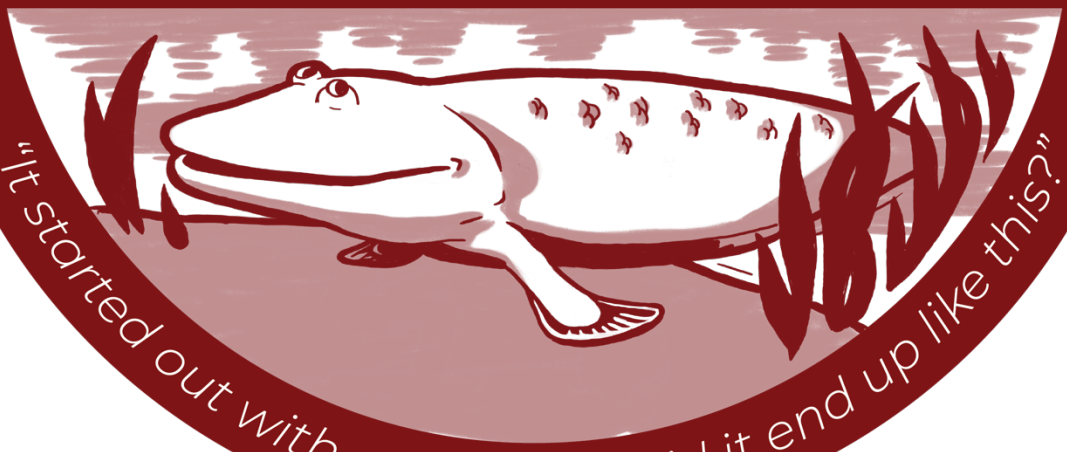
Great Lakes Student PaleoConference

GLSP 2022

Oct. 21st-23rd

The University of Chicago
Chicago, IL



"It started out with a fish, how did it end up like this?"

Welcome to the Fourth Annual Great Lakes Student PaleoConference (GLSP)! After a two-year hiatus due to the COVID-19 pandemic, we are so excited to host our returning event this year in Chicago, IL at the University of Chicago and the Field Museum of Natural History.

Founded in 2017, GLSP is a student-led effort to connect and share research in paleontology around the Great Lakes region. Initially including only students from University of Michigan and University of Chicago, it has expanded to invite students from many other institutions in the Midwest region. Eligible states include Illinois, Indiana, Michigan, Minnesota, Missouri, Ohio, and Ontario (Canada).

This year, GLSP is excited to announce that – for the first time in its history – it has representation from all states listed above! GLSP welcomes for the first time speakers from University of Minnesota, University of Missouri, Northwestern University, Ohio University, Ohio State University, University of Toronto, and University of Wisconsin-Madison. We are thrilled to see that GLSP is coming back stronger than ever, with almost 70 participants, 30 podium presentations, and 14 poster presentations.

Many thanks to our sponsors for this year's conference, including the Field Museum of Natural History, University of Chicago's Integrative Biology program, and University of Chicago's Committee on Evolutionary Biology.

Please enjoy your break time by exploring the Field Museum with the help of the maps you can find on the last pages of this program, and we hope you have a wonderful time in the Windy City!

Sincerely,

The 2022 GLSP Planning Committee

This Year's Logo:

The logo for the 4th GLSP was designed by Caroline P. Abbott. Using shades of University of Chicago's maroon, it depicts the early tetrapod *Tiktaalik roseae* (described in 2006 by University of Chicago's Neil Shubin) emerging from Lake Michigan, with the silhouette of downtown Chicago in the background. Beneath it, text reads "It started out with a fish, how did it end up like this?", a reference to an internet meme about biodiversity made by modifying the lyrics of the song "Mr. Brightside" by The Killers.

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Navigation Directions:

- We welcome all GLSP participants enter through the west entrance. This entrance is labeled with "Enter Here" on maps on pages 2 and 5.
- Upon entering the west entrance, participants may approach a check-in table to collect a nametag, program, etc. This area is labeled on the map on page 5
- Rooms LH2 and C are labeled on the map on page 4

Meals:

- Breakfast will be held in the hallway leading to LH2
- Lunch will be held in LH2 and surrounding areas
    - Weather permitting, participants are welcome to eat outdoors during lunch
    - Participants are also welcome to explore the eating areas of the museum during lunch

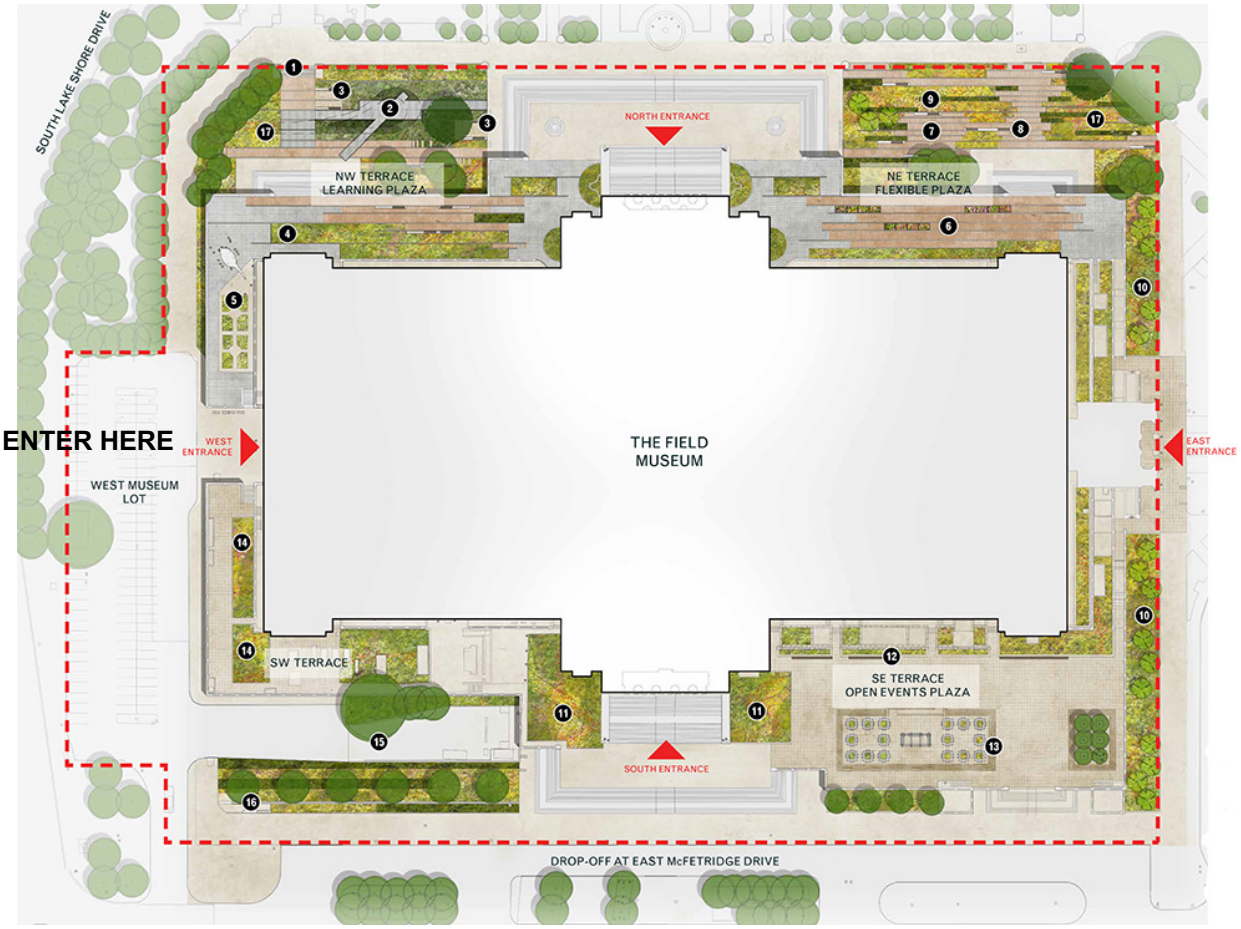
Posters:

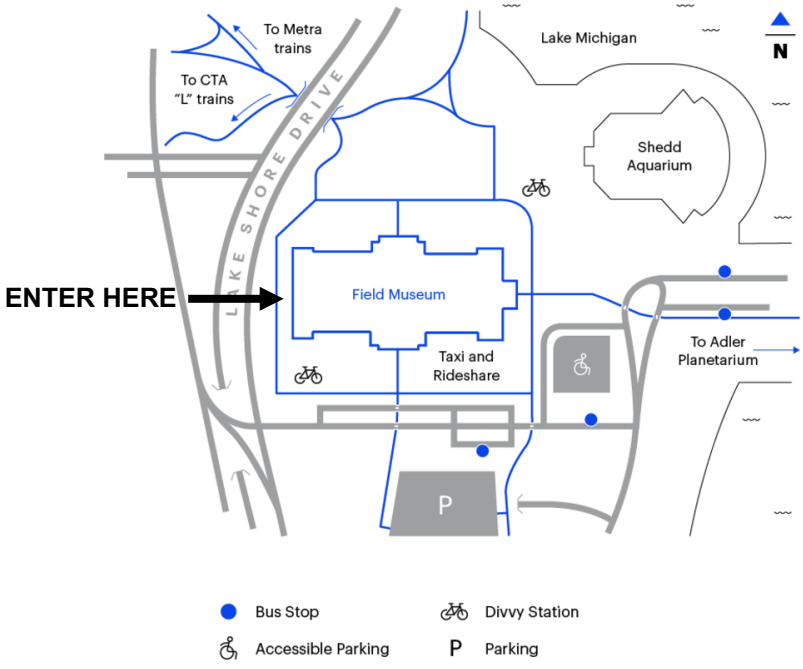
- Poster presenters are welcome to leave posters with the check-in table when they check-in. GLSP volunteers will put up the posters in advance of the session
- Poster session will be held in LH2

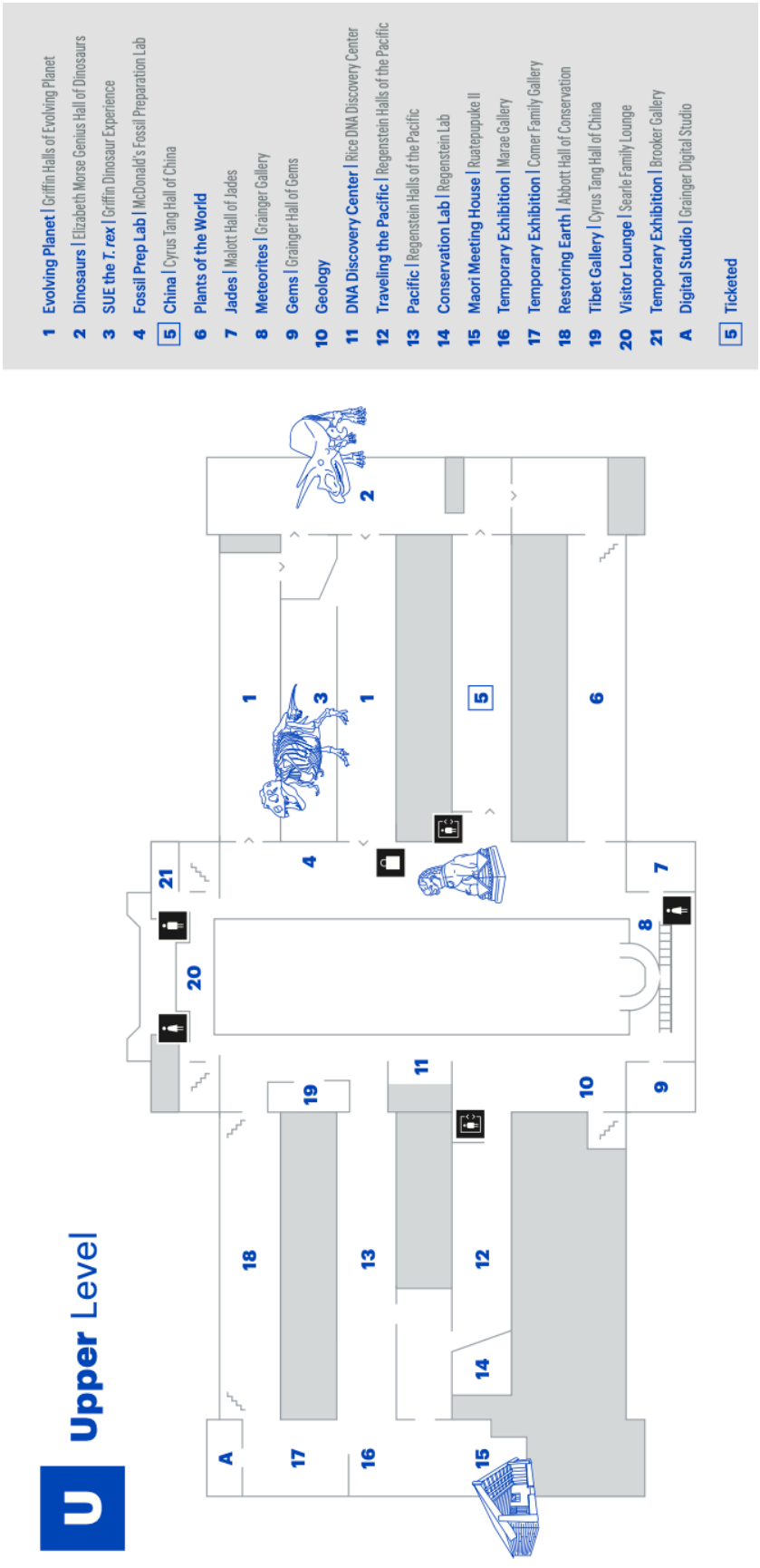
Program Note:

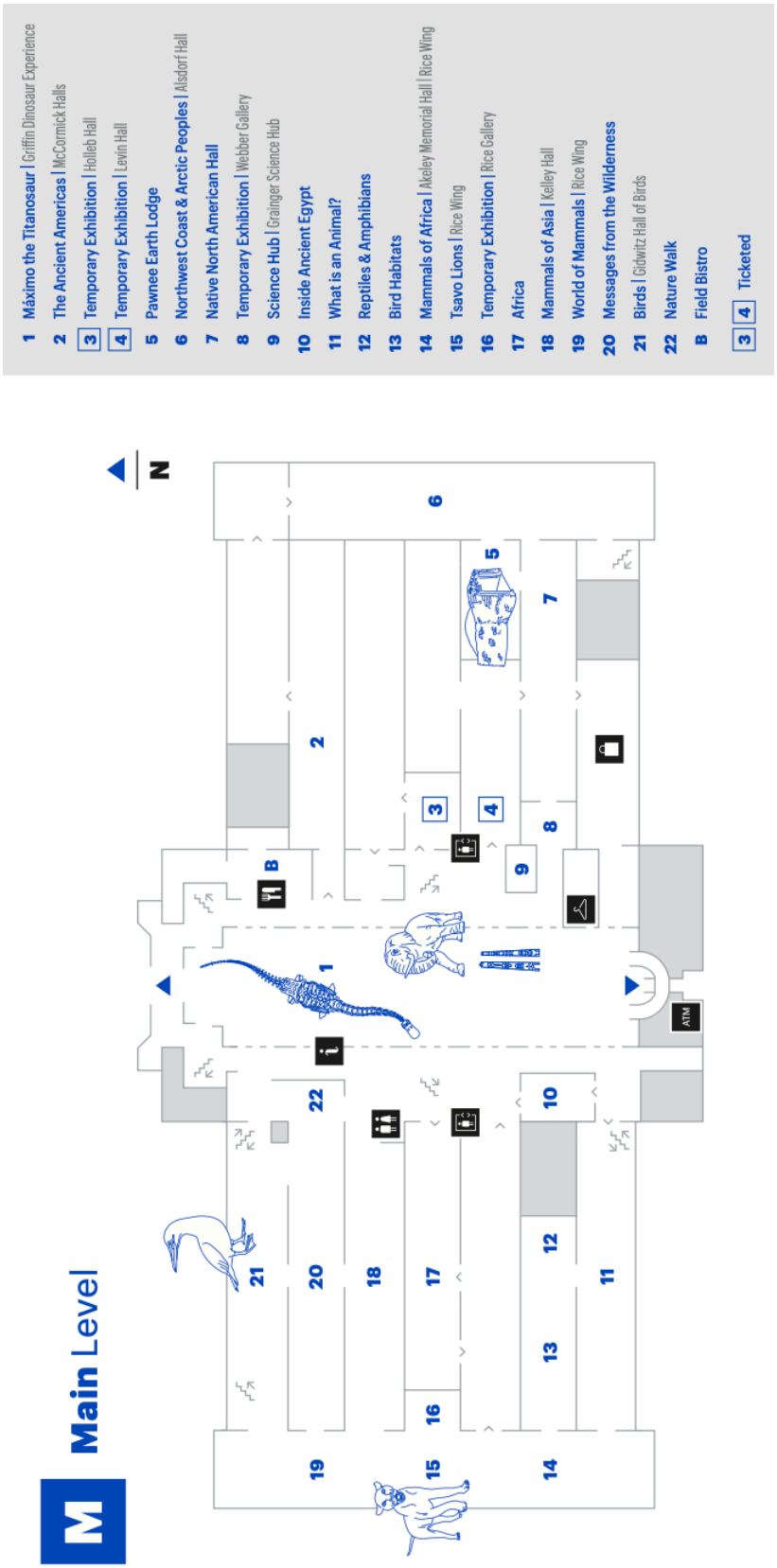
- Pages edged in **maroon** correspond with podium presentations given in **Room B**
- Pages edged in **silver** correspond with podium presentations given in **Room LH2**

