FOURTH INTERNATIONAL SYMPOSIUM ON PALEOHISTOLOGY

NEW JERSEY
STATE MUSEUM

Inspiration. On display.

FOURTH INTERNATIONAL SYMPOSIUM ON PALEOHISTOLOGY ISPH 2017

Volume 4

EDITORS

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FOURTH INTERNATIONAL SYMPOSIUM ON PALEOHISTOLOGY – ISPH 2017 – Volume 4

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FOURTH INTERNATIONAL SYMPOSIUM ON PALEOHISTOLOGY
July 10 - 12, 2017

NEW JERSEY STATE MUSEUM
Trenton, New Jersey USA

Symposium Convenors
David C. Parris
Rodrigo A. Pellegrini

Scientific Committee
Timothy G. Bromage
Barbara S. Grandstaff
Alexandra Houssaye
David C. Parris
Rodrigo A. Pellegrini
Allison Tumarkin-Deratzian

Organizing Committee
Sheila S. Blackwell
Wayne Callahan
Larry Conti
Robert Denton
Nicole Jannotte
Pamela Machold
Roland Machold
Margaret M. O'Reilly
Henry Sadowski
Lance Schnatterly
William J. Shankle

The 4th International Symposium on Paleohistology is organized by the New Jersey State Museum, and supported in part by the New Jersey State Museum Foundation.

Dedicated to Robert C. Ramsdell (1920-2014),
professor of Geology and Paleontology at Williams College,
Rutgers University and Montclair State University,
and long-time New Jersey State Museum volunteer.

The Professor was a devoted teacher, researcher, author, mentor and counselor. But most of all, to so many of us who study the Earth, he was a friend.

\- Wayne Callahan

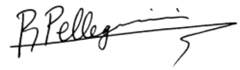
NEW JERSEY, WHERE NATURAL HISTORY INSPIRED AMERICAN SCIENCES!

Welcome to the New Jersey State Museum, the proud host of the Fourth International Symposium on Paleohistology! During this week, you will have ample opportunities to learn about the Museum collections and research, and to experience the traditions of paleontology in North America generally, as much of our science began in this region. The host hotel is located in Princeton, where University students Henry Fairfield Osborn and William Berryman Scott envisioned (and fulfilled) a full academic program in paleontology. Guyot Hall, location of the opening gathering, was one of the first university buildings in history to be designed with a large museum hall as its centerpiece, and the stone carvings on the molding around the building represent living animals at the Biology side of the building and extinct animals on the Geology side. In addition to the elegance of the campus, the town of Princeton has many tourist amenities, historic sites, shops, restaurants, recreational facilities, and other points of interest.

Symposium sessions will be held at the New Jersey State Museum at the Cultural Center in Trenton, practically within view of the classic gold-domed New Jersey State Capitol. Trenton, the site of two of the most critical battles of the American Revolution, once served as the capital of the United States. The State Museum, chartered in 1895, grew from extensive natural history collections amassed prior to that date by the antebellum field work of the New Jersey Geological Survey, which remains one of the Museum’s most important cooperating institutions. The current Museum campus, including the main building with its large Natural History Hall and Planetarium, was erected in 1964.

It was no accident that so much of the work of early paleontologists took place in this region. New Jersey is uncommonly rich in natural resources, having physiographic diversity and geologic resources far exceeding what one might expect for the size of the state. Although it is the most densely-populated of all the states in the Union, New Jersey’s substantial wild and preserved tracts still provide opportunities for field studies and collecting. The many opportunities for amateur and avocational paleontology have provided the Museum with many volunteer associates who are assisting with, and participating in, the Symposium. Among the professional paleontologists who encouraged amateur scientists was Professor Robert Ramsdell, a Trenton native, whom we honor at this Symposium.

