:00 pm</b><br>Catered lunch                    |   |
| <b>Evening</b>   | Arrival and meeting<br>with hosts | <b>1:00 pm - 4:30 pm</b><br>Talk session                      |   |
|                  |                                   | <b>4:30 pm - 5:30 pm</b><br>Faculty panel                     |   |
|                  |                                   | <b>6:30 pm - onward</b><br>Catered dinner<br>(Friedman house) |   |

The talk sessions and faculty panel will be held at 2009 Ruthven Museums Building, 1109 Geddes Avenue. The catered dinner on Saturday will be held at Prof. Matt Friedman's house.

## FACULTY PANEL

**PANEL MEMBERS:** Tomasz Baumiller, Matt Friedman, Selena Smith and Miriam Zelditch

This one-hour panel will be a chance for Michigan faculty and grad students from both schools to meet each other and discuss some topics related to the students' early professional career. We are planning to kick off the panel with a discussion about publications. Specifically, we look forward to hearing the faculty's experience as published authors, reviewers, and/or editors, and learning about things we should keep in mind as we collaborate with colleagues, write manuscripts, and choose journals to publish in. If time allows it, students may also ask questions related to the faculty's ongoing research or other topics of interest.

## SUNDAY TRIP – Visit to the Research Museum Center (RMC)

The visit to the RMC will be an opportunity to see the paleontology and zoology collections of the University of Michigan. Details to be determined.

# SCIENTIFIC PROGRAM

## (NOVEMBER 11<sup>TH</sup>, 2017)

| TIME        | EVENT   |
|-------------|---|
| 09:30-09:45 | Evaluating the role of India in plant biogeography: examples from fossil palm fruits from the Deccan intertrappean beds. <i>KELLY MATSUNAGA</i>   |
| 09:45-10:00 | Internal anatomy and paleophysiology of the Cretaceous crinoid <i>Decameros ricordeanus</i> . <i>JAMES SAULSBURY</i>  |
| 10:00-10:15 | Bend it like bourgueticrinids: Contractile Connective Tissues in crinoids. <i>MARGARET VEITCH</i>   |
| 10:15-10:30 | Tangled webs: a food web analysis of Mazon Creek. <i>BEN OTOO</i>   |
| 10:30-10:45 | COFFEE BREAK  |
| 10:45-11:00 | Fossil-based estimates for the origin times of intercontinental freshwater fish clades. <i>ALESSIO CAPOBIANCO</i>   |
| 11:00-11:15 | Cosmine means cosmine: morphology and phylogeny of sarcopterygian dermal tissue. <i>VISHRUTH VENKATAMARAN</i>   |
| 11:15-11:30 | A change in cell fate: a developmental genetics hypothesis for the fin to limb transition. <i>ALEXANDER OKAMOTO</i>   |
| 11:30-11:45 | Evidence for regional variability in recovery of tetrapod assemblages from the end-Permian mass extinction: setting the stage for the age of dinosaurs in southern Pangea. <i>BRANDON PEECOOK</i> |
| 11:45-12:00 | <i>ROUNDTABLE DISCUSSION</i>  |
| 12:00-13:00 | LUNCH   |
| 13:00-13:15 | New titanosaurian sauropod dinosaurs elucidate the potential paleobiogeographic roles of northern and southern Africa during the Late Cretaceous. <i>ERIC GORSCAK</i>                             |
| 13:15-13:30 | A new notosuchian from the Late Cretaceous of India. <i>TARIQ KAREEM</i>  |
| 13:30-13:45 | New azhdarchid pterosaur remains: biodiversity of Late Cretaceous Jordan and the biomechanics of giant pterosaurs. <i>KIERSTIN ROSENBAACH</i>   |
| 13:45-14:00 | Convergence in avian sternum morphology and relation to ecology. <i>STEPHANIE BAUMGART</i>  |

|             |  |
|-------------|--|
| 14:00-14:15 | COFFEE BREAK   |
| 14:15-14:30 | Increased disparity in Therapsida coincides with emergence of novel ecologies, Cistecephalidae (Therapsida:Anomodontia) as a case study. <i>JACQUELINE LUNGMUS</i> |
| 14:30-14:45 | Why is the opossum so awesome? Tooth innervation and the implications for early mammalian evolution. <i>KELSEY STILSON</i>   |
| 14:45-15:00 | Jaw rule: mammalian jaw morphologies correlate with diet and evolve toward trait optima. <i>DAVID GROSSNICKLE</i>  |
| 15:00-15:15 | Ecological diversity of mammalian faunas of the Mojave Desert, CA, and the Great Plains, in relation to landscape history. <i>BIAN WANG</i>                        |
| 15:15-15:30 | COFFEE BREAK   |
| 15:30-15:45 | African deinotheriid isotopic paleoecology: developing a diet and habitat proxy for an extinct proboscidean. <i>NICHOLE LOHRKE</i>                                 |
| 15:45-16:00 | Reproductive life histories of female woolly mammoths. <i>JOSEPH EL ADLI</i>   |
| 16:00-16:15 | Are fossil communities just spatiotemporally scaled-up versions of modern ones? <i>ANDREW DU</i>   |
| 16:15-16:30 | <i>ROUNDTABLE DISCUSSION</i>   |
| 16:30-17:30 | <i>FACULTY PANEL</i>   |
| 18:30-      | DINNER (at Matt Friedman's house)  |