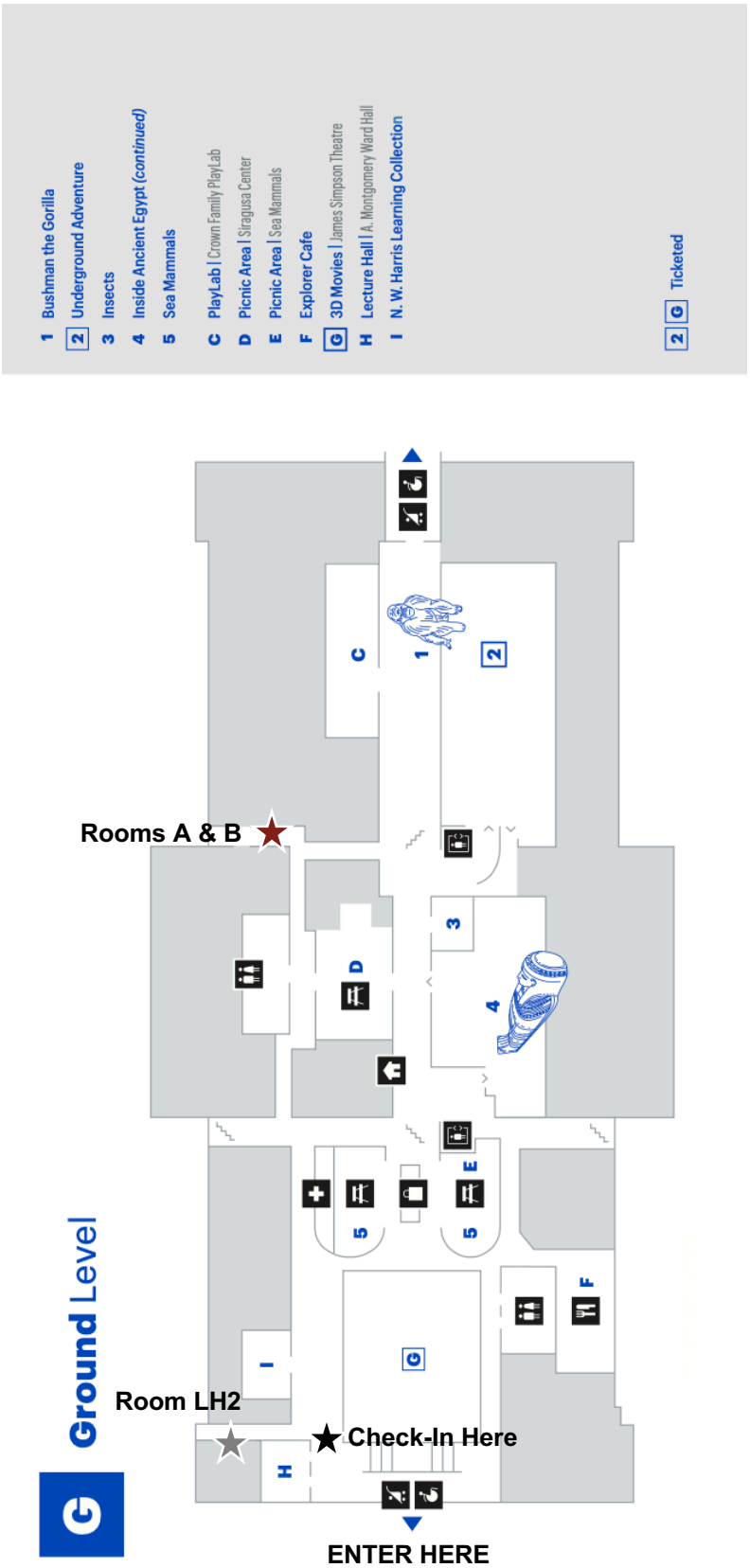
Field Museum Maps






1 Evolving Planet | Griffin Halls of Evolving Planet
2 Dinosaurs | Elizabeth Morse Genius Hall of Dinosaurs
3 SUE the T. rex | Griffin Dinosaur Experience
4 Fossil Prep Lab | McDonald's Fossil Preparation Lab
5 China | Cyrus Tang Hall of China
6 Plants of the World
7 Jades | Malott Hall of Jades
8 Meteorites | Grainger Gallery
9 Gems | Grainger Hall of Gems
10 Geology
11 DNA Discovery Center | Rice DNA Discovery Center
12 Traveling the Pacific | Regenstein Halls of the Pacific
13 Pacific | Regenstein Halls of the Pacific
14 Conservation Lab | Regenstein Lab
15 Maori Meeting House | Ruatepupuke II
16 Temporary Exhibition | Marae Gallery
17 Temporary Exhibition | Comer Family Gallery
18 Restoring Earth | Abbott Hall of Conservation
19 Tibet Gallery | Cyrus Tang Hall of China
20 Visitor Lounge | Seattle Family Lounge
21 Temporary Exhibition | Brooker Gallery
A Digital Studio | Grainger Digital Studio
5 Ticketed
U Upper Level


1 Máximo the Titanosaur | Griffin Dinosaur Experience
2 The Ancient Americas | McCormick Halls
3 Temporary Exhibition | Holleb Hall
4 Temporary Exhibition | Lewin Hall
5 Pawnee Earth Lodge
6 Northwest Coast & Arctic Peoples | Alsdorf Hall
7 Native North American Hall
8 Temporary Exhibition | Webber Gallery
9 Science Hub | Grainger Science Hub
10 Inside Ancient Egypt
11 What is an Animal?
12 Reptiles & Amphibians
13 Bird Habitats
14 Mammals of Africa | Akeley Memorial Hall | Rice Wing
15 Tsavo Lions | Rice Wing
16 Temporary Exhibition | Rice Gallery
17 Africa
18 Mammals of Asia | Kelley Hall
19 World of Mammals | Rice Wing
20 Messages from the Wilderness
21 Birds | Gidwitz Hall of Birds
22 Nature Walk
B Field Bistro
3 4 Ticketed
N
Main Level
ATM


1 Bushman the Gorilla
2 Underground Adventure
3 Insects
4 Inside Ancient Egypt (continued)
5 Sea Mammals
C PlayLab | Crown Family PlayLab
D Picnic Area | Siragusa Center
E Picnic Area | Sea Mammals
F Explorer Cafe
G 3D Movies | James Simpson Theatre
H Lecture Hall | A. Montgomery Ward Hall
I N. W. Harris Learning Collection
2 G Ticketed
Rooms A & B
Room LH2
Check-In Here
ENTER HERE
G Ground Level

ROOM B SCHEDULE:

8:00am – 9:00am Breakfast and Welcome

9:00am – 10:00am Session 1: Phylogenetics

9:00am – 9:15am **Fitch**
ORIGINS OF PTEROSAURIA: HIDDEN FOSSIL RECORD AND NEAR EXTINCTIONS OF THE FIRST AND LONGEST-LASTING FLYING VERTEBRATE LINEAGE REVEALED THROUGH A NEW PHYLOGENETIC HYPOTHESIS

9:15am – 9:30am **Aranda**
INTRODUCING THE EARLY HIGH DISPARITY PHYLOGENETIC COMPARATIVE MODEL, WITH APPLICATIONS TO BODY SIZE EVOLUTION IN WHALES (MAMMALIA: CETACEA) AND ICHTHYOSAURS (REPTILIA: ICHTHYOSAUROMORPHA)

9:30am – 9:45am **DeHaan**
A NEON-PALEONTOLOGICAL PERSPECTIVE ON THE MORPHOLOGICAL DIVERSIFICATION OF CARANGARIAN FISHES (JACKS, FLATFISHES, BILLFISHES, AND ALLIES)

9:45am – 10:30am Break

10:30am – 11:15am Session 2: Climate & Taphonomy

10:30am – 10:45am **Kokesh**
BIVALVE DEAD-SHELL ASSEMBLAGES ARE STRONG SURROGATES FOR WHOLE BENTHIC MACROINVERTEBRATE COMMUNITIES IN PUGET SOUND

10:45am – 11:00pm **Carden**
MOLLUSCAN DEAD SHELL ASSEMBLAGES ARE ARCHIVES OF URBANIZATION: DISCOVERING HOW NITROGEN ISOTOPIC SIGNATURES VARY ALONG A GRADIENT OF SEPTIC POLLUTION AND AS A FUNCTION OF TROPHIC GROUP

11:00am – 11:15am **Laker**
TRANSFORMING FOSSIL DIAGENESIS FROM A PROBLEM INTO A TOOL: MICROTAPHONOMIC FEATURES OF BONE REFLECT EARLY DEPOSITIONAL ENVIRONMENTS AND THUS THE DYNAMICS OF TIME-AVERAGING IN MIOCENE (CALVERT CLIFFS, MD) AND EOCENE (VALLEY OF THE WHALES, EGYPT) MARINE SILICICLASTIC RECORDS

11:15am– 11:30am **Shirley**
DOES LEARNING ABOUT DEEP-TIME EXTINCTION AFFECT VIEWS ON MODERN ENVIRONMENTAL PROBLEMS?

11:30am – 12:45pm Lunch is in LH2

12:45pm – 1:45pm Session 3: Biogeography

12:45pm – 1:00pm **Salem**
NEW MARINE REPTILE (PLESIOSAUR AND MOSASAUR) FOSSILS FROM THE UPPER CAMPANIAN DUWI FORMATION OF THE DAKHLA OASIS AREA, WESTERN DESERT OF EGYPT

1:00pm – 1:15pm **Wood**
PREDICTING PATTERNS OF VERTEBRATE FOSSIL PRESERVATION USING VARIATION IN RATES OF STRATIGRAPHIC ACCUMULATION: A CASE STUDY IN A MAMMAL-RICH INLAND BASIN (WASHAKIE FORMATION, WY)

1:15pm – 1:30pm **Doyle**
POLES APART: CENOZOIC SIZE DIFFERENTIATION OF HIGH LATITUDE BIVALVE FAUNAS

1:30pm – 1:45pm **Viglietti**
NETWORK-BASED BIOSTRATIGRAPHY FOR THE LATE PERMIAN-MID TRIASSIC BEAUFORT GROUP (KAROO SUPERGROUP) IN SOUTH AFRICA ENHANCES BIOZONE APPLICABILITY AND STRATIGRAPHIC CORRELATION

1:30pm – 2:15pm Break

2:15pm – 3:15pm Session 4: Brain & Behavior

2:15pm – 2:30pm **Strassberg**
PINEAL FORAMEN VARIATION AS A WINDOW INTO SENSORY EVOLUTION, CONVERGENCE OF MAMMAL-LIKE CRANIAL TRAITS, AND MAJOR LINEAGE DIVERGENCES IN PRE-MAMMALIAFORM SYNAPSIDA

2:30pm – 2:45pm **Ward**
A MULTI-ISOTOPE RECONSTRUCTION OF TELEOCERAS MAJOR (MAMMALIA, THINOCEROTIDAE) MATING SYSTEM FROM ASHFALL FOSSIL BEDS STATE HISTORICAL PARK, NEBRASKA

2:45pm – 3:00pm **Gaetano**
SINKING OUR TEETH IN: RECORDS OF CARNIVORAN MODIFICATION ON BONES OF SMALL PREY

3:00pm – 3:15pm **Figueroa**
THREE-DIMENSIONAL BRAIN SOFT-TISSUE PRESEVATION IN LATE PALEOZOIC ACTINOPTERYGIANS FROM BRAZIL INFORMS THE EVOLUTION OF THE RAY-FINNED FISH BRAIN

3:15pm – 5:00pm Poster Session is in Room A

ROOM LH2 SCHEDULE:

8:00am – 9:00am Breakfast and Welcome

9:00am – 10:00am Session 1: Ontogeny & Development

9:00am – 9:15am **Sombathy**
THE SIGNIFICANCE OF MULTI-LAGS IN CORTICAL BONE INFERRED FROM A LARGE HISTOLOGICAL SAMPLE OF THE THEROPOD DINOSAUR ALLOSAURUS

9:15am – 9:30am **Abbott**
THE IMPORTANCE OF ONTOGENY AND PHYLOGENY IN EVALUATING BODY SIZE CHANGE IN THE FOSSIL RECORD: A CASE STUDY OF LYSTROSAURUS (THERAPSIDA, ANOMODONTIA) IN THE KAROO BASIN, SOUTH AFRICA

9:30am – 9:45am **Ng**
ONTOGENY AS AN EVOLUTIONARY CONSTRAINT AND SOURCE OF NEOMORPHISM WITHIN THE EARLY CAMBRIAN TRILOBITE GENUS *ZACANTHOPSIS*

9:45am – 10:00am **Haridy**
MINERAL METABOLISM AND THE ORIGIN OF CELLULAR BONE

10:00am – 10:30am Break

10:30am – 11:15am Session 2: Functional Morphology 1

10:30am – 10:45am **Rivero-Vega**
A NEW LUNGFISH (SARCOPTERYGII: DIPNOI) FROM THE LATE DEVONIAN (FRASNIAN) FRAM FORMATION, NUNAVUT, CANADA

10:45am – 11:00am **Deng**
TESTING THE ROLE OF BIOTIC INTERACTION IN SHAPING TAXONOMIC, MORPHOLOGICAL, AND FUNCTIONAL DIVERSITY IN ANOMALODESMATAN BIVALVES

11:00am – 11:15am **Lowi-Merri**
USING COMPARATIVE FUNCTIONAL MORPHOLOGY TO RECONSTRUCT LOCOMOTION IN THE CRETACEUOUS BIRD ICHTHYORNIS (AVIALAE: ORNITHURAE)

11:30am – 12:45pm Lunch

12:45pm – 1:45pm Session 3: Functional Morphology 2

12:45pm – 1:00pm **Fulghum**
EVALUATING DIETARY DIVERSITY IN THE TRIBOSPHENIC DENTITION: ANALYSIS OF SIMPLE LINEAR MEASUREMENTS DISTINGUISH PRIMARY AND SECONDARY DIET TYPES IN EXTANT TAXA

1:00pm – 1:15pm **Magallanes**
A NEW DRYOLESTOID SPECIMEN FROM THE LATE JURASSIC PROVIDES NEW INSIGHTS ON THE SIGNIFICANCE OF TOOTH ROOT STRUCTURE THROUGHOUT MAMMAL HISTORY

1:15pm – 1:30pm **Hunter**
TEMPO AND MODE IN THE EVOLUTION OF PRIMATE DENTAL MORPHOLOGY

1:30pm – 2:15pm Break

2:15pm – 3:00pm Session 4: Functional Morphology 3

2:15pm – 2:30pm **Ayersman**
UNEARTHING THE INFLUENCES OF BODY SIZE, ECOLOGY, AND PHYLOGENY IN THE CLAW MORPHOLOGY OF DIGGING ANIMALS

2:30pm – 2:45pm **Zack**
FROM FAIRIES TO GIANTS: UNTANGLING THE EFFECTS OF BODY SIZE, PHYLOGENY, AND ECOLOGY ON VERTEBRAL BONE MICROSTRUCTURE OF XENARTHRAN MAMMALS

2:45pm – 3:00pm **Lawrence**
ACETABULAR ORIENTATION, PELVIC SHAPE, AND THE EVOLUTION OF HOMININ BIPEDALITY

3:15pm – 5:00pm Poster Session is in Room A

SESSION 1, ROOM B PHYLOGENETICS
9:00am – 10:00am

ORIGINS OF PTEROSAURIA: HIDDEN FOSSIL RECORD AND NEAR EXTINCTIONS OF THE FIRST AND LONGEST-LASTING FLYING VERTEBRATE LINEAGE REVEALED THROUGH A NEW PHYLOGENETIC HYPOTHESIS