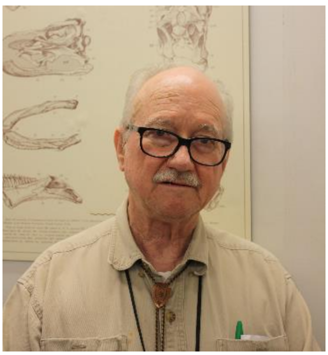
Paleohistology has a long history at both Princeton University and the New Jersey State Museum. Microscopy was applied in studies of the earliest collections, although not formally reported in many cases. At Princeton, Professors Scott, Sinclair, Jepsen, Dorf, Baird, and others applied new technologies to the study of fossils, including X-ray views of specimens in matrix, thin-section studies, and Scanning Electron Microscopy. The New Jersey State Museum continues these traditions, as is evident in staff and associate presentations. The Museum welcomes all participants to the state's capital city, and looks forward to dynamic dialogue as research is shared.



David C. Parris, Curator — Rodrigo A. Pellegrini, Registrar

Bureau of Natural History, New Jersey State Museum

SYMPOSIUM CONVENORS



David C. Parris is Curator of Natural History at the New Jersey State Museum (NJSM), where he has worked since 1971. A native of Kansas, he studied geology and paleontology at the New Mexico Institute of Mining and Technology (B.S.), the South Dakota School of Mines and Technology (M.S.), and Princeton University (M.A.). His research interests are vertebrate paleontology (Cretaceous to Recent), biostratigraphy of North America, zooarchaeology, and archaeological numismatics. David is also a member of the ISPH 2017 Organizing and Scientific Committees.

Rodrigo "Rod" A. Pellegrini is a graduate of the University of Kansas (B.S. Geology, M.S. Vertebrate Paleontology and M.A. Museum Studies), and, since 2006, Registrar of Natural History at the New Jersey State Museum. Among the first to study the histology of mosasaurs, Rod has conducted research in paleohistology throughout his career, and has been an active participant in ISPH since it first convened in Sabadell. His research interests, other than fossil marine reptiles, include the biostratigraphy of late Cretaceous North America and reptilian paleopathology (he is co-author of *Herpetological Osteopathology: Annotated Bibliography of Amphibians and Reptiles*, and of a chapter in *Morphology and Evolution of Turtles*). Rod is a member of the ISPH 2017 Organizing and Scientific Committees.

KEYNOTE SPEAKERS

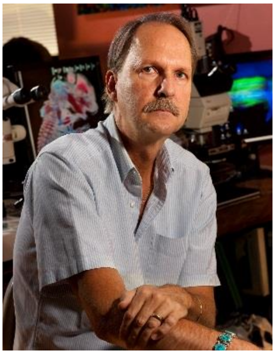
Gregory M. Erickson is a Professor of Biological Science at Florida State University. Dr. Erickson earned his bachelor's degree in Geological Science at the University of Washington, master's in Biology at Montana State University and Ph.D. in Integrative Biology at the University of California, Berkeley. He subsequently conducted Postdoctoral research as an NSF Fellow in the Departments of Biomechanical Engineering at Stanford University, and Ecology and Evolution at Brown University, before joining the faculty at FSU in 2000. His research program focuses on the paleobiology and evolutionary success of archosaurian reptiles with particular emphasis on growth curve reconstructions and feeding biomechanics. Erickson conducts field research in the Alaskan Arctic where he is co-director of the Arctic Paleontological Research Consortium, has written over 100 professional articles and was elected as a fellow of the American Association for the Advancement of Science in 2012.

Phillip L. Manning is Professor of Paleontology and Director of the Mace Brown Museum of Natural History at the College of Charleston. Dr. Manning also holds the Chair of Natural History at the University of Manchester (UK). His research focuses on the application of multiple imaging techniques and vertebrate biomechanics. The synchrotron-based imaging techniques that his research team have developed have shed new light on several iconic fossils, not least *Archaeopteryx*. His successful management of teaching, research and outreach at the University of Manchester has facilitated paleontology becoming a powerful vehicle that has enabled a wider public engagement in science. Phil has presented his research on multiple documentaries around the world, including on BBC, National Geographic and Discovery Channel.