# EVALUATING THE ROLE OF INDIA IN PLANT BIOGEOGRAPHY: EXAMPLES FROM FOSSIL PALM FRUITS FROM THE DECCAN INTERTRAPPEAN BEDS

Kelly K.S. Matsunaga\*<sup>1</sup>, Steven R. Manchester<sup>2</sup>, Selena Y. Smith<sup>1</sup>, Rashmi Srivastava<sup>3</sup>, Suresh D. Bonde<sup>4</sup>

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\* Speaker

Palms have a rich and geographically extensive fossil record that stretches back to the Late Cretaceous. Their distinctive morphology and anatomy, narrow environmental range, and continuous fossil record make them a model group of plants for addressing questions on plant evolution, biogeography, and terrestrial environments over the Late Cretaceous and Cenozoic. The Maastrichtian-Danian Deccan intertrappean beds (DIB) host a particularly rich fossil palm assemblage, from which more than 140 species have been described since the early 1930s based on isolated stems, leaves, roots, inflorescences, and fruits. Owing to the dynamic tectonic history of India, understanding the taxonomic affinities of these fossils may help shed light on biogeographic patterns in the radiation of palm lineages and the role that India played in these processes. We call attention to striking morphological and anatomical similarities between *Areoidocarpon*, a common fossil fruit type in the DIB, and fruits of extant *Orania* (tribe Oranieae). Recognition of tribe Oranieae in India at the end of the Cretaceous has interesting biogeographic implications — Oranieae belongs to a clade of three monotypic tribes (POS clade) that is disjunctly distributed and absent today in India, with the tribes Podococceae and Sclerospermeae in Africa, while Oranieae occurs in New Guinea, parts of Southeast Asia, and Madagascar. The DIB fossils in question are much more similar to Oranieae than the African taxa in the POS clade. Various biogeographic scenarios based on ancestral area reconstructions have been proposed to explain the geographic distribution of the POS clade. These include (1) migration into Africa from Eurasia and subsequent dispersal to the Indo-Pacific during the Oligocene, and (2) dispersal of stem POS from South America into Africa, with tribe Oranieae spreading into the Indo-Pacific through India. The presence of tribe Oranieae in India ~66 Ma pushes back divergence time estimates for the clade and supports an “out-of-India” dispersal hypothesis for the group. This is in contrast to other palms in the DIB assemblage, which include fruits belonging to modern South American and Asia-Pacific clades, indicating diverse biogeographic affinities of Deccan palms and broader historical ranges for some groups.

# **INTERNAL ANATOMY AND PALEOPHYSIOLOGY OF THE CRETACEOUS CRINOID *DECAMEROS RICORDEANUS***

James Saulsbury\*<sup>1</sup>, Samuel Zamora<sup>2</sup>

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<sup>2</sup> Instituto Geológico y Minero de España, Zaragoza, Spain

\* Speaker

Featherstars – those crinoids that discard their stalks as juveniles – constitute the majority of extant crinoid species and are prominent members of many coral reef and deep-sea invertebrate assemblages. However, their fossil record is sparse and fragmentary relative to other crinoids, and their paleobiology and evolution remains poorly-understood. Here, I redescribe the Cretaceous featherstar *Decameros ricordeanus* based on material from eastern Spain. X-ray micro-computed tomography ( $\mu$ -CT) reveals that the axial sinus, one region of the body cavity, is preserved in exquisite detail inside these fossilized crinoids, as is the nervous system. Comparison with homologues in extant crinoids shows the axial sinus to be variable and relatively conserved within some comatulid families, while the nervous system appears to be relatively invariant. The axial sinus is probably a circulatory organ, although its function remains enigmatic. Continued  $\mu$ -CT work on modern and fossil crinoids promises to resolve outstanding questions on the phylogeny and functional morphology of this charismatic and geologically important group.

# **BEND IT LIKE BOURGUETICRINIDS: CONTRACTILE CONNECTIVE TISSUES IN CRINOIDS**

Margaret Veitch <sup>1\*</sup>, Charles Messing <sup>2</sup>, Tomasz K. Baumiller <sup>3</sup>

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Among the most unusual and functionally important features of the Echinodermata is mutable collagenous tissue (MCT). Although collagen is the main component of animal connective tissues (e.g., ligaments, tendons), only echinoderms actively and rapidly (seconds to minutes) change its mechanical properties. Echinoderm MCT is involved in multiple functions including shedding of body parts (autotomy), often in response to predation, and various aspects of feeding, such as maintaining arm and stalk postures in crinoids. While the mutable nature of echinoderm collagen is well established, a more controversial suggestion is that collagenous tissues can actively contract (contractile connective tissues or CCT of Motokawa et al. 2006).