Adam J. Fitch[1,2,3]*; Bhart-Anjan S. Bhullar[4]; Adam C. Pritchard[5]; Joseph Bevitt[6]; David Lovelace[3]; Sterling J. Nesbitt[2]
[1]Smithsonian National Museum of Natural History; [2]Virginia Polytechnic Institute and State University; [3]University of Wisconsin-Madison; [4]Yale University; [5]Virginia Museum of Natural History; [6]Australian Nuclear Science and Technology Organisation; ***Presenting author**

Pterosaurs were prominent members of Mesozoic faunas, existing throughout the period to its end as one of or the primary aerial vertebrate clade. Survival across major biotic transitions (eg. mass extinctions) and the origins of pterosaurian diversity are important for understanding their morphological and flight evolution. Debate exists as to whether Triassic and Jurassic pterosaurs represent larger, monophyletic subclades or a series of successive sister taxa to Monofenestrata (pterodactyloids and pterodactyloid-like forms). Reexamination of early ornithodirans and of the 'eudimorphodontoid' pterosaur Arcticodactylus cromptonellus show a mosaic of lagerpetid and pterosaur features. Notably, A. cromptonellus lacks features diagnostic to the rest of Pterosauria while possessing features apomorphic of the Triassic endemic pterosaurian Eudimorphodontoidea and/or Raeticodactylidae, suggesting the paraphyly of this subclade(s) to later pterosaurs. To resolve this possible paraphyly, we have assembled a new phylogenetic dataset representing a concatenation of existing pterosaur phylogenetic analyses, revised characters, character states, and scores and include new characters from across the skeleton and a comprehensive sampling of archosauromorphs (including all lagerpetids), all pterosaurs from the Triassic-early Jurassic, and a representative sampling from the middle Jurassic-Cretaceous. We found a ladder-like grade in which few pterosaurs form side branches to the exclusion of middle Jurassic-Cretaceous pterosaurs. Eudimorphodontoidea/Raeticodactyloidea, Dimorphodontidae, and Scaphognathidae/Rhamphorhynchidae are recovered as respectively paraphyletic to each other and Monofenestrata, decreasing or eliminating many early pterosaur ghost lineages. We find only a single pterosaur lineage crossed the Triassic-Jurassic and Early-Middle Jurassic biotic transitions, the former of the ‘dimorphodontid’ grade (large-headed terrestrially adept forms) and the latter of the ‘rhamphorhynchid/scaphognathid’ grade (aerial predators). These results demonstrate a clear loss of diversity in early Pterosauria (here approaching extinction) with the loss of all but one pterosaur lineage akin to losses found in other groups that crossed the end Triassic and Early-Middle Jurassic biotic transitions into the late Mesozoic.

Keywords: reptilia; pterosauria

INTRODUCING THE EARLY HIGH DISPARITY PHYLOGENETIC COMPARATIVE MODEL, WITH APPLICATIONS TO BODY SIZE EVOLUTION IN WHALES (MAMMALIA: CETACEA) AND ICHTHYOSAURS (REPTILIA: ICHTHYOSAUROMORPHA)

Ricardo Aranda[1]*
[1]Department of Earth & Atmospheric Sciences, Indiana University

Phenotypic evolutionary models currently employed in phylogenetic comparative methods (PCMs) estimate parameters describing evolutionary rates and modes of morphological disparity. These models include Brownian Motion (BM), Trend (TR), Ornstein-Uhlenbeck (OU), and Early Burst (EB). In their standard forms, all of these models assume morphological disparity either increases or remains constant throughout the history of a clade. The fossil record deviates from this expectation, revealing many clades have experienced disparity peaks before their eventual extinctions (or before the present). Currently, no PCMs exist which incorporate parameters for describing Early High Disparity (EHD) in the history of a particular clade. A novel PCM for modelling the evolution of disparity through time is presented here, targeting clades which may display EHD. This model is a combination of EB and OU models, resulting in exponential increases in disparity, followed by rapid disparity decreases around an optimal value, remaining constant afterwards.

The EHD model is tested with a dataset of whales and ichthyosaurs, using body size as the trait of interest and time-calibrated phylogenies. Both clades of secondarily aquatic tetrapods passed through and adapted to shallow seas, complex environments subject to greater temperature, sea level, nutrient, etc. variabilities, producing greater niche variability, and thus greater disparity, before adapting to open-ocean environments with more hydrodynamic constraints (and thus lower disparity). This ecological transition potentially resulted in patterns of EHD in cetaceans and ichthyosaurs. The relative model fit (ΔAICc) of the EHD models in the cetacean and ichthyosaur datasets are compared to model fits of BM, OU, EB, and TR models, using fitContinuous_paleo in R. For cetaceans, BM and OU models are rejected (ΔAICc > 2), while TR, EB, and EHD models receive equivalent levels of support (ΔAICc < 2). For ichthyosaurs, EB and EHD models receive equivalent levels of support (ΔAICc < 2), but strongly reject all other models tested (ΔAICc > 10). The EHD model needs testing on other comparative datasets to assess the fit of this model across a taxonomic range. Paleontological datasets contain information on changes in disparity that cannot be inferred easily from extant-only datasets. The novel EHD PCM is the first model which takes into account a mode of evolution in disparity which can only be inferred with extinct taxonomic data.

Keywords: phylogenetic comparative methods; morphological disparity; macroevolution

A NEON-PALEONTOLOGICAL PERSPECTIVE ON THE MORPHOLOGICAL DIVERSIFICATION OF CARANGARIAN FISHES (JACKS, FLATFISHES, BILLFISHES, AND ALLIES)

Lindsey M DeHaan[1]*; Matt Friedman[1,2]
[1]Department of Earth and Environmental Sciences, University of Michigan; [2]Museum of Paleontology, University of Michigan; ***Presenting author**

With lineages as anatomically and ecologically disparate as flatfishes, remoras, billfishes, and jacks, the Cenozoic spiny-rayed fish clade Carangaria represents an intriguing system for studying patterns of morphological change. Past studies of patterns of body shape evolution in carangarians have employed two different approaches. The first quantifies fluctuating levels of disparity over time using fossil species, without a consideration of phylogenetic relationships. The second fits explicit models of trait evolution using data for living species and time-calibrated molecular phylogeny. Both offer incomplete perspectives on patterns of diversification. Here we combine neontological and paleontological approaches to test past hypotheses about shape evolution in carangarian fishes. We selected 16 well-preserved fossil specimens and integrated them into a molecular phylogenetic backbone containing 69 living species. Within the limits of the available fossil record, we attempted to sample fossil species across major clades and throughout the evolutionary history of Carangaria. Placing fossils within trees for which there are limited morphological datasets is challenging, so we adopted an approach based on a combination of taxonomy and verbally argued placements to assign fossils to specific internodes. The length of the branch subtending fossils (and their branching point along an internode) was inferred analytically. Our strategy uses a maximum likelihood approach to place these fossils under a Brownian motion model of shape evolution, conservatively biasing our results toward supporting a time-homogenous, diffusive model of change. Our integrated results, combining shape data from both extinct and extant species, support elevated rates of diversification early in the history of Carangaria and then slow down thereafter but disparity has continued to increase to the present day. These results deviate from the findings using only extant taxa which showed that the Carangarian diversity became constrained soon after rates slowed down. Our findings support the well-established significance of fossil data in understanding patterns of evolutionary diversification and provides one approach toward including fossils in a comparative framework when detailed character matrices are not available.

Keywords: neontology; paleontology; morphological diversification; carangaria

SESSION 2, ROOM B: CLIMATE & TAPHONOMY
10:30pm – 11:15pm

BIVALVE DEAD-SHELL ASSEMBLAGES ARE STRONG SURROGATES FOR WHOLE BENTHIC MACROINVERTEBRATE COMMUNITIES IN PUGET SOUND

Broc S Kokesh[1]*
[1]Department of the Geophysical Sciences, University of Chicago; ***Presenting author**

To integrate paleoecological data with the "whole fauna" data used in biological monitoring, analyses usually must focus on the subset of taxa that are inherently preservable (by virtue of biomineralized hardparts) and those skeletal remains must also be identifiable in fragmentary or otherwise imperfect condition (perhaps requiring genus- or family-level identification). However, can shelly death assemblages reflect similar patterns of compositional variation among samples as exhibited by the entire infaunal macroinvertebrate community? We evaluated faunal count data from ten established subtidal stations in Puget Sound, Washington State. Among-sample distance matrices were produced for data based on five taxonomic subsets (the whole fauna, polychaetes, malacostracans, living bivalves, dead bivalves) at four levels of taxonomic resolution (species, genera, families, orders) evaluated under four numerical transformations of the original count data (proportional abundance, square-root and fourth-root proportional abundances, presence-absence), resulting in a total of 80 surrogate matrices. Second-stage ordination was used to plot inter-matrix correlations and determine the strength of surrogates as proxies of the original live-collected whole fauna data. We found that living and dead bivalves had nearly identical potential to serve as surrogates of the whole fauna; they were further offset from the whole fauna than was the polychaete subset (which dominates the whole fauna), but were far superior as surrogates than malacostracans. Genus- and family-level data were consistently strong surrogates of species-level data for most taxonomic subsets, and correlations declined for all subsets with the intensity of data transformation. These strongly positive results in a setting with potential to impose strong taphonomic bias on shell preservation (e.g., strong tides, and dissolution stress from cold bottom waters) are encouraging for use of bivalve dead-shell assemblages as a complement to monitoring data in regions with strong natural environmental gradients.

Keywords: taxonomic surrogacy; data transformation; death assemblages; benthic; puget sound

MOLLUSCAN DEAD SHELL ASSEMBLAGES ARE ARCHIVES OF URBANIZATION: DISCOVERING HOW NITROGEN ISOTOPIC SIGNATURES VARY ALONG A GRADIENT OF SEPTIC POLLUTION AND AS A FUNCTION OF TROPHIC GROUP

Lilja Carden[1,2]*; Javier Lloret[3]; Susan Kidwell[1]
[1]Department of Geophysical Sciences, University of Chicago; [2]Department of Geology, University of Cincinnati; [3]Ecosystems Center, Marine Biological Laboratory; ***Presenting author**

Over the past century, increased coastal urbanization worldwide has resulted in increased nitrogen inputs to ecosystems, which can lead to eutrophication, anoxic conditions and other negative effects on marine wildlife and ecosystem services. Elevated nitrogen isotopic signatures (δ15N) in the soft tissues from live-collected animals is one established means of detecting eutrophication linked to wastewater inputs. Here, we used δ15N in molluscan shells from naturally occurring death assemblages to evaluate their potential to identify wastewater nitrogen inputs in two estuaries in Cape Cod, Massachusetts: Waquoit Bay, which currently receives pollution from private septic systems, and West Falmouth Harbor, which receives legacy nitrogen pollution associated with the groundwater plume from a municipal treatment plant. Using dead shells collected in these estuaries at ~0.5 m below low tide, we assessed the isotopic signatures of the nitrogen compounds present in those shells and their variations along the spatial wastewater pollution gradient. We also tested for variation in shell-nitrogen as a function of feeding type, comparing the shells of the filter-feeding mussel *Geukensia demissa,* the detritus-feeding gastropod *Nassarius obsoletus*, and the herbivorous gastropod *Littorina littorea*. The percent of nitrogen recovered from the shells varied widely among species, probably indicating differences in the total nitrogen content of shells, but also across sites, which may be due to local differences in the preservation of shell materials in these sites. We also found that, for all three species, nitrogen isotopic signatures varied significantly, and as expected, δ15N decreased with distance from the wastewater pollution source. Shells from filter-feeding bivalves had a

lower variance in δ15N than both gastropod species. Dead shells are an effective archive of nitrogen eutrophication along spatial gradients of both ongoing and legacy wastewater pollution. Dead shells would thus provide a useful complement to conventional monitoring programs, providing a means of acquiring the spatial profile from a single sampling, without the need for living animals, and with potential to be used in historical records to evaluate longer-term trends.

Keywords: death-assemblages; nitrogen isotopes; wastewater; legacy pollution; trophic groups

TRANSFORMING FOSSIL DIAGENESIS FROM A PROBLEM INTO A TOOL: MICROTAPHONOMIC FEATURES OF BONE REFLECT EARLY DEPOSITIONAL ENVIRONMENTS AND THUS THE DYNAMICS OF TIME-AVERAGING IN MIOCENE (CALVERT CLIFFS, MD) AND EOCENE (VALLEY OF THE WHALES, EGYPT) MARINE SILICICLASTIC RECORDS

Rachel M Laker[1]*
[1]Department of Geophysical Sciences, University of Chicago; ***Presenting author**

Although bonebeds are a rich record of vertebrate remains, they can reflect complicated overprinting by time-averaging processes such as erosional winnowing or prolonged exposure before permanent burial, with potential to affect the original biologic signal. Microtaphonomic and diagenetic features such as microboring, staining, cracking, and authigenic infills, which are often rarely considered, could provide a valuable additional means of recognizing taphonomically complex histories: bones are most reactive during their immediate post-mortem window and should thus acquire microscopic evidence of those environmental conditions. Bones from rapidly deposited sediments (minimal time averaging) should exhibit little alteration, as they've experienced comparatively brief opportunities for bioerosion, biogeochemical interactions in the taphonomically active zone, and other processes; bones from erosional settings have potential for overprinting by oxidized minerals and for evidence of drying and/or abrasion related to reworking and subaerial exposure; and bones from sediment-starved or other hiatal settings (delayed burial) should reflect the maximum opportunity for alteration, with heavily tunneled bone margins and complex infilling minerals related to redox cycling in the surface mixed layer. To test this hypothesis, cetacean bones were sampled from two well-known Cenozoic marine records where the duration of pre-burial conditions can be estimated from an already-established sequence stratigraphic context, and bones are known to display variable macroscopic preservation. Bones from the unlithified Miocene strata of the Calvert Cliffs do preserve diverse features consistent with their expected early depositional environment, such as both marine and terrestrial forms of microboring, microcracks from both swelling and drying, and varied degrees and compositions of infilling. Bones from the lithified Eocene strata of the Valley of the Whales are densely infilled with authigenic minerals, but still distinguish disparate pre-burial conditions via both microtaphonomic features and carbonate microfacies. Microtaphonomic and authigenic alteration of bones thus captures the early diagenetic, pre-burial conditions of bone accumulation in marine settings, correlative with the predicted duration of time averaging and persisting despite pervasive late diagenesis and weathering. Such features thus represent a valuable tool to understanding the nature of bone assemblages.

Keywords: taphonomy; marine; cetacean; diagenesis; authigenesis

DOES LEARNING ABOUT DEEP-TIME EXTINCTION AFFECT VIEWS ON MODERN ENVIRONMENTAL PROBLEMS?

Ethan A Shirley[1,2]*
[1]Department of Earth and Environmental Sciences, University of Michigan; [2]Museum of Paleontology, University of Michigan; ***Presenting author**

The study of deep-time evolution and extinction can be politically divisive but relevant for modern catastrophic climate change and species extinction. Deep-time climates varied by magnitudes greater than those of today's climate change, and past extinctions were greater in magnitude than the extinction that is occurring today. However, the rate and cause of extinction and climate change today are different from what we can observe in the fossil record. Attitudes about modern climate change and extinction could change in one of two ways in response to studying paleontology: (1) students could think that because magnitudes of extinctions and climate changes were greater in deep time, today's climate change and

extinction are less important; (2) on the other hand, students could think that because the rate and cause of modern climate change and extinction are so different, they are more important and urgent to address. Here, I use this potentially dichotomous attitude change response to a paleontology course to discuss how we teach paleontology. I surveyed students (n = 223) before and after they took a lower-level and two upper-level college paleontology courses with Likert-scale attitude questions and open-ended responses to gauge attitude changes related to the courses. Students changed their attitudes in both directions, many saying the course had made them feel modern environmental changes were less important in the context of deep time, and others saying the course made them feel that modern environmental problems are more urgent because of their human cause. Paleontology educators should be mindful of these attitude changes among students, and should demonstrate similarities and differences as well as actively correcting misconceptions about modern climate change and extinction while teaching about deep-time evolution and extinction.