Peter Dodson holds two degrees in geology (University of Ottawa, 1968; University of Alberta, 1970). He received his Ph.D. in paleontology from Yale University in 1974. He is a professor of veterinary gross anatomy and of dinosaur paleontology at the University of Pennsylvania, where he has taught since 1974. His work has taken him to India, Madagascar, Egypt, Argentina, Mexico and China. He has supervised more than 20 Ph.Ds. and his graduates teach in China, Japan, and Canada, as well as in the United States. With his students, he has described and named six species of dinosaurs. He is the author of more than 100 scientific papers, co-editor of *The Dinosauria*, (1990, 2004); author of *The Horned Dinosaurs* (1996), and of several children's books.

Allison R. Tumarkin-Deratzian received her B.S. in Geology and Environmental Geosciences from Lafayette College (1997), and her Ph.D. in Earth and Environmental Science from the University of Pennsylvania (2003), where she also served as a graduate instructor of Gross Anatomy in the School of Veterinary Medicine. She was a Visiting Assistant Professor in the Department of Earth Science and Geography at Vassar College, from 2003-2006. Since 2006, she has been with the Department of Earth and Environmental Science at Temple University, and currently serves as Associate Professor of Instruction and Undergraduate Chair for Geology and Environmental Science. Although her formal degrees are in geology, her educational training and research interests have always strayed to the biological side of the paleontology spectrum. Her research primarily involves study of bone microstructure and growth patterns of modern and fossil archosaurs, ontogeny and evolution of ornithischian dinosaurs, and vertebrate taphonomy. Dr. Tumarkin-Deratzian is also a member of the ISPH 2017 Scientific Committee.

WORKSHOP INSTRUCTORS



Timothy G. Bromage directs the Hard Tissue Research Unit (HTRU), a mineralized tissue preparation and imaging technology development laboratory of the Department of Biomaterials and Biomimetics, New York University College of Dentistry. The HTRU emphasizes evolutionary research in environmental context, employing a variety of 2D and 3D light and electron microscopy techniques, in addition to mass spectrometry-based approaches to the complete relevant inorganic spectrum detectable in hard tissues. Professor Bromage is recipient of the 2010 Max Planck Prize in the Life Sciences (paleobiomics; emphasis in Human Evolution), is Honorary Professor of La Salle University, Madrid, Spain, and an Honorary Research Fellow of the Department of Paleoanthropology, Senckenberg Research Institute, Frankfurt, Germany. He is also a member of the ISPH 2017 Scientific Committee.

Santiago Gomez is a professor of Pathology in the Faculty of Medicine, University of Cadiz, Spain. He has been a visiting scientist at University College London, Università La Sapienza Roma, Cornell University, and New York University. With an initial interest in pathological calcification, in the last 30 years his research has focused on hard tissues with special emphasis on their preparation, imaging, and analysis. His excellence in technical work and photomicrography has been recognized in winning several Buehler and Nikon Small World awards.

Ellen-Thérèse Lamm is the Histology Lab Manager at the Museum of the Rockies in Bozeman, Montana, where she has worked with Jack Horner and Montana State University students for over 26 years producing a vast collection of thin-sections of over 2,500 specimens. She is an Adjunct Instructor at MSU, teaching Paleohistology Techniques, and is the co-editor of *Bone Histology of Fossil Tetrapods*. Ellen-T. has worked with over 100 institutions around the world thin-sectioning fossil material, training visiting researchers, and presenting workshops at ISPH, SVP, and the National Society of Histotechnology.

SCIENTIFIC COMMITTEE

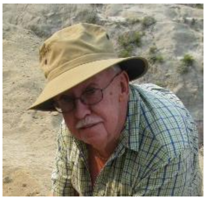
Barbara Smith Grandstaff attended Millersville State College (B.A.), Princeton University (M.A.) and the University of Pennsylvania (Ph.D.). She teaches gross anatomy, developmental biology, and neuroscience at the School of Veterinary Medicine of the University of Pennsylvania, and has also taught geology and paleontology courses at Temple University. Barbara's research focuses on vertebrate functional morphology, paleopathology, and late Cretaceous communities.