Multiple individuals of the stalked crinoid *Democrinus* cf. *brevis*, have been observed to raise themselves off the substrate in the apparent absence of external forces such as lift, or internal stalk muscles (Grimmer et al. 1984). *Democrinus* has 5 short arms, a stalk characterized by synarthrial columnal articulations (with a central fulcrum), and lives on sandy/muddy substrates where low current velocities predominate. The combination of low current and an open filter result in weak lift and drag on the crown, limiting the ability to passively reorient into an optimal feeding posture. The presence of CCT in the stalk may allow *Democrinus* to actively re-orient in response to changing current directions. While active contraction via MCT should be present in all crinoids, only bourgueticrinids have synarthrial articulation as adults which would allow active bending in the absence of external force. Since ontogenetic, fossil, and molecular data suggest that bourgueticrinids evolved from comatulids through paedomorphosis, CCT may characterize all extant crinoids (Articulata), and perhaps ancient crinoid clades. Although active bending may not be possible for other extant crinoids, CCT may ‘reset’ ligaments after prolonged stretch under bent feeding postures. For Paleozoic crinoids, many are thought to have lacked muscular articulations of any type, and in these the functional role of CCT may have been especially important.



# TANGLED WEBS: A FOOD WEB ANALYSIS OF MAZON CREEK

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\* Speaker

Mazon Creek is a world-famous lagerstätte of Late Carboniferous age (middle Pennsylvanian, Moscovian stage). The fossil beds were originally developed for coal exploitation, and have yielded thousands of specimens preserved in nodules. Concerted, interdisciplinary efforts in the 1970s and 1980s did much to fill out the faunal lists and reconstruct the paleoenvironment. One of the most significant results was the recognition of two faunal associations reflecting an environmental gradient in an ancient delta-estuary system: the freshwater ‘Braidwood’ assemblage and the brackish ‘Essex’ assemblage. Crucially, both assemblages include soft-bodied animals that typically do not fossilize. Mazon Creek has produced a stunning array of both invertebrates and vertebrates, including the famous Tully monster, hagfish, lampreys, and one of the earliest diverse insect faunas. However, this wealth of data has not been analyzed using modern paleoecological methods. Here we apply the Cascading Extinction on Graphs (CEG) model to the Mazon Creek biota. CEG models how disturbances can propagate through trophic networks and potentially cause secondary extinctions, providing insight into how changes in community composition and structure affect community stability. Application of the model to Permo-Triassic terrestrial ecosystems in southern Africa has helped to explain patterns of extinction selectivity, and elucidated the process by which stable communities were rebuilt following the extinction event. Mazon Creek is of great interest in this context not only because of the exceptionally preserved fauna, but also because it represents a more archaic terrestrial community structure with no tetrapod herbivores. We modeled the Essex and Braidwood assemblages separately, and compared their properties and behavior in the model.

# **FOSSIL-BASED ESTIMATES FOR THE ORIGIN TIMES OF INTERCONTINENTAL FRESHWATER FISH CLADES**

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\* Speaker

Widespread fish clades that occur mainly or exclusively in freshwater represent a key target of biogeographical investigation due what is presumed to be their limited potential for dispersing across marine barriers. Deriving a timescale for the origin and diversification of these clades is crucial to test vicariant scenarios in which continental breakups shaped their modern geographic distribution. Evolutionary timescales are commonly estimated through node-based paleontological calibration of molecular phylogenies, but this approach ignores most of the temporal information enclosed in the known fossil record of a given taxon.

Here, we used the stratigraphic distribution of fossils belonging to several freshwater fish clades with an intercontinental distribution in order to estimate confidence intervals on their times of origin. To do this, we employed a Bayesian framework that takes into account non-uniform preservation potential of freshwater fish fossils through time, as well as uncertainty in the absolute age of fossil horizons. Our results are generally congruent with published molecular timetree estimates (despite the use of semi-independent data), highlighting the relevance of probabilistic approaches to interpret the temporal information contained in the fossil record. We found that, while vicariance cannot be rejected for several examined clades (e.g. lungfishes, characiforms and temperate perches), killifishes and snakeheads are probably younger than any major continental split that might have affected their geographic distribution. Thus, in these cases, long-distance dispersal events – rather than vicariance – seem to be the most likely explanation of their current geographic distribution. Moreover, a thorough review of the fossil record of freshwater fishes suggests that some groups (like osteoglossomorphs and characiforms) might have had a complex biogeographic history – involving vicariance as well as dispersal events – that has been partially concealed by local extinctions.

# **COSMINE MEANS COSMINE: MORPHOLOGY AND PHYLOGENY OF SARCOPTERYGIAN DERMAL TISSUE**

Vishruth Venkataraman\*<sup>1</sup>, Phil Donoghue<sup>2</sup>, Sam Giles<sup>3</sup>

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\* Speaker

Cosmine has traditionally been described as a sarcopterygian synapomorphy consisting of a single enamel layer overlaying a series of pore cavities connected by underlying canals in dentine. The discovery of such pore canals in several actinopterygian taxa have caused confusion about the definitive structure and phylogenetic signature of cosmine. I used synchrotron tomography and CT based reconstruction to model the first three dimensional structure of cosmine in the osteolepiform *Megalichthys hibberti*. Cosmine in *Megalichthys* consists of conical pore chambers surrounding pulp cavities in a systematic arrangement connected by an anastomosing canal network underneath. Crucially, cosmine is found to be an informative rhipidistian synapomorphy, typified by the combination of an elaborate pore canal system and a single enamel layer, implying complete resorption of older generations. Each cosmine sheet represents one developmental event. Phylogenetic ancestral state reconstruction shows cosmine to be a rhipidistian elaboration of a plesiomorphic osteichthyan pore canal system. Other modifications to the pore canal system, or the method of enamel deposition can explain pore canal systems found in non- sarcopterygian osteichthyans. Finally, traditional theories of growth and development used to describe the formation of cosmine, particularly in Dipnoi, are analyzed and found to be untenable.