Keywords: conservation paleobiology; social impact of paleontology

SESSION 3, ROOM B: BIOGEOGRAPHY
12:45pm – 1:45pm

NEW MARINE REPTILE (PLESIOSAUR AND MOSASAUR) FOSSILS FROM THE UPPER CAMPANIAN DUWI FORMATION OF THE DAKHLA OASIS AREA, WESTERN DESERT OF EGYPT

Belal S. Salem[1,2,3,4]*; Patrick M. O'Connor[2,5]; Matthew C. Lamanna[6]; Sanaa El-Sayed[3,7]; Erik R. Seiffert[8]; Joseph J. W. Sertich[9,10]; Hesham M. Sallam[3,11]

[1]Department of Biological Sciences, Ohio University; [2]Ohio Center for Ecology and Evolutionary Studies, Ohio University; [3]Mansoura University Vertebrate Paleontology Center, Department of Geology, Faculty of Science, Mansoura University; [4]Department of Geology, Faculty of Science, Benha University; [5]Department of Biomedical Sciences, Ohio University Heritage College of Osteopathic Medicine, Ohio University; [6]Section of Vertebrate Paleontology, Carnegie Museum of Natural History; [7]Museum of Paleontology, Department of Earth and Environmental Sciences, University of Michigan; [8]Department of Integrative Anatomical Sciences, Keck School of Medicine of USC, University of Southern California; [9]Department of Earth Sciences, Denver Museum of Nature and Science; [10]Department of Geosciences, Warner College of Natural Resources, Colorado State University; [11]Institute of Global Health and Human Ecology, School of Sciences and Engineering, American University in Cairo; ***Presenting author**

Upper Cretaceous deposits exposed in southern Egypt, near the Dakhla Oasis in the Western Desert, preserve abundant vertebrate fossils from nearshore marine paleoenvironments. Fieldwork carried out by researchers from the Mansoura University Vertebrate Paleontology Center in this area during 2008, 2010, 2011 and 2013 resulted in the discovery of numerous new vertebrate fossil localities within the upper Campanian part of the Duwi Formation. Fossils recovered from this unit include those of sharks, sawfishs, actinopterygians, and marine reptiles (mosasaurs and plesiosaurs). Here we report on elasmosaurid (Sauropterygia: Plesiosauria: Elasmosauridae) and mosasaurid (Squamata: Mosasauridae) fossils from the Duwi Formation. Elasmosaurids are represented by numerous large posterior cervical and dorsal vertebrae that are referable to this plesiosaur clade based on their possession of centra with lateral ridges and dumbbell-shaped articular facets. Mosasaurids are the most abundant and diverse marine reptiles recovered from the Duwi Formation, with many craniodental (e.g., dentaries and teeth with differing morphologies) remains and dozens of vertebrae having been identified as those of Mosasaurinae or Halisaurinae. Within Mosasaurinae, an isolated, robust, and globular tooth crown of Globidens and a complete tooth of Carinodens (identified on the basis of its lateral flattening and two relatively pronounced sulci) indicate the presence of Globidensini. Many fragmentary dentaries pertain to an indeterminate mosasaurine, with two of these preserving teeth in situ and another showing a replacement tooth developed within a resorption pit. One small, fragmentary dentary with two preserved teeth is referred to Halisaurinae based on the presence of small, striated, hooked, snake-like teeth. This fossil represents the first record of Halisaurinae from Egypt and the oldest occurrence of this group from northern Africa. Egyptian mosasaurids ranged in size from small-bodied (~3 to 4 m) Halisaurinae to medium-sized (~6 to 8 m) Mosasaurinae, and were similarly diverse in morphology. Tooth crowns range in shape from cones adapted to pierce and hold, to bulbous teeth adapted to crush, to cutting blades; jaw morphology is also diverse. The new elasmosaurid and mosasaurid remains from the Duwi Formation therefore reveal high taxonomic and functional diversity and elevated endemism in the uppermost Cretaceous marine reptile faunas of northeastern Africa.

Keywords: elasmosaurid; mosasaurid; duwi formation; campanian; Egypt

PREDICTING PATTERNS OF VERTEBRATE FOSSIL PRESERVATION USING VARIATION IN RATES OF STRATIGRAPHIC ACCUMULATION: A CASE STUDY IN A MAMMAL-RICH INLAND BASIN (WASHAKIE FORMATION, WY)

Melissa Wood[1]*
[1]Department of Geophysical Sciences, University of Chicago; ***Presenting author**

Paleontologists typically prospect for well-preserved, taxonomically identifiable fossils by seeking fine-grained floodplain deposits or other low-energy facies. However, predicting the specific beds among such deposits that will yield fossils ideal for the project at hand remains difficult. We hypothesized that the degree of fragmentation and abundance of fossils should vary with respect to rates of rock accumulation, determined by the supply of siliciclastic sediment into the basin and the basin's availability to store that sediment (accommodation). Settings with high rates of both accommodation and sediment supply would permit rapid burial and thus be most inclusive of large-bodied animals and articulated specimens, whereas

if accommodation is high but sediment supply is low, complete burial would occur less frequently, with only occasional preservation of small material expected. Low rates of accommodation should limit preservation potential regardless of sediment supply, given greater erosional reworking and fragmentation of deposited floodplain assemblages, and the only taxonomically identifiable material should be small, durable material. We tested this hypothesis using measured sections of the middle Eocene Washakie Formation in Wyoming (50-46 Ma). Relative changes in rates of accommodation (A) and sediment supply (S) were determined using lithologic evidence such as the frequency of lacustrine facies, multi-story sandstones, and mature paleosols. We find that the Washakie Fm. exhibits mostly high-A/low-S supply conditions in its basal Kinney Rim Member (KR), followed by high-A/high-S conditions during the lower and middle Adobe Town Members (AT1 and AT2), and a strong decrease in accommodation with moderate-high sediment supply in the upper Adobe Town Member (AT3). New material from pilot fieldwork in 2021 was combined with data from Field Museum collections to compare preservation. We found a strong pattern linked to this three-phase history of rock accumulation: several concentrated assemblages of exclusively small mammals in the KR, abundant large mammals and some articulated small mammals in the AT1 and AT2, and highly fragmented, sparsely distributed small mammals in the AT3. The rate of rock accumulation, rather than facies alone, plays a strong role in determining the composition and nature of mammal assemblages in this inland basin, providing insight for prospecting and understanding the occurrence of fossils in fluvial records.

Keywords: mammals; sequence stratigraphy; eocene

POLES APART: CENOZOIC SIZE DIFFERENTIATION OF HIGH LATITUDE BIVALVE FAUNAS

Amanda Doyle[1]*
[1]Department of Geophysical Sciences, University of Chicago; ***Presenting author**

Although regions at the same latitudes in different hemispheres are assumed to be (and, relative to different latitudes, generally are) quite similar in taxonomic, functional, and morphological diversity, the contrasting histories and configurations of the high latitudes might promote greater divergence in their trait diversity. Using global modern occurrences of bivalves, fossil polar bivalves from the Paleocene and Eocene, and presence/absence data for Miocene bivalves of Patagonia, analyses comparing size, functional groups, and taxonomic affiliation were performed. Modern Antarctic bivalves were found to be consistently smaller than Arctic bivalves, whether considering the whole fauna, species only from families present at both poles, species only from genera present at both poles, or species in the same pool of functional groups, though the differing family compositions of the two regions contributes somewhat to the size contrast. More broadly, bivalves from high temperate latitudes in the Northern Hemisphere did not differ significantly in size from tropical bivalves, whereas bivalves from the same latitudes of the Southern Hemisphere were far smaller than tropical bivalves and their northern counterparts. However, polar Paleocene and Eocene bivalves did not show any size differentiation and were not significantly different from modern Arctic bivalves. Meanwhile, a slight majority of globally extant genera now locally extinct in Patagonia - but present in the Miocene - were larger than their remaining Patagonian family members, potentially displaying an early point in the size-reduction of the southern high latitude bivalves. Although the precise drivers of size differentiation of high latitude bivalve faunas are still unclear, the consistent contrast in size between the hemispheres despite the cooling of both poles implies that there are pressures in the Southern Hemisphere favoring small bivalves that began in the early Neogene.

Keywords: paleobiology; high-latitude; biogeography; size; evolution

NETWORK-BASED BIOSTRATIGRAPHY FOR THE LATE PERMIAN-MID TRIASSIC BEAUFORT GROUP (KAROO SUPERGROUP) IN SOUTH AFRICA ENHANCES BIOZONE APPLICABILITY AND STRATIGRAPHIC CORRELATION

Pia A. Viglietti[1,2]*; Alexis, Rojas[3]; Martin, Rosvall[4]; Brady, Klimes[5]; Kenneth D. Angielczyk[1,2]
[1]Negaunee Integrative Research Center, Field Museum of Natural History; [2]Evolutionary Studies Institute, University of the Witwatersrand; [3]Department of Computer Science, University of Helsinki; [4]Integrated Science Lab, Department of Physics; [5]Roosevelt University; ***Presenting author**

The Beaufort Group vertebrate assemblage zones (AZs) of South Africa's Karoo Basin have become a standard for local and global correlations of Permo-Triassic strata. However, temporal, geographical and

methodological limitations challenge the reliability of these biostratigraphic units. We analyzed a unique fossil dataset comprising 1408 occurrences of 115 species grouped into 19 stratigraphic bin intervals spanning the Cistecephalus, Daptocephalus, Lystrosaurus declivis, and Cynognathus AZs. Using network science tools, we compare frameworks based on historical data (Broom, Rubidge) and modern schemes incorporating recent lithostratigraphic, chronostratigraphic (unconformities), radiometric, and paleontological information (Viglietti, Formation, Member). We also test an additional framework suggesting diachroneity of the Daptocephalus/Lystrosaurus AZ boundary (Gastaldo) to determine whether it is an improvement over other frameworks in the study. By modelling fossil occurrence data as bipartite networks, we demonstrate that historical frameworks still identify meaningful AZs and can be useful in corroborating frameworks that identify more unique Karoo Basin AZs. None support the Cistecephalus AZ, and it likely comprises two discrete communities. The Lystrosaurus declivis AZ is traced across all models, despite many shared species with the underlying Daptocephalus AZ. This suggests the extinction event across this interval is not a statistical artifact. An AZ shift with few shared species at the Katberg/Burgersdorp formation boundary may indicate a depositional hiatus. This has important implications for regional correlations, and Mesozoic ecosystem evolution. Analysis of meter-level occurrence data indicates that 20-50 m sampling intervals adequately capture Karoo AZs. Despite its different temporal groupings, the Gastaldo model still identifies the Lystrosaurus/Daptocephalus AZ shift, does not significantly improve recent AZ models (Viglietti), and highlights important issues with some AZ studies. Over-interpretation of localized bed-scale lithostratigraphy (sandstone datums), and singleton fossils cannot be used to reject patterns shown by hundreds of fossil specimens, and regional (> 100 km) chronostratigraphic markers of the Karoo foreland basin. Our results unify the use of meter-level placements of singleton fossils to delineate biozone boundaries, and improves Karoo AZ applicability for correlations across southern and eastern Africa, and globally.

Keywords: karoo basin; network analysis; permo-triassic; biostratigraphy

SESSION 4, ROOM B: BRAIN & BEHAVIOR
10:15pm – 3:15pm

PINEAL FORAMEN VARIATION AS A WINDOW INTO SENSORY EVOLUTION, CONVERGENCE OF MAMMAL-LIKE CRANIAL TRAITS, AND MAJOR LINEAGE DIVERGENCES IN PRE-MAMMALIAFORM SYNAPSIDA

Sarah Saxton Strassberg[1]*; Kenneth D. Angielczyk[2]; Christian R. Sidor[3]
[1]Committee on Evolutionary Biology, University of Chicago; [2]Negaunee Integrative Research Center, Field Museum; [3]Department of Biology, University of Washington; ***Presenting author**

Many pre-mammaliaform synapsids are inferred to have had a parietal eye based on the presence of a pineal foramen, although this structure disappeared independently in multiple therapsid and cynodont lineages. The morphology of the synapsid pineal foramen is highly variable, yet few studies address its morphological variation and disparity across the synapsid phylogeny as a whole, especially in relation to large-scale morphological changes that characterize the evolution of the mammalian cranium. For instance, convergent shifts to larger, more dorsally-oriented temporal fenestrae, evolution of the zygomatic arch, and narrowing of the intertemporal bar might have affected the size, shape, and/or location of the pineal foramen and the functionality of the parietal eye across multiple lineages. Addressing such questions could shed light on evolutionary pressures and mechanisms that contributed to independent losses of a seemingly valuable sensory structure and the evolution of increasingly mammal-like cranial traits. Here, we examine covariance between linear measurements of the pineal foramen and other dorsal skull features across Synapsida, and investigate whether major lineage divergences correlate with saltatory or clinal changes in pineal foramen and dorsal skull morphology. We find evidence of significant differences in pelycosaur and therapsid morphologies but more clinal variation among various therapsid lineages. We also find relatively strong phylogenetic signal in the placement of the pineal foramen along the sagittal axis of the skull (Pagel's lambda ranges from 0.753 to 0.790), which is indicative of this trait approaching a Brownian motion model of evolution. Intertemporal bar narrowing strongly correlates with lateral compression of the pineal foramen, which may signify decreased functionality or even vestigiality of the parietal eye. Such instances of pineal foramen reduction might indicate points on the synapsid phylogeny where the parietal eye became less important in sensory systems and circadian rhythm regulation and the functional benefits of larger jaw musculature were able to take precedence. Therefore, broad-scale morphological shifts toward mammal-like dorsal crania may have helped set the stage for convergent losses of the parietal eye, most notably in the ancestors of mammaliaforms.

Keywords: vertebrate paleontology; morphology; morphometrics; synapsids; sensory evolution

A MULTI-ISOTOPE RECONSTRUCTION OF TELEOCERAS MAJOR (MAMMALIA, THINOCEROTIDAE) MATING SYSTEM FROM ASHFALL FOSSIL BEDS STATE HISTORICAL PARK, NEBRASKA

Clark T Ward[1]*; Brooke E Crowley[1,2], Ross Secord[3,4]
[1]Department of Geosciences, University of Cincinnati; [2]Department of Anthropology, University of Cincinnati; [3]Department of Earth and Atmospheric Sciences, University of Nebraska- Lincoln; [4]University of Nebraska State Museum, University of Nebraska- Lincoln; ***Presenting author**

Modern rhinoceroses are highly endangered and studying fossil taxa are a non-invasive alternative to investigate the diversity of rhino behavior and ecology outside of human-dominated landscapes. Herding behavior is suggested in fossil taxa such as *Teleoceras*, but not observed in modern rhinos. Numerous skeletons (100+) of *Teleoceras major* are preserved in a mid-Miocene (11.93 ± 0.13 Ma) volcanic ash lens at Ashfall Fossil Beds State Historical Park, Nebraska. We are using stable carbon ($\delta^{13}C$), oxygen ($\delta^{18}O$), and strontium isotopes ($^{87}Sr/^{86}Sr$) of bulk second and third lower molar (M_2 and M_3, respectively) enamel from Ashfall *T. major* to reconstruct the foraging ecology and landscape use before and after cow-calf separation. Depending on sexual segregation and mating system, these ecological shifts would have been similar or different for male and female individuals. If they did herd, we would expect to find similar isotopic trends for females but variable trends for males (reflecting their individual life histories), and if this species was solitary, then all life histories should be independent. Here, we present preliminary isotopic results of M_2's and M_3's from six individuals (three males and three females). All females show similar positive shifts

from M_2 to M_3 for all three isotopes. Males also show positive shifts in $\delta^{13}C$ and $\delta^{18}O$ but they have higher $\delta^{13}C$ values and a larger $\delta^{18}O$ shift than females. Males also have negative shifts in $^{87}Sr/^{86}Sr$, opposite of females. These results suggest females shared a maternal herd, while males aged unrelated to these females' herd. These results are promising, but it is unknown how seasonal changes from M_2 to M_3 formation affect these isotopic results. Future work includes analyzing additional bulk and new serial samples from this population to further resolve seasonal and developmental ecological changes.