Alexandra Houssaye received a Ph.D. from and works at the Muséum National d'Histoire Naturelle of Paris, France. She is a CNRS paleobiologist specializing in functional morphology. Dr. Houssaye focuses her work on the analysis of bone microanatomical adaptations and their link with anatomical changes and biomechanical constraints.

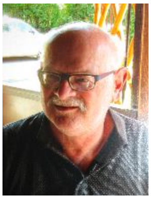
Other members of the Scientific Committee include Timothy G. Bromage, David C. Parris, Rodrigo A. Pellegrini, and Allison Tumarkin-Deratzian, whose biographical information is available earlier in this publication.

LOCAL ORGANIZING COMMITTEE

Sheila Scott Blackwell is a volunteer in the State Museum's Bureau of Natural History. She is a graduate of Trenton State College, with a Bachelor of Science in Biology, and works for the New Jersey State Department of Agriculture, Division of Plant Industry, as a horticulturist.



Wayne Callahan is a volunteer in the Division of Paleontology of the American Museum of Natural History, in addition to volunteering with the Natural History Bureau of the NJSM. Although his professional career took him into manufacturing engineering and production management, Wayne pursued his life-long interest in paleontology in the graduate program in geoscience at Montclair State College. He has collected and studied fossils, collaborated on fieldtrip guides, scientific papers and abstracts for over 45 years. Wayne became a Research Associate in paleontology at the New Jersey State Museum over 25 years ago, and is a member of the Society of Vertebrate Paleontology.



Lawrence "Larry" G. Conti is a native Trentonian and a Board Member of the New Jersey State Museum Foundation. At the request of Uncle Sam, he spent a year and a half blowing up balloons in the desert of New Mexico, and the next thirty-five years as a bureaucrat for the State of New Jersey in Vocational Rehabilitation. Larry volunteers at the NJSM, and has done some paleontology work with the institution. He enjoys visiting his relatives in Rome and Umbria, and has visited the K-Pg boundary in Gubbio, Italy.

Robert "Bob" Denton Jr. attended Richard Stockton State University and graduated from Thomas Edison State University with a B.A. in Natural Science. Bob has been a research associate of the NJSM for nearly 40 years, and is the co-discoverer of both the Ellisdale Fossil Site in New Jersey and the Zuni Basin Dinosaur Site in New Mexico. He described two new taxa of animals from Ellisdale, and is currently working on the description of a new taxon from the Zuni Site. Bob is a Certified Professional Geologist and a Licensed Professional Soil Scientist, and is the senior geologist at a geotechnical consulting firm in Ashburn, VA.

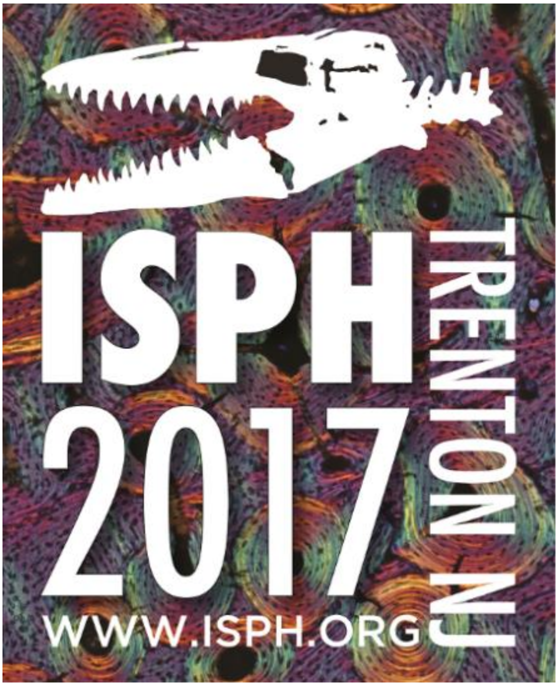
Pamela Machold is a graduate of Sarah Lawrence College and has a master's degree in physical therapy from Acadia University. She has served on Princeton's Environmental and Shade Tree Commissions, and as the President of the Marquand Park Foundation. She and her mother founded the Princeton Child Development Institute, which was the first school for autistic children in New Jersey.