# **A CHANGE IN CELL FATE: A DEVELOPMENTAL GENETICS HYPOTHESIS FOR THE FIN TO LIMB TRANSITION**

Alexander Okamoto\*<sup>1</sup>, Tetsuya Nakamura<sup>2</sup>, Neil Shubin<sup>2</sup>

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\* Speaker

The fin to limb transition is one of the most important events in the evolutionary history of vertebrates. During this transition, a group of sarcopterygian fishes adapted to a terrestrial environment to become the first tetrapods. The question of how crown group tetrapods arose from fish has captivated evolutionary biologists since the 19th century. In particular, the potential for homology between fins and limbs has been explored in great detail—originally through examination of the paleontological record and more recently using approaches from molecular and developmental biology.

The series of transitional forms shows that the loss of dermal bones and extension of endochondral bones are major trends in appendage evolution from fish to tetrapods. This transition takes place primarily in the most distal portion of the limb, a region known as the autopod. Developmental work in mice has shown that the homeotic *hox13* genes exhibit autopod specific expression in the limb. Homologs of these genes in zebrafish have been shown to have a biphasic expression domain in the distal portion of the pectoral fin. These successive bursts of expression pattern the dermal and endochondral areas of the distal fin, respectively.

Double knockouts of *hox13* genes show a marked reduction in the dermal skeleton and a significant increase in the number of distal endochondral elements. This suggests that the cell fate change from a dermal to an endochondral program played a major role in the fin to limb transition; however, genetic mechanisms underlying this cell fate change remain elusive. The transition between the two is likely due to a change in cell fates. I am studying the genetic regulatory elements responsible for the cell fate changes from dermal to endochondral bones through RNA-seq experiments in wild type and mutant fish to determine the downstream targets of *hox13* genes as well as ChIP-seq for *hox13* to determine its binding sites within the genome. This work aims to illuminate the changes in cell fate that likely facilitated the evolution of digits in tetrapods.

# **EVIDENCE FOR REGIONAL VARIABILITY IN RECOVERY OF TETRAPOD ASSEMBLAGES FROM THE END-PERMIAN MASS EXTINCTION: SETTING THE STAGE FOR THE AGE OF DINOSAURS IN SOUTHERN PANGEA**

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\* Speaker

Mass extinctions are recognized as global events; however, studies of single localities deepen our understanding of extinction and recovery by revealing heterogeneity in timing and process. For terrestrial tetrapods, data on the end-Permian mass extinction (EPME) comes primarily from the Karoo Basin of South Africa, which contains a near-continuous record of middle Permian to Middle Triassic vertebrate evolution. This record shows that ecologically stable assemblages collapsed during the EPME. By the Middle Triassic taxonomic diversity and ecological stability increased, but not to pre-EPME levels. Across southern Pangea, late Permian tetrapod assemblages are recognized as broadly similar, while those of the Middle Triassic share few features.

To understand the underlying drivers of post-EPME dissimilarity I studied successive terrestrial tetrapod assemblages from Zambia and Tanzania, compiling a database combining museum collections and discoveries from fieldwork over the last decade. Biostratigraphy ties the assemblages to middle Permian, late Permian, and Middle Triassic Karoo assemblages, providing alternative in situ model systems of tetrapod evolution before and after the EPME. After employing apomorphy-based specimen identification, I calculated taxonomic richness, evenness, and relative abundances, and assigned taxa to ecological guilds (estimated biomass + inferred diet) to calculate ecological guild richness and relative abundances. My results support a cosmopolitan late Permian fauna in southern Pangea with extremely similar measures of taxonomic and ecological diversity, including many shared genera and species. During the post-EPME recovery in the Middle Triassic the three regions are notably dissimilar. Not only are constituent taxa different (e.g., carnivores, large-bodied taxa, and archosaurs are diverse and abundant in Zambia and Tanzania, but relatively uncommon or absent in South Africa), but signals for recovery are discordant. Ecological diversity levels of the Zambian and Tanzanian assemblages equal or exceed Permian ecological diversities, whereas those of the Karoo lag. These discrepancies could be due to actual geographic heterogeneity, but could also be the result of a temporal mismatch between the regions via inexact biostratigraphy.