Keywords: behavior; herding; mating system; rhinocerotidae; stable isotope ecology

SINKING OUR TEETH IN: RECORDS OF CARNIVORAN MODIFICATION ON BONES OF SMALL PREY

Madison Gaetano[1]*; Joshua Miller[2]; Eric Wald[3]; Patrick Druckenmiller[1]
[1]Department of Geology, University of Cincinnati; [2]U.S Fish and Wildlife Service; [3]University of Alaska Museum; ***Presenting author**

Carnivore modification on bones provide some of the only paleobiological proxies for predator- and scavenger-prey interactions. However, species interactions can be difficult to interpret from bone accumulations because not every predation event is recorded on prey bones. Furthermore, carnivore modification of smaller-bodied prey can be underrepresented because those bones are more likely to be entirely destroyed. To test the fidelity with which carnivore modification records known predator-prey dynamics for prey with easily modified bones, we evaluated carnivore modification on the bones of caribou (Rangifer tarandus) calves from the Arctic National Wildlife Refuge, AK. Calf bones were collected using standardized taphonomic surveys from 2010-2018. Each of the recovered calf bones (NISP = 435) was visually inspected for modification traces left by carnivores (mammalian and avian) and rodents. We then compared the frequencies of observed mammalian and avian bone modification (summarized by MNI and NISP) to observations (1983-2001) of carnivore activity on caribou calves on the Arctic Refuge. Available records indicate that the dominate predator of caribou calves was golden eagles (Aquila chrysaetos: 37% of calf mortalities annually), followed by brown bears (Ursus arctos) and wolves (Canis lupus), which were responsible for a combined 24% of mortalities. 39% of calf deaths were not predator related. We found that 18% of calf MNI recorded modification by avian predators, 35% by mammalian carnivores, and 55% were unmodified. Thus, avian modification is significantly underrepresented ($P < 0.01$). While 9% of calf MNI recorded both mammalian and raptor modification, co-occurrence was never observed on the same bone element. Discrepancies between observed calf predation and bone modification can be accounted for by differences in bone destructive by golden eagles relative to bears and wolves. The incongruence could also be attributed to high incidence of mammalian scavenging, as bite marks from active carnivory are difficult to distinguish from those produced during scavenging. Rodent modification is not present on any calf material, despite the high local abundances of microtine rodents. Carnivore modification of caribou calf bones are biased towards mammalian carnivores. Thus, paleobiological studies of prey seem unlikely to faithfully characterize predation patterns, at least for small and easily modified (neonatal) bones.

Keywords: taphonomy; ungulate; prey

THREE-DIMENSIONAL BRAIN SOFT-TISSUE PRESEVATION IN LATE PALEOZOIC ACTINOPTERYGIANS FROM BRAZIL INFORMS THE EVOLUTION OF THE RAY-FINNED FISH BRAIN

Rodrigo T. Figueroa[1]*; Matt Friedman[1,2]
[1]Department of Earth and Environmental Sciences, University of Michigan; [2]Museum of Paleontology, University of Michigan; ***Presenting author**

The understanding of the evolution within the animal fossil record is mostly restricted to hard-parts such as the exo- and endoskeleton of vertebrates and invertebrates. Exceptional fossil preservation however is informative on the diversity of soft-bodied animals as well as providing additional information regarding organisms that are otherwise only known from hard parts. Neural tissues are not common in the fossil record, but there are reports of brain and nerves for several groups, ranging from cambrian arthropods to Carboniferous chondrichthyans. These examples provide valuable information on brain evolution in deep time that could otherwise be only accessed through indirect approaches (e.g. natural and virtual endocasts of vertebrates). The knowledge on ray-finned fish brain evolution is so far limited to inferences from fossil

endocasts and information available in living lineages, which—despite being informative—provide only an indirect understanding of the evolution of the brain in the stem group. Here we describe the occurrence of Carboniferous-Permian actinopterygian brains from southern Brazil, found in the Lontras Shale unit of the Campo Mourão Formation in the Paraná Basin. Through micro-computed tomography (μ-CT) of these fossils it was possible to extract three-dimensional models of the brains of at least two species of early actinopterygians, based on osteological characters. These brains are bilaterally symmetrical and show clear differentiation in forebrain, midbrain and hindbrain, as well as showing several cranial nerves, some of which are piercing the cranial cavity through foramina. The gross morphology of these brains is consistent with the expectation for a stem actinopterygian—based on knowledge from extant taxa—but some features of these fossil brains challenge current interpretations of actinopterygian brain evolution. This includes a distinct hypothalamic inferior lobe, which is restricted to actinopterans (i.e., crown ray-finned fishes to the exclusion of polypterids) among living species. Other unexpected characteristics include variation in the complexity of rhombencephalic meningeal tissues. Most appear like those of Polypterus, but one specimen shows a well-developed myelencephalic gland similar in shape and positioning to that of the holostean Lepisosteus. Other similarities to Polypterus include the absence of intraventricular projections (e.g., torus longitudinalis and semicircularis) within the mesencephalon, which are only known in extant actinopterans. Thus, our results demonstrate that these fossil brains exhibit a mosaic of characteristics expected for early ray-finned fishes. The presence of unexpected features in these fossil brains more closely resembling actinopterans and holosteans challenges the use of Polypterus as a model for early ray-finned fish brain evolution.

Keywords: neuroanatomy; cranial nerves; Actinopterygii; actinopteri; polypterus

SESSION 1, ROOM LH2: ONTOGENY & DEVELOPMENT
9:00am – 10:00am

THE SIGNIFICANCE OF MULTI-LAGS IN CORTICAL BONE INFERRED FROM A LARGE HISTOLOGICAL SAMPLE OF THE THEROPOD DINOSAUR ALLOSAURUS

Riley Sombathy[1]*; Michael D'Emic[2]
[1]Department of Biological Sciences, Ohio University; [2]Department of Biology, Adelphi University; ***Presenting author**

In paleohistology, a line of arrested growth (LAG) is recognized as a thin ring in cortical bone that represents a temporary cessation of tissue apposition. LAGs are hormonally entrained features that record the circumference of an element during what generally corresponds to a season of resource scarcity. LAGs are not always single rings but can be made up of multiple rings that sometimes diverge along their path around the bone, bounding thin deposits of interstitial tissue that have reduced or absent vascularity and cellularity. These anomalous LAGs are commonly referred to as 'double LAGs', 'triple LAGs', 'supernumerary LAGs', all of which we refer to as 'multi-LAGs'. Multi-LAGs have been reported in a wide variety of vertebrates, including extinct and extant mammals, squamates, amphibians, and archosaurs, including birds. The handful of studies that have focused on multi-LAGs have tentatively linked their presence to the attainment of sexual maturity, hibernation, or migration, but their precise cause remains unknown. To better understand the distribution and causes of multi–LAGs, we investigated their presence in the Jurassic theropod dinosaur Allosaurus. The sample consists of 12 femora and three tibiae, all from different individuals. We inferred growth models from age-body mass estimates for each specimen using nonlinear regression. Specimens in the dataset had a 20-fold variation in estimated body mass at the time of death, 6.5-fold variation in estimated asymptotic body mass, threefold variation in estimated longevity, and were recovered across 5° of paleolatitude. In total, nearly 150 LAGs were traced, with 23 (16%) of them being multi-LAGs. Of the 23 multi-LAGs, 16 are double LAGs (70%), six are triple LAGs (26%), and one is a quadruple LAG (4%). Paleolatitude, perhaps a proxy for environmental differences over the ~550 km north-south transect represented in the dataset, had no relationship with the presence or number multi-LAGs nor the number of sub-rings within multi-LAGs. Asymptotic body mass, body mass at the time of death, and age at death (i.e., longevity) were likewise uncorrelated with the presence or number of multi-LAGs. Stochastic environmental factors may underlie the development of multi-LAGs in Allosaurus; alternately, hidden taxonomic or sex-specific differences may be revealed to explain their development upon sampling of a larger dataset.

Keywords: paleohistology; allosaurus; histology; jurassic; theropoda

THE IMPORTANCE OF ONTOGENY AND PHYLOGENY IN EVALUATING BODY SIZE CHANGE IN THE FOSSIL RECORD: A CASE STUDY OF LYSTROSAURUS (THERAPSIDA, ANOMODONTIA) IN THE KAROO BASIN, SOUTH AFRICA

Caroline P Abbott[1]*; Mark Webster[2]; Kenneth D Angielczyk[3]
[1]Committee on Evolutionary Biology, University of Chicago; [2]Department of Geophysical Sciences, University of Chicago; [3]Negaunee Integrative Research Center, Field Museum of Natural History; ***Presenting author**

Patterns of body size change, such as Cope's Rule, Bergman's Rule, Foster's Rule, and the Lilliput Effect, are widely recognized in the fossil record. However, despite the large body of work on body size trends, there is little consensus on the mechanistic underpinnings of these patterns. Existing approaches, including heterochronic frameworks and phylogenetic comparative methods, provide ways to investigate the mechanisms of body size evolution. The age-size-shape space developed by Pere Alberch and colleagues is especially relevant and provides the means to quantify body size and other aspects of phenotype, and to compare ontogenetic trajectories between taxa. Furthermore, evolutionary patterns of body size change cannot be properly evaluated without a robust phylogeny because clade-level patterns of size change only make sense in a stemward-crownward context. Many studies of fossil body size change utilize stratigraphy alone to evaluate the polarity of changes in size, but apparent patterns of size change can look entirely different in the context of a phylogeny. An excellent example of these issues is the therapsid genus Lystrosaurus, an abundant, widespread taxon that lived during the End Permian Mass Extinction (EPME). In the past decade, Lystrosaurus has been recognized as an example of the Lilliput Effect, a pattern of size decrease during mass extinctions. In addition to a stark decrease in average body size, Triassic individuals

appear to be developmentally younger than equivalently-sized Permian counterparts based on bone histology. In a purely stratigraphic context, it appears that Lystrosaurus gets smaller during the EPME, but the current phylogeny implies that Triassic and Permian species diverged before the EPME from a small ancestor. Lystrosaurus species boundaries are notoriously contentious, however, so additional taxonomic and phylogenetic work is needed to ensure that patterns of size change are reconstructed accurately. Furthermore, patterns of size change need ontogenetic context. Although we have relevant data regarding size and age, further data are needed to appropriately relate measures of ontogenetic shape change to age and size. Without these data, the mechanisms driving size change, including ontogeny, species sorting, and taphonomic bias, cannot be identified.

Keywords: synapsid; permo-triassic; extinction; body size; macroevolution

ONTOGENY AS AN EVOLUTIONARY CONSTRAINT AND SOURCE OF NEOMORPHISM WITHIN THE EARLY CAMBRIAN TRILOBITE GENUS *ZACANTHOPSIS*

Reuben Y. Ng[1]*; Mark Webster[1]
[1]Department of Geophysical Sciences, University of Chicago; ***Presenting author**

Ontogenetic allometry may act as a line of evolutionary least resistance, constraining and channelling phenotypic evolution to a morphological trajectory established by an ancestral ontogeny. Alternatively, ontogenetic allometry may itself be repatterned, generating neomorphisms and novel allometries. Whether and how macroevolutionary dynamics are influenced, or even driven, by constraint and release of ontogenetic allometries remains incompletely explored. Here, we characterize the diversity of ontogenies within the Cambrian trilobite genus Zacanthopsis using geometric morphometrics. Ontogenies are examined in the context of a novel phylogenetic hypothesis which includes previously undescribed species. With this hypothesis of evolutionary relationship, morphology can be compared in a phylomorphospace. In turn, this may be translated into a phyloallometryspace in which the evolution of ontogeny itself is readily explored. A clear image of the diversity and phylogenetic distribution of both morphology and ontogeny permits powerful insight into the temporal and phylogenetic persistence of allometric patterns as well as any influence they may exert on the evolutionary structure of disparity within Zacanthopsis. The ways in which ontogenetic allometry may serve to constrain evolution are contrasted with the modes by which modification to allometry can propel evolution in unexpected phenotypic directions. Careful understanding of the dynamics of developmental constraint and release in this early metazoan radiation contributes to the larger macroevolutionary picture of the evolution of developmental systems through deep time.

Keywords: developmental constraints; ontogeny; allometry; trilobites; morphometrics

MINERAL METABOLISM AND THE ORIGIN OF CELLULAR BONE

Yara Haridy[1]*
[1]Department of Organismal Biology and Anatomy, University of Chicago; ***Presenting author**

Bone is a living and regenerative tissue that is capable of growth, adaptation, and healing. These functions are a major driver in the evolution of vertebrates and make the vertebrate skeleton unique and much more dynamic in its physiology than that of invertebrates. Many of the functions ascribed to bone tissue are due to the internalized cellular system known as the lacunocanalicular network (LCN), which houses entrapped osteocytes and their many cellular processes. The LCN is a highly interconnected network whose interconnectivity is unparalleled except by the neuronal network. Medical studies attribute various physiological roles to osteocytes, including bone remodeling, mechano-sensation, and mineral homeostasis. Given these critical physiological roles, it is intriguing that the earliest bone to appear in vertebrate evolution is the anosteocytic (lacking osteocytes) bone of jawless heterostracans. Nothing is known of the evolutionary conditions that led to the origin of osteocytes or the initial functions and benefits of osteocytes. Studying the earliest bone cells has been hampered by methodological limitations that preclude resolution of the LCN's complex 3D nature or that have been unable to achieve cell-process-level resolution in fossil material. To produce high-resolution 3D images of the earliest osteocytes, I apply focused ion beam–scanning electron microscopy (FIB-SEM) tomography in concert with machine learning for cell detection and segmentation to image cell spaces in osteostracans. This novel application resolves

areas of low density around osteocyte lacunae and their canaliculi in osteostracan bone. This provides evidence for demineralization that would have occurred in vivo as part of osteocytic osteolysis, a known mechanism of mineral homeostasis and one of the key roles of osteocytes in extant vertebrates. Heterostracans' anosteocytic bone, lacking a LCN, was inherently unable to metabolize its mineral composition as efficiently as their co-occurring osteostracans. Therefore, the novel evidence for mineral metabolism in osteostracans strongly supports the hypothesis that a physiological demand for phosphorus was the principal driver in the initial evolution of osteocytic bone in osteostracans and potentially facilitated their success and the subsequent retention of osteocytic bone in vertebrates.

Keywords: histology; cell evolution; FIB-SEM; bone; osteostracans

SESSION 2, ROOM LH2: FUNCTIONAL MORPHOLOGY 1
10:30am – 11:15am

A NEW LUNGFISH (SARCOPTERYGII: DIPNOI) FROM THE LATE DEVONIAN (FRASNIAN) FRAM FORMATION, NUNAVUT, CANADA

Rafael A. Rivero-Vega[1,2*], Edward B. Daeschler[3], Matthew Friedman[1,2]
1University of Michigan Museum of Paleontology, University of Michigan; 2Department of Earth and Environmental Sciences, University of Michigan; 3Department of Vertebrate Biology, Academy of Natural Sciences of Drexel University

Expeditions to the NV2k17 locality, Late Devonian (Frasnian) Fram Formation of Ellesmere Island, Nunavut, Canada have uncovered an ecosystem consisting of placoderms, porolepiforms, tetrapodomorphs, and dipnoans. This assemblage bears a striking similarity to the Upper Devonian (Frasnian) Escuminac Formation of Miguasha, Quebec, Canada with one major difference—the most abundant lungfish in the Escuminac is Scaumenacia curta, whereas it appears to be completely absent from the Fram Formation. In its place is a new species described here. We diagnose this new lungfish using the E bones scalloped laterally by the 'M' and 'L2' bones, elongated heptagonal 'B' bone with a small anterior projection, expansive pustular and vermiform ornamentation that extends to the anterior portion of C bone and becomes more pronounced laterally, and the much larger body length of approximately one meter. Additional material is also used to enhance the description, including various skull roofs, incomplete lower jaw elements, opercula, shoulder girdle, and an articulated postcranial skeleton, among an assortment of other smaller bones. This articulated specimen allows for further comparison with material previously available for Scaumenacia, discussion of its place in the general ecosystem of the Fram Formation, and adds a new lens with which to examine the diversity of Late Devonian lungfishes.

TESTING THE ROLE OF BIOTIC INTERACTION IN SHAPING TAXONOMIC, MORPHOLOGICAL, AND FUNCTIONAL DIVERSITY IN ANOMALODESMATAN BIVALVES

Yue Deng[1*]
[1]Department of Geophysical Sciences, University of Chicago; ***Presenting author**

Bivalve sister clades Anomalodesmata (Anomalos) and Imparidentia (Imparis) exhibit contrasting diversity trajectories from their divergence in the Ordovician to the present, potentially indicating clade interactions. Within-clade competition may lead to diversity dependence; competition, incumbency, or predation may lead to elevated extinction or depressed origination rates; and environmental perturbations can also drive extinction. In this study I test for the roles of within-clade interactions and negative interactions with its sister clade and predators on the diversity pattern of Anomalos. Anomalos and Imparis dynamics show the most significant correlations in the Mesozoic, with positive correlations of origination of each group with extinction rates of the other. The Mid Triassic marks a dramatic transition as Imparis diversify strongly while Anomalos show only modest diversification through the Mesozoic. Within Anomalos, lineages that have adopted novel food sources or substrata may show a different dynamic from those resembling Imparis, potentially reflecting interactions among Anomalo lineages, between Anomalos and Imparis, with predators, or some combination. More work is needed to identify the exact relationship between these two ecological groups of Anomalos and their respective relationship with Imparis, but the fact that Anomalos achieved net diversification rates in the Cenozoic more than 4 times higher than in the Mesozoic and similar to Cenozoic Imparis suggests evasion from negative interactions. I also expect morphological disparity to reflect interactions or evasion from interactions. In a preliminary morphospace comparison between Jurassic and living Anomalos using shell outlines, Anomalos appear to occupy smaller morphospace volume today than in Jurassic despite almost double the diversity. The Anomalos groups that adopted novel feeding or substratum ecology appear to expand in the morphospace, whereas the rest appear to shrink or stay constant, again suggesting evasion from negative interactions–both within Anomalos and among clades (including predators).