Roland Machold is a graduate of Yale and the Harvard Business School. He worked in investment banking for a dozen years, and then for twenty three years he served as the Director of the Division of Investment for the State of New Jersey, with over $80 billion of assets under his management when he retired in 1998. He came out of retirement in 1999 and served as the State Treasurer until 2001. He currently is on the Board of the Child Health Institute of New Jersey and is an emeritus Trustee of both Bryn Mawr College and Columbia Teachers College. In 1989, he helped found "Dobro," a Russian charity to help autistic children in that country.

Margaret M. O'Reilly was named Executive Director of the New Jersey State Museum in 2016. She began her career at the State Museum in 1988 as the Publications/Graphics Art Director. In 1997, she was named Assistant Curator, Fine Art Collections and Exhibitions, and in 2008 became the Curator of Fine Art. Ms. O'Reilly has been a panelist or lecturer at museums, colleges, and professional conferences on topics including 20th century American art, collection stewardship, museums and copyright, and careers in museums, among others. Ms. O'Reilly currently serves on the Board of the Mid-Atlantic Association of Museums and on the Visual Arts Advisory Committee of Mercer County Community College.

Henry Sadowski is a retired attorney who received his law degree at Rutgers Law School and served 35 years in the U.S. Department of Justice. He has been a volunteer with the New Jersey State Museum for four years, specializing in fossil preparation. He also leads tours as a docent for the Museum.

Lance Schnatterly received his degree in Astronomy/Computer Science from the Pennsylvania State University and is currently a senior staff engineer at Lockheed Martin, where he has worked since 1981. Lance has been focusing his spare time on dinosaur excavations in the Hell Creek and Lance Formations of Montana, South Dakota and Wyoming. He is a member of the Society of Vertebrate Paleontology and the Paleontological Society, and serves on the board of the Delaware Valley Paleontological Society (DVPS).



The **ISPH 2017 logo** shows the silhouette of NJSM 11053, a nearly complete skull of *Mosasaurus maximus* that has become emblematic of the natural history program at New Jersey State Museum. The specimen has been used repeatedly for dental histological studies by NJSM scientists for previous ISPH symposia, and is on display in the Museum galleries. The silhouette is over a micrograph of Haversian canals in *Hipparion* by Dr. Santiago Gomez, which serves not only as a background, but as a colorful link to paleohistology.

MISSION

As a center of cultural, educational, and scientific engagement, the New Jersey State Museum inspires innovation and lifelong learning through collections, research, exhibitions and programs in science, history and art. The New Jersey State Museum fosters state pride, serves as a cultivator of tomorrow's leaders and engages visitors of all ages and diverse backgrounds in an exploration of New Jersey cultural and natural history presented within a global context.

HISTORY

In 1895, the New Jersey State Legislature formally established the New Jersey State Museum in the capital city of Trenton with a mission to collect and exhibit specimens in natural history, archaeology, and industrial history. Original collections included natural history specimens amassed in the 19th century by the New Jersey Geological Survey. Between 1900 and 1912, the State Museum strengthened its archaeology focus by initiating a field research program.

It adopted a statewide Education Extension Service in 1914 that lent models, lantern slides, and specimens to schools throughout the state. In 1929, expanded space in the newly-constructed State House Annex permitted extensive exhibitions of the natural history and New Jersey prehistory collections. Decorative arts became a third collection field at this time when the State Museum expanded its focus beyond industrial history to include the manufacture of ceramics. The ethnographic collection was initiated in 1932 when the State Museum purchased part of an exhibition of North American Indian art. The collection was strengthened in the 1940s when anthropologist Frank Speck made field collections for the State Museum among the Delaware Indians of Oklahoma and Canada. Exhibitions of these artifacts attracted the interest of New Jersey residents whose donations from private collections built the collection in the ensuing years. Growing interest in education and culture in the late 1950s resulted in the construction of a modern cultural complex near the State House that opened in 1965 and included a four-level Museum building, an adjoining planetarium, and an adjacent auditorium. At that time, fine art became the Museum's fourth collection area.

The State Museum was initially accredited by the American Alliance of Museums in 1974. Since 1983 it has been a division of the New Jersey Department of State.