# NEW TITANOSAURIAN SAUROPOD DINOSAURS ELUCIDATE THE POTENTIAL PALEOBIOGEOGRAPHIC ROLES OF NORTHERN AND SOUTHERN AFRICA DURING THE LATE CRETACEOUS

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\* Speaker

The post-Cenomanian Cretaceous continental fossil record of Africa (to the exclusion of Madagascar) is largely incomplete when compared to nearly equivalent deposits from adjacent regions (e.g., Europe, South America). This scarce fossil record and ambiguous paleobiogeographic role of Africa has remained a sizable gap for the Late Cretaceous from both Gondwanan and global perspectives. Titanosaurian sauropod dinosaurs recently recovered from Egypt, Kenya, and Tanzania can now initiate the development of paleobiogeographical perspectives for the Late Cretaceous of Africa. Using tip-dated Bayesian phylogenetic and likelihood-based paleobiogeographic methods that incorporates these new titanosaurs, their estimated evolutionary history is utilized to initially assess a paleobiogeographic perspective for the Late Cretaceous of Africa. Models with a relaxed clock, varying speciation, extinction, and character evolution rates with paleobiogeographic models that allowed long distance dispersal were best supported.

Two titanosaurians from the Campanian of the Dakhla and Kharga Oases, Egypt, exhibit close affinities with titanosaurians from Europe and Asia. KNM-WT 65086, from the Maastrichtian Lapurr Sandstones of Kenya, is grouped with middle Cretaceous titanosaurians from both South America and northern Africa (e.g., *Paralititan stromeri* from the Cenomanian of Egypt). Finally, the revised age for the Namba Member of the Tanzanian Galula Formation allows the re-interpretation of *Rukwatitan biseptus* as a ‘relictual’ lineage whereas *Shingopana songwensis* maintains a closer relationship with Late Cretaceous South American aeolosaurines than other African forms. These results suggest a coarse bipartite Africa during the Late Cretaceous with southern African (Kenya and Tanzania) titanosaurians bearing close relationships with those from South America and older lineages whereas northern African (Egypt) titanosaurians bear closer affinities with Eurasian titanosaurians than with any other African taxa. This pattern may be, in part, tectonically-driven with the progressive isolation of southern Africa from the rest of Gondwana during the Early Cretaceous whereas northern Africa developed its own Afro-Eurasian fauna post-separation from South America around 100 million years ago.

# A NEW NOTOSUCHIAN FROM THE LATE CRETACEOUS OF INDIA

Tariq Abdul Kareem\*<sup>1</sup>, Jeffrey Wilson<sup>1,2</sup>

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\* Speaker

Notosuchians were highly unusual crocodylomorphs with a distinctive Cretaceous Gondwana diversity. The oddness of these animals as crocodilians can be attributed to a suite of features, especially heterodont dentition –rendering some of them herbivorous, a body plan mostly suited for terrestrial adaptations, and possible jaw mechanics that contrasts all other crocodilians.

Despite being present across much of Gondwana, no definite notosuchian has yet been described from the Indian subcontinent, except for an isolated tooth from the Kallamedu Formation of South India that has been shown to be extremely similar to *Simosuchus clarki*, a notosuchian from Late Cretaceous Madagascar. Considering the paleogeographic positioning of the Indian landmass, it is reasonably fair to expect notosuchians from India. The lack of any established notosuchian from India would be more due to undersampling and not the actual absence of corresponding fossils; fossil collection and sampling is still largely very undeveloped in India.

The present study will focus on a possible notosuchian from Late Cretaceous India, and is yet to be described. Apart from the age, notosuchian affinities for this specimen has been inferred from presence of scutes, fragmentary digits and jaw elements. Still nascent, this study will try to describe this specimen through detailed study of *Simosuchus*, which has already been found to have a possible contemporary through the isolated tooth crown. Fortunately, fossils of *Simosuchus* are the most complete and the best described notosuchian, serving as a good basis for inferring the Indian material.

The main motive of the study will be to fill the paleobiogeographic void rendered by the absence of any notosuchian from India. Anatomy, which would form the majority of my work, will include CT scans, comparisons to extant crocodiles, and time permitting, biomechanical inferences. The other major aspect would be to describe the specimen in a geological context, which will necessitate stratigraphic and paleoenvironmental inferences, the specifics yet to be planned out. Phylogeny is planned to be done by forming new character matrices and the use of PAUP and Mesquite, but the overall motive for phylogeny in this study is loose; phylogeny of notosuchians is largely labile and could require much more time than is available.

# **NEW AZHDARCHID PTEROSAUR REMAINS: BIODIVERSITY OF LATE CRETACEOUS JORDAN AND THE BIOMECHANICS OF GIANT PTEROSAURS**

Kierstin L. Rosenbach\*<sup>1</sup>, Jeffrey A. Wilson<sup>1,2</sup>, Iyad S.A. Zalmout<sup>2</sup>