Keywords: bivalvia; anomalodesmata; origination; extinction; biotic interaction

USING COMPARATIVE FUNCTIONAL MORPHOLOGY TO RECONSTRUCT LOCOMOTION IN THE CRETACEUOUS BIRD ICHTHYORNIS (AVIALAE: ORNITHURAE)

Talia Lowi-Merri[1]*; Oliver E. Demuth[2]; Daniel J. Field[2]; Roger Benson[3]; Santiago Claramunt[1]; David C. Evans[1]

[1]University of Toronto; [2]University of Cambridge; [3]University of Oxford; ***Presenting author**

The evolution of flight was a critical aspect to the success of modern birds (Neornithes) after the K/Pg extinction, and the avian skeleton shows unique adaptations to flight styles and other locomotory ecologies. Functional morphological traits, especially in features of the pectoral and pelvic girdles, show statistically robust associations with locomotory styles, such as soaring, burst flight, and foot-propelled diving, and these extant form-function relationships provide the opportunity to estimate locomotory modes in extinct taxa. The fossil bird Ichthyornis (Avialae: Ornithurae), found in Late Cretaceous shallow-water marine sediments of North America, has been hypothesized to be a volant seabird, similar to modern terns or gulls. While certain skeletal features in Ichthyornis have been noted to resemble diving bird adaptations, rigorous quantitative testing of locomotory hypotheses in Ichthyornis have yet to be performed. Here, we provide the first whole-skeleton morphometric analysis of Ichthyornis to test hypotheses on its locomotory ecology. We performed a 3D geometric morphometric analysis on the sternum, as well as a linear morphometric analysis of measurements across the entire skeleton of Ichthyornis and a broad phylogenetic scope of ecologically diverse Neornithine taxa. Locomotory variables associated with morphology were identified using a Procrustes distance-based phylogenetic generalized least squares approach, and presence of locomotory traits were estimated in Ichthyornis using a phylogenetic flexible discriminant analysis. We find strong support for Ichthyornis being both a soarer and foot-propelled underwater diver, as indicated by its sternal morphology, which is similar to the extant darter (Anhinga anhinga: Suliformes). We also find that the sternum alone provides much greater predictive power for locomotory mode than overall skeletal proportions. Our study is the first detailed statistical analysis of Ichthyornis' locomotory ecology, and suggests an earlier origin of foot-propelled diving in birds than previously estimated. Further, these results underscore the importance of sternal morphology in the origin and evolution of flight across the dinosaur-bird transition, and suggest that functional ecological traits may require more complex characterization than discrete categories have allowed.

Keywords: functional morphology; ecomorphology; geometric morphometrics; discriminant analysis

SESSION 3, ROOM LH2: FUNCTIONAL MORPHOLOGY 2
12:45pm – 1:45pm

EVALUATING DIETARY DIVERSITY IN THE TRIBOSPHENIC DENTITION: ANALYSIS OF SIMPLE LINEAR MEASUREMENTS DISTINGUISH PRIMARY AND SECONDARY DIET TYPES IN EXTANT TAXA

Henry Z. Fulghum[1]*; P. David Polly[1]
[1]Department of Earth and Atmospheric Sciences, Indiana University

The evolution of the tribosphenic molar is considered a landmark event in mammalian history. As the foundation from which all therian dental specializations have evolved, the functional morphology of this ancestral dental system is essential to our understanding of the pattern and timing of mammalian evolution and ecological diversification. However, most paleobiological studies have assessed the form-function relationship in Mesozoic groups based on proxies from select, archetypal extant taxa (e.g., possums, tree shrews). Thus, the true breadth of dietary ecology and associated dental specializations in modern tribosphenic mammals remains unclear. Therefore, to better infer the dietary radiation of Mesozoic mammals, it is critical to establish a greater understanding of the dental functional morphology of modern tribosphenic mammals. Here we test a set of simple indices of dental functional morphology for use in dietary prediction. Nine linear measurements capturing key functional aspects of tooth shape (e.g., grinding basin area, length of shearing surfaces) were taken from the penultimate lower molar of 55 modern tribosphenic taxa. Primary and secondary dietary categories were assigned to each taxon. We used a combination of multivariate methods, including MANOVA, linear discriminant analysis (LDA), and principal component analysis (PCA), in concert with the machine learning technique of regression trees to assess which functional measurements might best serve as a proxy for diet. While primary diet was a partial predictor of tooth morphology, secondary diet was an important discriminator in both the regression tree and MANOVA, especially cristid obliqua and paracristid length, and hypoflexid width. The post-hoc analysis of our MANOVA returned a significant difference of means for 5/15 (33%) of our pairwise comparisons of dietary categories. Notably, our measurement scheme reliably distinguishes between “carnivore” and “insectivore with vertebrate supplement”, and “frugivore” and “insectivore with fruit supplement” dietary categories, with cristid obliqua and maximum molar length being the greatest factors. As the departure from strictly insectivorous ecologies is central to mammalian diversification during the Mesozoic, understanding the components that distinguish insectivory from other dietary categories is essential to interpretations of mammalian evolution and dietary radiation.

Keywords: functional morphology; dietary categorization; tribosphenic; theria

A NEW DRYOLESTOID SPECIMEN FROM THE LATE JURASSIC PROVIDES NEW INSIGHTS ON THE SIGNIFICANCE OF TOOTH ROOT STRUCTURE THROUGHOUT MAMMAL HISTORY

Isaac Magallanes[1,2]*; K. Christopher Beard[3,4]; Zhe-Xi Luo[5]
[1]Committee on Evolutionary Biology, University of Chicago; [2]Field Museum of Natural History; [3]Biodiversity Institute, University of Kansas; [4]Natural History Museum, University of Kansas; [5]Department of Organismal Biology and Anatomy, University of Chicago; ***Presenting author**

Dryolestidan mammals are diverse with a wide distribution in the Jurassic and Cretaceous on the Laurasian continents, plus Africa. They are diagnosed by derived dental characters, including high molar counts (up to nine lower molars), zalambdodont-like upper molars, and lower molars with a single cusp on the talonid “heel.” Some dryolestidans also exhibit a derived morphology of lower molar roots: the mesial root is larger and more expanded mesiodistally than the simple and smaller distal root. Here we report on a new dryolestid specimen (KUVP 134101) from the Late Jurassic Morrison Formation in Wyoming, USA that we tentatively refer to Laolestes eminens. CT visualization of this new specimen revealed new patterns of variation in the molar roots. From p4 to m6, the mesial root for each tooth is greater than the distal root in diameter and length. In m2-m6, the mesial root is kidney-shaped in cross-section with a concave internal face; it envelops the distal root. In lateral view, the tooth roots in the mandible also change their angle consistently from being posteriorly directed in the p3-p4, to nearly vertical in m1-m4, and anteriorly oriented in m5-m6. These new observations in KUVP 134101 prompted us to employ a morphometric approach to examine tooth roots in modern and fossil mammals, and to explore their functional significance across evolutionary timescales. To date, the evolution and functional morphology of molar crowns have been

examined extensively for early mammals, including dryolestids. Key innovations like the precise occlusion of upper and lower molars, and the evolution of tribosphenic molars are two examples of how changes in dental and jaw morphology can increase biomechanical efficiency in mastication and facilitate more versatile feeding adaptations. However, few studies have focused on the evolution of the tooth roots or have investigated the functional relationship between the tooth crowns, roots, and jaws. We made measurements of the tooth roots associated with biomechanical function in modern didelphids. Our pilot results recovered consistent gradients in shape and orientation of the tooth roots from the anterior to posterior end of the mandible in modern didelphids. These patterns have functional implications and can be compared to those found in dryolestidans. Therefore, variance in tooth roots across evolutionary timescales can be useful for testing hypotheses of functional evolution of roots in early mammals.

Keywords: vertebrate paleontology; mammals; teeth; evolution

TEMPO AND MODE IN THE EVOLUTION OF PRIMATE DENTAL MORPHOLOGY

Laura E Hunter[1]*; Anna L Wisniewski[2]
[1]Department of Organismal Biology and Anatomy, University of Chicago; [2]Department of Geophysical Sciences, University of Chicago;
***Presenting author**

Primate dental morphology is highly correlated with diet across the over 400 species alive today, allowing paleontologists to make inferences about the ecology of taxa for which little else is known. Armed with such data it becomes possible to test hypotheses about tempo and mode in ecomorphological evolution, such as early burst adaptive radiation. To explore the evolutionary history of tooth morphology, and by extension diet, across the order Primates, we measured the occlusal surface complexity of the second mandibular molars of 100 extinct and 140 extant species, representing all major taxonomic groups. Using a phylogenetic tree of living and extinct primates, we compared a series of evolutionary models to characterize the tempo and mode of primate dental evolution. When simple models of continuous trait evolution are considered, a single stationary peak Ornstein-Uhlenbeck receives the most model support. However, we also explore if relaxing model assumptions and allowing for multiple adaptive peaks suggests a more complex adaptive landscape for primate dental morphology.

Keywords: primates; dentition; diet; macroevolution; phylogenetic comparative methods

SESSION 4, ROOM LH2: FUNCTIONAL MORPHOLOGY 3
2:15pm – 3:00pm

UNEARTHING THE INFLUENCES OF BODY SIZE, ECOLOGY, AND PHYLOGENY IN THE CLAW MORPHOLOGY OF DIGGING ANIMALS

Mallory Ayersman[1]*; Kenneth D Angielczyk[2]; Stephanie M Smith[2]; E. Hartrich Zack[3]
[1]DePaul University; [2]Negaunee Integrative Research Center, Field Museum of Natural History; [3]Department of Organismal Biology and Anatomy, University of Chicago; ***Presenting author**

Fossoriality is a common behavioral trait among an ecologically and phylogenetically diverse range of mammals. Digging in mammals has been studied in both behavioral and morphological contexts. These studies have examined skeletal indicators of digging and focused on functional implications of claw, digit, and forelimb morphologies. Although fossoriality is common in mammals, few studies have examined the interplay between phylogenetic, functional, and body size controls on relative claw size and shape. To understand how claw shape relates to these factors, we used photogrammetry to collect size and shape data on the claws of 55 specimens of eulipotyphlans, afrosoricids, rodents, xenarthrans, and carnivorans from the zoological collections at the Field Museum of Natural History. We created models of the keratinous sheath on the third digit of the manus for mesh-based spherical harmonic (SPHARM) geometric morphometrics. Digging carnivorans have relatively smaller, laterally-compressed claws with strong curvature, whereas fully subterranean eulipotyphlan moles have broad, dorsoventrally-flattened claws. Chrysochlorids (Afrosoricidae) have dorsoventrally deep, robust claws which are distinct from those of eulipotyphlan moles, even though chrysochlorids are also subterranean. Xenarthrans tend to have deep claws with varying degrees of curvature. Digging deeper into the data, we hope to elucidate how much the functional capabilities of these claw shapes differ, and to assess the possibility of many-to-one mapping for differently shaped claws in animals with similar ecologies but different phylogenetic histories.

Keywords: ecology; phylogeny; morphology; photogrammetry; mammals

FROM FAIRIES TO GIANTS: UNTANGLING THE EFFECTS OF BODY SIZE, PHYLOGENY, AND ECOLOGY ON VERTEBRAL BONE MICROSTRUCTURE OF XENARTHRAN MAMMALS

E. Hartrich Zack[1]*; Stephanie M. Smith[2]; Kenneth D. Angielczyk[2]
[1]Department of Organismal Biology and Anatomy, University of Chicago; [2]Negaunee Integrative Research Center, Field Museum; ***Presenting author**

Trabecular bone is a spongy bone tissue that serves as a scaffolding-like support inside many skeletal elements. Previous research found allometric variation in some aspects of trabecular bone architecture (TBA) and bone microstructure, whereas others scale isometrically. However, most of these studies examined very wide size and phylogenetic ranges or focused exclusively on primates or lab mice. We examined the impact of body size on TBA across a smaller size range in the mammalian clade Xenarthra (sloths, armadillos, anteaters). We µCT-scanned the last six presacral vertebrae of 23 xenarthran specimens (body mass 120g-35kg). We collected ten gross-morphology measurements and seven TBA metrics and analyzed them using phylogenetic and non-phylogenetic methods. Most metrics had similar allometries to previous work. However, because ecology and phylogeny align closely in Xenarthra, the phylogenetic methods likely removed some covariance due to ecology; clarifying the impact of ecology on TBA in xenarthrans requires further work. Regressions for Folivora had high p-values and low R-squared values indicating that the extant sloth sample either is too limited to determine patterns or that the unique way sloths load their vertebral columns causes unusually high TBA variation. The southern three banded armadillo sits far below the regression lines, which may be related to its ability to roll into a ball. Body size, phylogeny, and ecology impact xenarthran TBA, but parsing these effects is highly complex.

Keywords: functional morphology; trabecular bone; phenotypic plasticity; xenarthra; vertebrae

ACETABULAR ORIENTATION, PELVIC SHAPE, AND THE EVOLUTION OF HOMININ BIPEDALITY

Austin B. Lawrence[1]*; Ashley S. Hammond[2,3]; Carol V. Ward[1]
[1]Department of Pathology and Anatomical Sciences, University of Missouri; [2]Division of Anthropology, American Museum of Natural History; [3]New York Consortium in Evolutionary Primatology; ***Presenting author**

Hominin pelvic form differs dramatically from that of other primates by having more laterally facing iliac blades, a wider sacrum and a larger, transversely broad pelvic inlet. The orientation of the acetabulum may also differ, plausibly related to differences in load transmission during habitual bipedal posture and locomotion, which may, in turn, affect overall pelvic geometry. We compared acetabular orientation in humans, extant anthropoid primates, and fossil hominins including Australopithecus afarensis (A.L. 288-1, KSD-VP-1/1), A. africanus (Sts 14), A. sediba (MH 2), and the Kebara 2 Neanderthal. We measured the 3D orientation of the acetabulum on in silico models of individual hipbones aligned to the median plane by registering models to landmark coordinates that had been collected on articulated pelves. We fit a plane to the acetabular rim and measured its orientation relative to the median plane, a plane on the lumbosacral joint, and a third plane orthogonal to both the median and lumbosacral planes ("orthogonal comparative plane"). Differences in acetabular orientation among taxonomic groups were evaluated using multivariate analysis of variance and visualized in ternary space. Humans and fossil hominins exhibit significantly more ventrally and caudally opening acetabula than non-hominin anthropoids, which exhibit more laterally facing acetabula. Kebara 2 has less ventrally oriented acetabula than other hominins in our sample. The similarity in acetabular orientation of humans and Australopithecus despite differences in hip joint size, pelvic inlet breadth and iliac morphology, possibly suggesting that hip joint orientation is independent of these other aspects of pelvic form. These results suggest that the orientation of the acetabulum is a key component in the suite of pelvic characteristics related to habitual bipedality in hominins and should be considered in future analyses of hominin pelvic morphology.