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\* Speaker

During the Late Cretaceous, Jordan was located at the northern margin of Afro-Arabia, partially ringed by the Neo-Tethys Ocean. The fossil record of terrestrial vertebrates from the Maastrichtian of Jordan consists solely of nine specimens attributed to the azhdarchid *Arambourgiania philadelphiae*, one of the largest known pterosaurs. The vertebrate fossil record of Afro-Arabia during the latest Cretaceous is scarce, especially in comparison to other Gondwanan landmasses. For this reason, new discoveries are paleobiogeographically and evolutionarily significant. Here we report on recent fieldwork in uppermost Cretaceous deposits in Jordan. Prospection in the Phosphorite Unit of the Amman Formation in the Ruseifa phosphate mines uncovered the shaft of an exceptionally large humerus. Broken ends of this shaft reveal thin cortical bone surrounding trabeculae, and the ratio of matrix to trabecular bone indicates a high Air Space Proportion (ASP), consistent with the interpretation of this bone as pterosaurian. The locality and large size suggest that this humerus likely pertains to *A. philadelphiae*. In addition, exposures of the Muwaqqar Formation in south-central Jordan yielded the most complete individual pterosaur ever uncovered from the Afro-Arabian paleocontinent. Material collected consists of cranial elements, vertebrae, and a nearly complete wing (~2.5 m). The humerus of this individual has a different cross-sectional shape and is 2.5 times smaller than the probable *A. philadelphiae* humerus, and so it is unlikely to pertain to the same species. Rather, its distinct spatiotemporal context, body size, and long, edentulous beak suggest that it represents a new azhdarchid species. Both specimens are preserved in three dimensions making them ideal for studying internal structure as it relates to ASP, body mass, and adaptations for the biomechanical strains of flight. Preliminary scans of the humeri of these individuals indicate that species exhibit characteristic patterning to internal struts, and that these patterns differ between closely-related species with varying body size. These new discoveries provide insight into the structure and functional anatomy of pterosaurs and expand our understanding of the vertebrate biodiversity of Late Cretaceous Afro-Arabia.



# CONVERGENCE IN AVIAN STERNUM MORPHOLOGY AND RELATION TO ECOLOGY

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\* Speaker

Two factors central to flight mechanics in birds are forces exerted by the flight muscles on the wing and wing shape that governs its aerodynamics. Wing shape has been linked to behavior, but comprehensive morphometric analysis of avian sternum shape has yet to be conducted, even though the sternum anchors the major flight muscles and its morphology is very diverse throughout Aves. Keel shape and size correlate strongly with flight muscle mass and keel position with mechanical advantage. Disparity in sternum morphology, thus, may hold clues to differences in flight mechanics and to extrapolating those results to extinct taxa.

Here, I examine wings and sterna of 82 “water birds” using two-dimensional geometric morphometrics on images of wings and of ventral and lateral sternal surfaces with homologous landmarks and semi-landmarks. The resulting phylomorphospaces and statistical analyses reveal a high degree of convergence in both wing shape and sternum shape. Plotting foraging behavior onto the phylomorphospaces reveals regions of shape space in which certain groups inhabit and others do not. Surface divers generally have a distinct keel and sternum morphology from the rest of the water bird clade, and fall on the opposite side of shape space as birds that spend much of their time foraging on the ground or at the water’s edge. Aerial divers tend to have a short, wide sternum in contrast to the long, narrow sternum of shorebirds. Statistical tests suggest that the ventral view of the sternum is correlated with ecological behavior, and the lateral view - which includes keel shape and relative size - is not correlated with ecological behavior. These results suggest that keel shape may not be as important for function as previously thought, or that the correlation is confounded by other variables that will require further study. These findings suggest that sternum morphology should be taken into account and analyzed with wing shape to more fully test coevolution, convergence, and disparity of functional adaptations in the forelimb and girdle for powered flight.

# **INCREASED DISPARITY IN THERAPSIDA COINCIDES WITH EMERGENCE OF NOVEL ECOLOGIES, CISTECEPHALIDAE (THERAPSIDA:ANOMODONTIA) AS A CASE STUDY**

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Synapsid evolution can be characterized by three successive radiations: the Permo-Carboniferous pelycosaurs, the Permo-Triassic Therapsida, and finally the Late Triassic Mammaliaformes. While descriptive studies suggest increased morphological disparity concurrent with the rise of therapsids, no work has compared disparity across the entire interval. We present detailed analysis of shape disparity in synapsid humeral elements of the majority of pelycosaur and therapsid groups, and a selection of Triassic cynodonts. Clades were analyzed for Procrustes variance, in 5 million year time bins from 305 - 235 Mya (Carboniferous - Triassic). We found that pelycosaurs show lower disparity than therapsids, and increased disparity coincides with the emergence of Therapsida. Macroevolutionary changes observed in Therapsida have historically been associated with ecological diversification. To confirm associations between clade-wide dynamics and novel ecomorphologies, we conducted comparative geometric and linear morphometric analyses on pelycosaurs, therapsids, and extant tetrapods, with emphasis on the therapsid family Cistecephalidae - small arguably fossorial dicynodonts. We found that Cistecephalidae morphospace is unoccupied by any known pelycosaur group, and the expansion of therapsid morphospace is associated with novel synapsid ecomorphologies such as that of Cistecephalidae. This provides evidence that increased disparity associated with novel ecomorphologies may have been critical to the evolutionary success of early Synapsida.