Keywords: human evolution; functional morphology; locomotion; joints; hip

POSTER SESSION, ROOM A
3:15pm – 5:00pm

BROAD COMPARATIVE ANALYSIS OF TYRANNOSAUROID CRANIAL STRESSES AND BITE PERFORMANCE THROUGH MUSCLE FORCE RECONSTRUCTION AND FINITE ELEMENT ANALYSIS

Evan Johnson-Ransom[1]*; Feng Li[2]; Xing Xu[3]; Adam J Midzuk[4]; Ulrike Thon[5]; Eric Snively[6]
[1]Department of Organismal Anatomy and Biology, University of Chicago; [2]Tianjin Natural History Museum; [3]Institute of Vertebrate Paleontology and Paleoanthropology; [4]University of the Witwatersrand, Johannesburg; [5]Mannheim University of Applied Sciences; [6]Oklahoma State University College of Osteopathic Medicine at the Cherokee Nation; ***Presenting author**

Adult Tyrannosaurus exerted a bone-splintering bite force between 35,000 and 60,000 Newtons, delivered via a cranium strengthened with fused nasals, a secondary palate, and functional akinesis. A few studies have explored feeding adaptations of other tyrannosaurids, but none has addressed cranial performance and inferred feeding behavior across the larger clade Tyrannosauroidea, including early-diverging tyrannosauroids (Dilong, Proceratosaurus, and Yutyrannus). Here we broadly assessed the cranial performance and feeding function of various tyrannosauroids to investigate the evolution of feeding behavior in Tyrannosauroidea through muscle force reconstruction and finite element analysis. We analyzed several tyrannosauroids of variable body size, including (smallest to largest): Proceratosaurus, Dilong, Raptorex, Alioramus, juvenile Tyrannosaurus, Teratophoneus, and adult Tyrannosaurus. New muscle forces for tyrannosauroid specimens were scaled from relative subtemporal fenestra areas, and forces of individual muscles already calculated for tyrannosaurine specimens of similar body sizes. Finite element analysis was used to quantify and evaluate cranial stresses of an anterior bite in tyrannosauroids, derived from modeled 3D geometry, Alligator skull material properties, and the calculated muscles forces. Jaw muscle forces scaled predictably with increasing size in tyrannosauroids and in Tyrannosaurus and close relatives. The juvenile tyrannosaurid Raptorex had greater calculated muscle forces and experienced greater cranial stress than similarly sized earlier tyrannosauroids (Proceratosaurus, Dilong). This suggests that the juvenile condition of more derived tyrannosauroids delivered greater bite forces than small, early tyrannosauroids. While at similar body sizes, the juvenile Tyrannosaurus demonstrated relatively higher jaw muscle force than Alioramus and the early deep-snouted tyrannosaurine Teratophoneus. Deep-snouted tyrannosauroids exhibited relatively lower cranial stress than present in gracile-snouted tyrannosauroids. This suggests that deep-snouted tyrannosauroids could resist high stresses and deliver relatively powerful bite forces. With both high muscle force and stress, small juvenile tyrannosaurids over-performed forces in earlier tyrannosauroids, and strained cranial reinforcement adaptations that became more effective in adults.

Keywords: tyrannosaurs; dinosaurs; biomechanics; feeding; phylogeny

CANUS RUFUS HAS CHANGED SIGNIFICANTLY SINCE THE IMPLEMENTATION OF THE CAPTIVE BREEDING PROGRAM, AND BOTH MORPHOTYPES ARE SIGNIFICANTLY DIFFERENT FROM *CANIS LUPUS*

Allison E Nelson[1]*
[1]Department of Earth and Atmospheric Sciences, Indiana University; ***Presenting author**

The origin of Canis rufus (red wolves) has been hotly contested. Three main hypotheses exist: 1. It is a native North American species distinct from the grey wolves that came across the Bering Land Bridge. 2. Red wolves never were a separate species but are instead hybrids between Canis lupus (grey wolves) and Canis latrans (coyotes). 3. It is a native North American species, but not distinct from the pre-Columbian “grey wolves” that inhabited the eastern seaboard. Due to nearly complete eradication and rampant hybridization with coyotes, a captive breeding program (CBP) was created in the 1970s. In October 2021 the CBP had 266 red wolves. Whether red wolves are a separate species affects their Endangered Species List (ESL) status and therefore conservation funding, including the CBP. Without a clear definition of red wolf there cannot be a clear conservation goal. With so few individuals, it has not been clear what traits distinguish red wolves from grey wolves and coyotes. Recent years have seen the delisting and relisting of grey wolves, which heavily disrupted conservation efforts. Cranial geometric morphometric analysis of 240 museum specimens of wild red wolves prior to the CBP, CBP individuals, and specimens of wild and captive grey wolves supports the first hypothesis. Procrustes analysis and one-way PERMANOVA (permutational

multivariate analysis of variance) were completed. Red wolves from the 1970s wild populations are different from grey wolves, both wild (p=0.0001) and captive (p=0.0088). Likewise, red wolves in the CBP are different from both wild (p=0.0001) and captive (p=0.0007) grey wolves. Interestingly, red wolves produced by the CBP are significantly different (p=0.0002) from the initial wolves selected and bred. Of these four groups, the only two that are not significantly different are wild and captive grey wolves (p=0.176). This rejects the third hypothesis, as red and grey wolves are significantly different. The second hypothesis is also rejected by grey wolves being significantly different from the initial CBP red wolves. The first hypothesis is supported. This result that red wolves are a separate species from grey wolves supports their continued ESL listing. It is interesting that red wolves have changed significantly in the near 50 years of the CBP. Unique red wolf traits need to be determined.

Keywords: wolf; red wolves; grey wolves; speciation; cenozoic

CONSTRAINING THE SHURAN δ13C EXCURSION WITH THE δ44/40Ca – δ88/86Sr MULTI-PROXY

Niloufar L Sarvian[1]*; Andrew D Jacobson[1]; Tia Chung-Swanson[1]; Matthew T Hurtgen[1]; Magdalena R Osburn[1]; Kristin D Bergmann[2]
[1]Department of Earth and Planetary Sciences, Northwestern University; [2]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology; ***Presenting author**

The Shuram Excursion is the largest negative carbon isotope excursion (CIE) in Earth's history. Major questions surround whether the CIE resulted from primary or secondary processes, and whether those processes were local, global, or some combination thereof [1,2]. This research aims to address these questions by employing the novel δ44/40Ca-δ88/86Sr multi-proxy, which is sensitive to variable mass-dependent isotope fractionation, fluid buffered early diagenesis, and temporal shifts in the isotopic composition of seawater due to end-member mixing. Utilizing high-precision TIMS techniques, we apply the multi-proxy to the Shuram CIE recorded in carbonate rocks of the Huqf Supergroup, Oman, which was deposited ~574 – 567 Ma [3]. The minerology of these samples varies by unit and includes primary aragonite that has neomorphized to calcite, primary calcite, and very early dolomite. We analyzed 30 samples spanning the Khufai, Shuram, and Buah formations. When examined as δ88/86Sr vs. δ44/40Ca, the data broadly define a negative trend with samples grouping by minerology. Calcite samples from the nadir of the CIE display among the lowest δ88/86Sr, as well as the highest 87Sr/86Sr. The trend between δ44/40Ca and mineralogy appears to fit a diagenetic model where aragonite transforms to calcite and dolomite in the presence of seawater. However, such a model does not explain the complementary trend in δ88/86Sr. No evidence suggests aragonite could initially incorporate heavier Sr isotopes, nor does a mechanism exist to decrease δ88/86Sr through fluid-buffered alteration as carbonates are well-understood to lose Sr during diagenetic transformation. No evidence supports meteoric alteration of δ44/40Ca values [1]. Carbonates kinetically incorporate lighter Ca and Sr isotopes. Therefore, application of kinetic mass-fractionation laws points to a rapid decrease in seawater δ88/86Sr during the Shuram CIE, which appears superimposed on a longer-term increase in δ88/86Sr up-section. End-Ediacaran seawater likely had high δ88/86Sr [4], whereas continental runoff has low δ88/86Sr [5]. Our initial results raise the possibility that seawater-freshwater mixing was a characteristic of this near shore setting, consistent with observations that the onset of the Shuram CIE coincides with a major marine transgression [6].
[1] Busch et al., 2022 [2] Geyman and Maloof, 2019 [3] Rooney et al., 2020 [4] Sawaki et al., 2010 [5] Vollstaedt et al., 2014 [6] Osburn et al., 2013

Keywords: shuram; isotopes; carbonates; carbon isotope excursions

ASSESSING THE VARIABILITY OF STABLE CALCIUM ISOTOPES IN CRETACEOUS CARBONATE OYSTER FOSSILS

Dana Small[1], Anna Waldeck[1], Andrew Jacobson[1], Bradley Sageman[1], Benjamin Linzmeier[2]
[1]Department of Earth and Planetary Sciences, Northwestern University; [2]Department of Earth Sciences, University of South Alabama; ***Presenting author**

Past ocean acidification events and their effects on ocean organisms have been previously studied through analyses of stable calcium isotope abundances in bulk sedimentary carbonate. Stable calcium isotopes can record global calcium cycle variation, changing carbonate precipitation rates, and diagenetic alteration.

Bulk sedimentary carbonate records are complex because they comprise sediment from several sources, including inorganically precipitated calcite and shell material from multiple organisms with differing vital effects. To control for vital effects, this study aims to assess the fidelity and meaning of calcium isotope signatures in Pycnodonte oyster shells from the Cretaceous period. While bulk sediment can average the calcium isotope composition of carbonate accumulated over tens to thousands of years, oyster shells offer much higher temporal resolution because they record only a few years of organism growth. To use Pycnodonte oysters as long-term archives of calcium isotope change, we need to determine whether shells preserve primary or secondary signals, and constrain the magnitude and direction of short-term fluctuations. Here, we focus on Pycnodonte kellumi oyster fossils collected from the Western Interior Seaway, USA, from approximately 95 million years ago. We use optical and SEM imaging as well as analyses of carbon and oxygen isotopes to distinguish between primary and secondarily altered calcite and guide sampling locations. Along with carbon and oxygen analyses, we use stable calcium isotopes to assess short-term fluctuations in growth conditions. If these fossils offer high-fidelity archives of calcium isotope signals, they can be used to reconstruct longer-term temporal records of calcification conditions, with the overall objective of assessing environmental change during candidate ocean acidification events.

Keywords: calcium isotopes; ocean chemistry; calcification; oysters; cretaceous

DIVERSIFICATION OF THE RUMINANT SKULL ALONG AN EVOLUTIONARY LINE OF LEAST RESISTANCE

Daniel Rhoda[1]*, Kenneth Angielczyk[2]
[1]Committee on Evolutionary Biology, University of Chicago; [2]Negaunee Integrative Research Center, Field Museum; ***Presenting author**

Morphological integration is relevant to paleontology because the structure of variation within populations determines the ways in which a population can respond to selective pressures. However, understanding the macroevolutionary consequences of morphological integration is elusive because the adaptive landscape is dynamic and population-level constraints themselves evolve. By analyzing a previously published dataset of 2857 ruminant crania with 3D geometric morphometrics and phylogenetic comparative methods, we find that variation within and between ruminant species is strongly biased by a highly conserved mammalian-wide allometric pattern, CREA, where larger species have proportionally longer faces. Ruminant species with variation more aligned with CREA diverge from their ancestors farther, and Ruminantia as-a-clade diversifies farther than expected given a Brownian motion model of evolution, but only in directions anticipated by CREA. Our analyses indicate that CREA is acting as an evolutionary 'line of least resistance' and is facilitating morphological diversification due to its alignment with the browser-grazer continuum. Our results demonstrate that biological processes constraining variation at the microevolutionary level can produce highly directional phenotypic evolution over macroevolutionary timescales and provides an empirical example of morphological integration acting as a facilitator, rather than an impediment, to morphological diversification.

Keywords: morphometrics; integration; macroevolution; allometry; artiodactyla

RAPTOR PELLETS OF THE ARTIC NATIONAL WILDLIFE REFUGE REVEAL SPATIAL GRADIENT IN SMALL MAMMAL COMMUNITIES

Bianca L. Neale[1]*; Joshua H. Miller[1]; Eric J. Wald[1]; Patrick Druckenmiller[1]
[1]Department of Geosciences, University of Cincinnati; ***Presenting author**

Historical and subfossil skeletal remains provide important resources for evaluating extant small mammal diversity. Owls (Strigiformes), many hawks (Accipitridae), and ravens (Corvidae) have the ability to consume prey whole, and regurgitate pellets of indigestible bones and remaining tissues. Resulting pellet accumulations faithfully record local prey diversity because these birds feed largely indiscriminately. Here, we use pellet-derived bone accumulations to evaluate changes in rodent communities across the Coastal Plain of the Arctic National Wildlife Refuge, Alaska. This region is dominated by three microtine rodents; collared lemming (Dicrostonyx groenlandicus), North American brown lemming (Lemmus trimucronatus), and tundra vole (Microtus oeconomus), but there are limited data on how their populations change across

space. Furthermore, because pellets can accumulate across decades or more, they may be particularly useful for establishing long-term population metrics for microtine rodents and other species that undergo large population boom and bust cycles. Pellets were collected during taphonomic surveys of openly vegetated tundra habitats (Dryas terraces) near seven major river systems (Canning, Katakturuk, Hulahula, Jago, Aichillik, Kongakut, and Turner Rivers). Rivers flow south-north, bisecting the Coastal Plain at semi-regular intervals across 200 km. Mammalian remains were dissected from pellets and identified based on tooth morphology. Pellets and local bone accumulations were summarized by the minimum number of individuals for each species. We find significant changes in microtine community composition across the Coastal Plain. The community is strongly dominated by lemmings (Dicrostonyx + Lemmus) in the west and voles (Microtus) in the east. The shift in arcsine-transformed proportional abundance of voles is roughly continuous across longitude and is highly significant (weighted linear regression; $p < 0.01$, $R2 = 0.75$). This dramatic shift in the Coastal Plain microtine species was previously unrecognized. Our results illustrate that (i) even in species-poor tundra settings, biological heterogeneity can be high, and (ii) conservation paleobiology can provide novel insights relevant to understanding cryptic diversity changes in modern ecosystem.

Keywords: ecology; small mammal; arctic

QUANTIFYING WINNOWING OF SKELETONS IN VERTEBRATE ASSEMBLAGES

Aaron M. Kufner[1]*; David M. Lovelace[1]
[1]Department of Geoscience, University of Wisconsin-Madison; ***Presenting author**

Preferential preservation of vertebrate skeletal elements in a bone bed (i.e., localized concentration of skeletal elements) can be indicative of different modes of accumulation or of winnowing. The effects of hydrodynamic sorting observed in bone beds are often discussed in terms of “Voorhies Groups”, based on flume experiments by Voorhies in the 1960s on the dispersal potential of mammal bones. However, subsequent flume experiments on turtle and crocodilian skeletons have demonstrated a continuum of dispersal potential influenced by bone density and complexity of morphology. In addition, homologous elements between turtle, crocodilian, and mammal skeletons did not follow the same hydrodynamic dispersal patterns; this has been largely attributed to differences in gross morphology and density (i.e., variance in hydrodynamic equivalence). As such, Voorhies group assignments may not fully capture hydrodynamic dispersal potentials if homologous elements differ enough in gross morphology, density, or both across disparate taxa. These issues are compounded with fossil taxa because diagenetic alteration of bone density and taphonomic deformation of gross morphology mask original conditions present at the time of deposition. In an attempt to mitigate uncertainties surrounding original bone density and element geometries of specific fossil taxa, we employ a simple count of non-articulated skeletal elements normalized to the minimum number of individuals to infer hydrodynamic conditions. We hypothesize that a normalized distribution of elements can offer a more robust comparison between bone beds of similar taxa better supporting paleoenvironmental and paleoecological interpretations. We suggest that this method will provide a framework that is more versatile than discrete bins defined by limited taxon sampling. This framework can be further tested through modeling and actualistic studies of more disparate taxa. Although this method relies on proper anatomical and taxonomic identification of all elements within the bone beds being compared, it avoids assumptions of the hydrodynamic equivalence of homologous bones.

Keywords: taphonomy; bonebeds; hydrodynamic sorting

STABLE Ca and Sr ISOTOPES IN DOLOMITE FROM EARLY CRETACEOUS PACIFIC OCEAN SEDIMENTS

Sara J. Yen[1]*; Anna R. Waldeck[1]; Andrew D. Jacobson[1]
[1]Department of Earth and Planetary Sciences, Northwestern University

For much of Earth history, the mineral dolomite was a major sink of marine carbon. However, the formation of dolomite through primary and secondary processes remains enigmatic. Previous studies have used stable calcium isotopes ($\delta 44/40Ca$) to investigate dolomite formation mechanisms, ranging from syndepositional to later stage diagenesis. Less is known about the behavior of stable strontium isotopes

(δ88/86Sr) during dolomitization. To better understand the dolomitization process, we analyzed the stable Ca and Sr isotope compositions of dolomite-bearing sediments from ODP core 866A drilled in Resolution Guyot, mid-Pacific Mountains. We observe a range of Mg/Ca ratios from 2% to 76%, which reflects partial to considerable dolomitization. Higher dolomite proportions correlate with lower Sr/Ca ratios, consistent with expectations that dolomitization reduces Sr concentrations. Dolomite that forms under fluid-buffered (open system) conditions should display high δ44/40Ca values compared to precursor minerals, such as aragonite and calcite. However, δ44/40Ca values for 866A dolomitized sediments overlap with those for younger calcitic sediments from the same site (Wang et al. 2021). The similar δ44/40Ca values observed for calcite and partial dolomites suggests that secondary alteration occurred under rock-buffered (closed system) conditions. Complementary δ88/86Sr values for the overlying calcitic sediments correlate with δ44/40Ca values according to a kinetic-mass fractionation law, which provides evidence for primary signal preservation. We expect that stable Sr isotope analyses of the partial dolomites will provide additional constraints on formation pathways and conditions.

Keywords: dolomite; dolomitization; Ca isotopes; Sr isotopes

BIZARRE BACKBONES: A SYNAPOMORPHY IN THE LUMBAR VERTEBRAE FOR FERUNGULATA

Anne Kort[1]*
[1]Department of Earth and Atmospheric Sciences Indiana University Bloomington; ***Presenting author**

Abstract: Mammals have a highly regionalized presacral spine, with constrained vertebral count controlled by development and ancestry. In contrast, individual vertebral morphology, especially within the lumbar region, appears to be evolutionarily labile, varying with locomotor style and body size. I looked at the fossil record to search for patterns of phylogenetic history underlying this variation. I used a combination of Paleogene fossils and modern specimens from across Mammalia to assess the phylogenetic history of lumbar morphology through the Cenozoic. I sample lumbar vertebrae from 57 mammals: 30 from a combination of extant and Neogene mammals, and 27 from Paleogene mammals. I developed qualitative characters to describe lumbar morphology to account for fossils with missing elements. I coded these 17 characters based on the morphology of the zygapophyses, transverse processes, neural spines, and centra. Specimens were accessed through the William R. Zooarchaeology Lab (WRAZL), descriptive papers, loans from University of Wyoming, and Morphosource.org. I mapped these characters onto a supertree of extinct and extant mammals using parsimony in the software Mesquite. I then calculated the retention indices for each character and the matrix as a whole. The retention index for all characters across the matrix was 0.369, indicating a high amount of homoplasy in this character set. Only three characters had a retention index (RI) of greater than 0.5: presence of xenarthran articulations (RI=1), presence of anapophyses (RI=0.667), and presence of a lamina on the dorsal edge of the postzygapophyses forming an S-shape in the frontal plane (RI=0.538). Xenarthran articulations are a well-known synapomorphy of Xenarthra and anapophyses are likely plesiomorphic to therian mammals. Among extant mammals, the S-shaped postzygapophysis is known only from Artiodactyla. However, this feature is found in many extinct Paleogene mammals, including hyaenodonts, oxyaenids, mesonychids, arctocyonids, and the stem perissodactyl Cambaytherium. This suggests that this character may be basal to Ferungulata and secondarily lost in Carnivora and crown Perissodactyla. Previous study has shown that these S-shaped zygapophyses prevent torsion between vertebrae. It is possible this feature evolved in response to a need for stabilization in posterior spine as ribs became reduced.

Keywords: vertebrae; mammal; paleogene

AN EARLY PALEOCENE (DANIAN) RECORD OF MOONFISHES (CARANGARIA: MENIDAE), WITH IMPLICATIONS FOR EARLY DIVERSIFICATION IN CARANGARIAN FISHES

Sanaa El-Sayed[1,2,3]*; Matt Friedman[1]; Robert Speijer[4]; Belal S. Salem[2,3,5,6]; Hesham M. Sallam[2,3,7]
[1]Museum of Paleontology, Department of Earth and Environmental Sciences, University of Michigan; [2]Mansoura University Vertebrate Paleontology Center (MUVP); [3]Department of Geology, Faculty of Science, Mansoura University; [4]Department of Earth and Environmental Sciences, KU; [5]Department of Biological Sciences, Ohio University; [6]Ohio Center for Ecology and Evolutionary Studies, Ohio University; [7]Institute of Global Health and Human Ecology (I-GHHE) School of Sciences and Engineering, American University in Cairo; ***Presenting author**

Carangaria (jacks, flatfishes, billfishes, and kin) are a morphologically diverse clade of primarily marine spiny-rayed fishes characterized by a wide array of peculiar behavioral and anatomical novelties. The oldest undisputable body-fossil records of carangarians are from around the Paleocene-Eocene boundary, with many examples from faunas apparently coincident with the Paleocene-Eocene Thermal Maximum (~56 Ma). Molecular clocks point to the origins of the group late in the Cretaceous or early in the Cenozoic. Here, we report on a new species of the carangarian Mene from the Eastern Desert of Egypt. The fish-bearing horizon characterizes the anomalous marl beds of the Latest Danian Event, a hyperthermal, and is securely dated to 62.2 Ma. Assignment of the new specimens to Mene is supported by numerous synapomorphies (e.g., compressed disc-like body, anteroposteriorly elongated dorsal and anal fins with relatively short rays, narrow pelvic fins with a compressed and greatly elongated second ray. However, these new specimens exhibit a unique combination of features compared to other species of Mene: separate first and second neural spines, no lateral laminar expansions of the dorsal pterygiophores, rounded dorsal and ventral profiles of the maxilla, a distinctive patterns of ridges on the frontal-supraoccipital crest, straight posterior border of the angular, and a rectangular shaped ceratohyal with no dorsal expansion. These suggest that the Danian Mene from Egypt represents a new species, with the retention of primitive features indicating it might represent the sister lineage of all other members of the genus. The discovery of definitive material of Mene in the early Paleocene extends the record of that genus by over six million years. More significantly, the highly specialized anatomy of Mene makes the new Egyptian fossils an robust new marker for establishing the timeline of diversification within Carangaria, and indicates that some of the most specialized anatomies within the group were already present a few million years after the Cretaceous-Paleogene extinction. The remarkable similarity of Mene species over 60 million years of evolutionary history represents a striking example of anatomical stasis.

Keywords: acanthomorpha; carangaria; menidae; africa; egypt

THE ECOLOGY AND EVOLUTION OF BITE FORCE IN GEOMORPH RODENTS

Madeline P Ball[1]*; Dylan M Poorboy[2]; Francesca Socki[3]; Jonathan JM Calède[4]
[1]The Ohio State University; [2]Department of Evolution, Ecology, and Organismal Biology, The Ohio State University; [3]University of Minnesota Twin Cities; [4]Department of Evolution, Ecology, and Organismal Biology, School of Earth Sciences, The Ohio State University; ***Presenting author**

Geomorpha is a highly diverse clade of rodents containing both geomyids (pocket gophers) and heteromyids (kangaroo rats, pocket mice, and their relatives). The rich taxonomic diversity of this group is associated with a great morphological disparity. Here, we explore one aspect of geomorph ecomorphology, bite force (BF), using measurements of the lower incisor and body size estimates to calculate the bite force quotient (BFQ) of 893 specimens from 65 extant species and 86 specimens from 52 fossil species spanning the Oligocene through Pleistocene. We tested the hypothesis that there is sexual dimorphism in BFQ, as male geomyids and heteromyids are known to display agonistic behavior, but our results show instead that males and females do not significantly differ in BFQ. We do, however, find evidence to support our hypothesis of a link between ecology and BFQ. A herbivorous species of kangaroo rat displays a higher BFQ than granivorous species in the same genus. Chisel-tooth digging pocket gophers have a higher BFQ than scratch-diggers. The significant difference in BFQ between digging ecologies among extant taxa enables us to reconstruct the burrowing behavior of several fossils. For example, we interpret Geomys persimilis, an extinct geomyid gopher, as a chisel-tooth digger. Moreover, we interpret the extinct entoptychine gopher, Entoptychus sheppardi, as a scratch digger. An ancestral character state reconstruction reveals an increase in BFQ in the common ancestor of geomyids as well as a decrease in the common ancestor of heteromyids from an ancestral condition of intermediate bite force. Our model-fitting analysis supports an early burst evolution of BFQ. In association with our findings for ecology, we propose that the initial divergence in ecology between families of rodents within Geomorpha was associated with functional adaptations in BFQ. Future analyses of procumbency and body size will help shed light on the ecological diversification of this very diverse clade of rodents.

Keywords: ancestral character state reconstruction; fossoriality; bite force quotient; diet; ecomorphology

THE EVOLUTION OF PROCUMBENCY IN GEOMORPHA: THE INFLUENCE OF LOCOMOTORY SPECIALIZATION

Francesca M.C. Socki[1]*; Jonathan J.-M. Calède[2]
[1]Department of Earth and Environmental Sciences, University of Minnesota - Twin Cities; [2]Department of Evolution, Ecology, and Organismal Biology, The Ohio State University at Marion; ***Presenting author**

Procumbency (anteriorly projecting incisors in relation to the rostrum or dentary) has been studied extensively in many fossorial rodents, including within Thomomys, a genus of pocket gopher in the clade Geomorpha. However, few analyses have considered the evolution of procumbency over geological time scales. Geomorph rodents offer this opportunity thanks to recent developments of a phylogenetic framework for the clade. Using data on both upper and lower incisor procumbency as well as phylogenetic information, we explore ecological specialization,canalization, and the macroevolution of procumbency in a taxonomically and ecologically diverse rodent clade. Specifically, we used linear measurements from 115 specimens of fossil and extant taxa, conducting ANOVAs and linear regressions at the family level and within families. We also performed an ancestral character state reconstruction for both upper and lower procumbency. We find that across all observed families, upper incisor procumbency is lower and less variable than lower incisor procumbency. The Geomyidae display a higher level of upper incisor procumbency than Heteromyidae and Florentiamyidae. They also have the least variable procumbency. The lower incisor procumbency of Geomyidae is similar to that observed in Heteromyidae. Geomyids are the only clade to exhibit a significant correlation between upper and lower procumbency. Character state reconstructions reveal that increased upper procumbency evolved multiple times within the extant subfamily of Geomyidae, in four different geomyine genera. Procumbency decreased independently multiple times within Heteromyidae as well in Florentiamyidae from a common ancestor with higher procumbency. We conclude that higher upper procumbency evolved in relation to burrowing, including in taxa that do not use their incisors as a primary mode of digging. Restriction to higher levels of upper procumbency, coupled with strong correlations between upper and lower incisor procumbency, suggest the existence of morphological canalization associated with fossoriality within Geomyidae.

Keywords: rodentia; functional morphology; ecology; fossorial

A DIGITAL ATLAS OF THE ABELISAURID FOOT: NEW INSIGHTS FROM MAJUNGASAURUS CRENATISSIMUS (THEROPODA: ABELISAURIDAE) FROM THE LATE CRETACEOUS OF MADAGASCAR

Alexander L. Acker[1]*; Patrick M. O'Connor[2]; Joseph R. Groenke[3]
[1]Department of Biological Sciences, Ohio University.; [2]Department of Biomedical Sciences, Ohio University; [3]Ohio Center for Ecological and Evolutionary Studies, Ohio University; ***Presenting author**

Late Cretaceous Gondwanan continental ecosystems are dominated by abelisaurids among non-avian theropods. Although many abelisaurid taxa are based on relatively complete specimens, there remain some regions of the skeleton that are not preserved well or at all. The abelisaurid foot is known only in moderate detail from a limited number of taxa (e.g., Eoabelisaurus, Aucasaurus, and Skorpiovenator). Detailed anatomy of the hind limb in Majungasaurus is lacking due to the incomplete nature of this region of the skeleton, limiting inferences related to hind limb-based body size proxies and locomotor biology more generally. Moreover, previous descriptions of the foot in Majungasaurus have relied on composite descriptions derived from partially associated-to-isolated specimens from different localities. Here we report the recovery of associated hind limbs from an exquisitely preserved skeleton, including for the first time a nearly-compete foot of this important Maastrichtian abelisaurid. The specimen includes both right and left pelvic girdles and the associated hind limb skeleton, with most individual bones represented on at least one of the two feet. Metatarsals II-IV are preserved on both the left and right side, along with a near-complete phalangeal series (missing only phalanx I-1) on the right side. In addition to providing the first associated pedal remains, the new specimen augments previous descriptions by importantly preserving MT I and phalanx III-4, providing an ability to characterize and digitally model the entire foot in both neutral anatomical and inferred life-position (i.e., in contact with the substrate) contexts. Majungasaurus displays pedal characteristics consistent with other abelisaurids, including a non-pronounced flexor tubercle on the unguals, a proximal ventral depression on the unguals[OP1] , and a laterally placed hyper extensor pit on the dorsal surface of digit IV-1. Hyper extensor pits on MT II-IV appear better developed in Majungasaurus

than in other abelisaurids. The new specimen exhibits a strong lateral divergence of MT IV characteristic of Majungasaurus. Novel digital models of individual foot bones and the reconstructed foot of this specimen provide important comparative data for phylogenetic and functional students of this widespread Cretaceous lineage.

Keywords: majungasaurus; foot; abelisauridae; cretaceous

A PUTATIVE SPADEFISH (ACANTHOMORPHA: EPHIPPIDAE) FROM THE INDO-PACIFIC REGION AND ITS IMPLICATIONS FOR MARINE FISH BIOGEOGRAPHY IN THE PALEOGENE

Hadeel Saad[1]*; Matt Friedman[2]
[1]Department of Earth and Environmental Science, University of Michigan; [2]Museum of Paleontology, University of Michigan; ***Presenting author**

Ephippidae (spadefishes) is a clade of marine fishes containing 15 extant species divided among 8 genera. Found on coral reefs and in open waters worldwide, ephippids are laterally compressed fishes with small, non-protrusive mouths and often bear striking, dark vertical bars of pigmentation on their flanks. Apart from so-called “Tilly bones,” fossil hyperostotic elements attributed to ephippids and other tropical fishes, the paleontological record of ephippids is poor. Articulated remains of putative ephippids derive almost exclusively from the early Eocene (Ypresian, ca. 49 Ma) deposits of Bolca, Italy, and include two extinct genera: Eoplatax and Archaephippus. Today the greatest diversity of extant spadefish species is in the Indo-West Pacific, yet there are no known fossil ephippid remains from this region. Here we report the first fossil spadefish from the Indo-Pacific, from the middle Eocene (Lutetian, ca. 47 Ma) Habib Rahi Formation of western Pakistan. Preserved as an impression on a limestone slab, this single articulated individual does not preserve definitive synapomorphies of ephippids, such as the branchial skeleton, dentition, and pelvic girdle. However, intact portions of the skeleton correspond closely to the anatomy of Eoplatax from Bolca. Major similarities include a nearly circular body, greatly elongated dorsal- and anal-fin rays, and a very deep caudal peduncle. The discovery of an Eoplatax-like fossil in the middle Eocene of Pakistan could have important implications for marine fish biogeography in the Paleogene. At this time, Indo-Pakistan is thought to have been outside the margins of an ancient biodiversity hotspot centered in the West Tethys. The presence of similar faunal elements in the ancient Indo-Pacific can help to constrain models of shifting biodiversity hotspots during the Cenozoic. Such hotspot migration is supported by fossil evidence as well as patterns of relationships among some extant groups. Integration of putative fossil ephippids, including the new form from Pakistan, into a phylogenetic framework with living examples will be critical for determining what–if any–bearing spadefishes might have on these broad biogeographic questions.

Keywords: cenozoic; actinopterygii; indo-west pacific; biogeography

COMPARING STOMATAL PRESERVATION OF LEAF CUTICLE ANALYSIS TECHNIQUES

Mike D. Machesky[1*], Selena Y. Smith[1], Nathan D. Sheldon[1], Kate Morrison[1], Kelly Martin[1]
[1]Department of Earth and Environmental Sciences, University of Michigan; ***Presenting author**

Plants record the environmental conditions they grew in through both the morphology and chemistry of their leaves, making them useful paleoclimate proxies. One of the most well studied plant leaf traits as it relates to paleoclimate is stomatal index: the ratio of stomata to the total number of epidermal cells on the bottom of a leaf. In environments with lower atmospheric CO2 concentrations, leaves have more stomata because plants are more limited in their carbon uptake. The opposite is true for when CO2 is abundant and leaves have fewer stomata to minimize water loss. The size of the stomata themselves is also correlated to atmospheric CO2 concentrations, with leaves from environments with higher pCO2 having larger stomata, and vice versa. This relationship has been proven effective in use with both modern and fossil leaves, and has been used to refine and corroborate paleoCO2 estimates. Despite their usefulness, the method for measuring stomatal size and index has yet to be standardized, with different methods of leaf cuticle impression having potential to yield different results. We seek to test how the stomatal size and index analyses differ between four different means of making cuticle impressions: using silicone-based dental putty molds made from cuticles of both fresh and dried leaves, which are then transferred to microscope slides using clear nail polish, applying clear nail polish directly onto fresh leaves, and chemically clearing

the leaves to analyze the cuticle under a fluorescence microscope. We used leaves from three different species, *Ginkgo biloba*, *Canna* 'City of Portland', and *Zingiber mioga*, and assessed the stomatal index and size of each leaf using each of the four methods. Results show that the measurements most affected by cuticle preservation method are stomatal index and guard cell width, while total stomatal length, pore length, and inferred maximum stomatal conductance all show correlation between methods with $R^2>0.7$. This highlights the need for standardization in the methods of cuticle preservation for stomatal analysis, specifically with regards to stomatal index and guard cell width.

Keywords: Paleobotany, paleoclimate, methods, geochemistry