# **WHY IS THE OPOSSUM SO AWESOME? TOOTH INNERVATION AND THE IMPLICATIONS FOR EARLY MAMMALIAN EVOLUTION**

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The mouth is a multimodal sensory system that combines chemosensation (taste), thermosensation (temperature), and proprioception (the sense of position relative to one's own body). Previous studies have hypothesized that having a sensitive mouth is useful for protecting the body from noxious chemicals, avoiding foreign debris, and more efficiently masticating food. Testing the limits of just one sense for the entire mouth, in this case proprioception, is difficult. One measurable and modular piece of oral proprioception is the tooth and associated connective tissue, which holds the tooth in the alveolar socket. This tissue is termed the periodontal ligament (PDL) and is innervated by sensory neurons. These mechanosensors send information to the brain about the pressure the tooth is experiencing and from what direction the pressure is coming from, at least in humans. The brain then integrates this information from every tooth with every bite. What are the selection pressures to evolve such a system and when does extensive PDL innervation appear in the fossil record?

What we do know about extensive PDL innervation comes from studies of placental mammals. This makes a marsupial exemplar such as the North American opossum (*Didelphis virginiana*) an appropriate comparison to study the morphological, physiological, and phylogenetic variability of the PDL. Mammalia have some of the most morphologically variable dentition and most restrictive tooth replacement cycles within Vertebrata, leading to unique and highly specialized dental sensory structures. I am studying the distribution of nerves within the PDL, the signals that travel from the alveolar sockets to the brain, and the osteological correlates of PDL innervation using immunohistochemistry, computed tomography scanning, and neural recordings. Understanding the basics of marsupial dental sensory structures through the opossum is key to understanding the broader evolutionary phylogenetic patterns of neuroplasticity.

# **JAW RULE: MAMMALIAN JAW MORPHOLOGIES CORRELATE WITH DIET AND EVOLVE TOWARD TRAIT OPTIMA**

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Although studies commonly examine correlations between tooth shape and diet using taxonomically diverse mammalian samples, comparable analyses of jaw morphologies and diet across Mammalia are rare. This is surprising because mandibular shape may offer considerable insight into the diets and evolutionary histories of mammals, including fossil lineages. Jaw morphologies are expected to correlate with diet due to common functional demands on the masticatory apparatus of taxa with similar diets. I test this prediction by applying phylogenetic comparative methods to linear jaw measurements and dietary information for over 200 modern mammalian species. Results identify several jaw metrics that are significantly correlated with diet even after accounting for phylogenetic non-independence of data. The distance from the jaw joint to the angular process is an especially powerful predictor of diet, increasing with greater herbivory. This distance reflects the moment arms of the force vectors of the superficial masseter and medial pterygoid muscles, which are particularly important for transverse jaw movements and grinding of plant material. To test the evolutionary mode of jaw evolution, I compare the fit of multiple evolutionary models to the morphological data. I find strong support for the hypothesis that there are unique selective regimes associated with herbivory and carnivory in mammals. Further, mandibles of herbivorous species appear to have evolved much more rapidly than carnivores toward a trait optimum, suggesting especially strong selective pressures on these taxa. Thus, this study presents novel data concerning jaw correlates of diet across Mammalia and offers new evidence on the macroevolutionary patterns associated with mammalian diets and morphologies.

# **ECOLOGICAL DIVERSITY OF MAMMALIAN FAUNAS OF THE MOJAVE DESERT, CA, AND THE GREAT PLAINS, IN RELATION TO LANDSCAPE HISTORY**

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\* Speaker

Much of the study of biodiversity has traditionally focused on the geographic trends of species richness, but disentangling individual ecological and evolutionary factors that shape the observed species richness patterns remains a major challenge in ecology and evolutionary biology. Here, we analyze the ecological diversity of extant and fossil North American mammals to investigate the effect of landscape history (i.e. topography and climate) and associated environmental filtering processes on mammalian biogeography. In modern ecosystems, physiographically complex areas are found to support a higher number of mammal species than adjacent areas with low relief, but little is known about the difference in ecological functions represented by mammalian faunas in these areas. We hypothesize that topographically and climatically complex regions support a greater number of mammal species due to the greater environmental heterogeneity that accommodates more ecologically different species.

Our current research investigates the trends in two functional traits of extant North American mammals, body size and dietary habit, along environmental gradients as well as the effect of the climate space of mammal species on their geographic ranges. Our data show that the observed overall species richness pattern is the result of multiple mammalian diversity gradients that exist across North America. Future work will focus on the diet and body size of large herbivorous mammals from the middle Miocene of the Mojave Desert, California and the central Great Plains. The Mojave Desert is part of the Basin and Range province that underwent substantial tectonic changes during the middle Miocene, while the Great Plains has remained tectonically quiescent. These two topographically and climatically distinct regions presumably supported different levels of ecological diversity of mammals. We will analyze the stable-isotope composition of mammalian tooth enamels and compare the morphological disparity and body mass of large herbivorous mammals from the middle Miocene deposits of the Mojave and the central Great Plains.

# **AFRICAN DEINOTHERE ISOTOPIC PALEOECOLOGY: DEVELOPING A DIET AND HABITAT PROXY FOR AN EXTINCT PROBOSCIDEAN**

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The term “deinothere” refers to a group of large-bodied proboscideans that emerged by the early Miocene and survived into the Pliocene. During this time, the lineage spread from Africa to Eurasia, forming at least two genera (*Prodeinotherium* and *Deinotherium*) and six species. Deinotheres are characterized by their bilophodont teeth and are easily discernable with dorsally directed lower tusks. The fossil specimens display an intriguingly low rate of evolution, with deinotheres merely growing in overall body size and varying slightly in tooth and bone morphology over time. Despite their large size and expansive range, this taxon remains poorly studied, especially in Africa.

Deinothere teeth are common in the fossil assemblages of East Africa and thus are frequently included in isotopic studies of paleoenvironments. The overwhelming majority of the literature describes this proboscidean as having a purely browsing, C<sub>3</sub> diet based on the stable carbon and oxygen isotopes found in their enamel. Multiple researchers have gone as far as to label them an “end-member taxon” and use them as an indicator for the presence of woodland habitats. While the literature points to apparent consistency in the isotopic data from deinotheres, there is, as of yet, no published attempt to compile the data and develop a more cumulative perspective.

This study aims to further the knowledge of this extinct proboscidean with implications for paleoenvironments and evolutionary trends in coexisting taxa in three ways. First, an exhaustive collection of deinothere isotopic data is useful for establishing deinothere diet and discerning the timing of any shifts in diet over time. Second, new  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  data from multiple localities and various ages are included in order to better discern the verity of previous claims. Finally, the inter-tooth isotopic data are complemented with a first look into deinothere intra-tooth isotopic variation along with morphological tooth measurements.

The results of this study indicate that East African deinotheres were not consistently C<sub>3</sub> browsers, and in fact partook in a considerable amount of grazing at multiple points in time. These instances occur at key localities and during key environmental shifts, culminating in a more detailed picture of the extinct lineage as well as the environments they inhabited.

# REPRODUCTIVE LIFE HISTORIES OF FEMALE WOOLLY MAMMOTHS

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Woolly mammoth (*Mammuthus primigenius*) tusks consist of a series of conical dentin increments that form over known temporal intervals. Recent studies have shown that dentin cones observed in microCT form on an annual basis with certain aspects of attenuation associated with specific seasons (e.g., an abrupt transition from high to low attenuation has been associated with the boundary between winter and spring). We analyzed several complete woolly mammoth tusks from northern Siberia using a Nikon XT H 225 ST industrial microCT scanner housed at the University of Michigan. Annual increments within each tusk were measured for area, extensional length, and appositional thickness from curved slices along the longitudinal axis. In general, annual increments representing juvenile, subadult, and early adult years show successive increases in increment area through time (within juvenile years) followed by a gradual decline in area into old age. Over periods of three to five years, adult female tusks recorded a pattern of decrease and then increase in both increment area and extensional length. This pattern has not been observed in extensional increments of male mammoths, and was not found in either area or extensional length measurements of increments formed during subadult years in females. The onset of this pattern was observed in an individual beginning at approximately the expected age of sexual maturation. However, the appearance of this pattern only in adult females, and not in males or young individuals of either sex, suggests that it reflects some aspect of female reproductive life history. Given the similarity in duration of this pattern to calving interval duration in modern elephants, it seems reasonable to interpret these cycles of change in annual increment area as representing calving intervals.

# ARE FOSSIL COMMUNITIES JUST SPATIOTEMPORALLY SCALED-UP VERSIONS OF MODERN ONES?

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It is well known that ecological patterns and processes change across spatial and temporal scales. This makes difficult the exchange of theory and methods between neo- and paleoecology, two fields which study ecology at very different scales, especially temporal ones. One way to assess the comparability of ecological phenomena across orders of magnitude of scale is to study scaling relationships in ecological patterns. It has been demonstrated in many systems that species richness scales positively with area and time but with a negative interaction between the two on a log-log scale (i.e., the species-time-area relationship or STAR). We tested whether this pattern 1) exists in a modern large mammal community and 2) can be scaled up to predict richness in a fossil community. For our modern community, we analyzed the large mammal skeletal assemblage from Amboseli, southern Kenya, using data collected over multiple decades ( $10^{-3}$ - $10^1$  km<sup>2</sup>,  $10^0$ - $10^1$  years). For our fossil community, we analyzed the Pleistocene large mammal assemblage from Koobi Fora, northern Kenya ( $10^0$ - $10^1$  km<sup>2</sup>,  $10^3$ - $10^5$  years). Like other systems, we find Amboseli follows a STAR pattern when accumulating species richness with increasing area and time. Extrapolating the STAR to fossil spatiotemporal scales is complicated by the negative interaction term which can actually cause predicted richness to decrease with area and time, which is impossible. While the STAR is inappropriate for extrapolation to fossil scales, its form potentially illuminates the mechanisms by which species richness accumulates with increasing scale: increasing space and time are simply analogous ways of sampling the larger species pool, which must turn over at larger spatiotemporal scales (likely due to speciation) to “offset” the STAR’s negative interaction term. A model of origination will be explored to test the latter hypothesis. This research highlights the limitations of extrapolating modern ecological patterns to larger temporal scales and the need to study the fossil record in order to understand large-scale ecological processes.