The New Jersey State Museum Foundation was founded in 1968 as a non-profit 501(c)(3) to support the Museum collections, exhibitions and programs through fundraising, volunteerism, and advocacy. In recent years, the Foundation has received generous support from the Hyde and Watson Foundation; the National Endowment for the Arts; New Jersey Historical Commission; New Jersey State Council on the Arts; NJM Insurance Group; and the PNC Foundation. In addition to a robust membership program and special events, the Foundation operates a retail shop featuring merchandise related to the Museum exhibitions and New Jersey history and culture. Proceeds from the Foundation's activities support the Museum collections, exhibitions and programs.

PROGRAM – MAIN EVENTS

SATURDAY, JULY 8, 2017

Time	Event	Location
10:00 AM – 6:00 PM	Workshop I How to perform excellent paleohistology: preparation and imaging methods (*basic*)	New York University College of Dentistry, 345 East 24th Street, Room 817-S, New York, NY
10:00 AM – 6:00 PM	Workshop II How to perform excellent paleohistology: preparation and imaging methods (*advanced*)	New York University College of Dentistry, 345 East 24th Street, Room 817-S, New York, NY

SUNDAY, JULY 9, 2017

Time	Event	Location
8:30 AM	Shuttle to NJSM, Trenton	Nassau Inn, Princeton
9:00 AM – 12:30 PM	Workshop III The Process of Paleohistology: Standard Thin Sectioning	NJSM STEAM Center (Natural History Hall Classroom and Public Paleontology Lab, 2nd Floor)
12:30 PM – 1:30 PM	Lunch (on your own)	NJSM 1st Floor
1:30 PM – 5:00 PM	Workshop IV Advanced Histology Techniques for Fossils & Modern Bone Basics	NJSM STEAM Center (Natural History Hall Classroom and Public Paleontology Lab, 2nd Floor)
5:15 PM	Shuttle to Nassau Inn, Princeton	NJSM, Trenton
5:30 PM – 6:00 PM	Early Registration	Guyot Hall, Princeton University
6:00 PM – 8:00 PM	Ice Breaker	Guyot Hall, Princeton University

PROGRAM – MAIN EVENTS

MONDAY, JULY 10, 2017

Time	Event	Location
8:00 AM	Shuttle to NJSM, Trenton	Nassau Inn, Princeton
8:30 AM – 9:00 AM	Registration	NJSM Auditorium Lobby
8:30 AM – 9:00 AM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
8:30 AM – 9:00 AM	Upload talks & Poster set-up	NJSM Auditorium
9:00 AM – 9:15 AM	Welcome Address	NJSM Auditorium
9:15 AM – 10:15 AM	Keynote Lecture (Greg Erickson)	NJSM Auditorium
10:15 AM – 10:45 AM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
10:45 AM – NOON	Session I: Ontogeny and Development, part 1	NJSM Auditorium
NOON – 1:30 PM	Lunch (on your own)	Local Restaurants
1:30 PM – 2:45 PM	Session II: Ontogeny and Development, part 2	NJSM Auditorium
2:45 PM – 3:15 PM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
3:15 PM – 4:45 PM	Session III: Dental Tissues	NJSM Auditorium
5:00 PM	Shuttle to Nassau Inn, Princeton	NJSM, Trenton

TUESDAY, JULY 11, 2017

Time	Event	Location
8:00 AM	Shuttle to NJSM, Trenton	Nassau Inn, Princeton
8:30 AM – 9:00 AM	Registration	NJSM Auditorium Lobby
8:30 AM – 9:00 AM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
8:30 AM – 9:00 AM	Upload talks & Poster set-up	NJSM Auditorium
9:00 AM – 10:00 AM	Keynote Lecture (Phil Manning)	NJSM Auditorium
10:00 AM – 10:30 AM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
10:30 AM – 11:15 AM	Session IV: Biomechanics	NJSM Auditorium
11:15 AM – NOON	Session V: Methodologies and Nomenclature	NJSM Auditorium
NOON – 1:30 PM	Lunch (on your own)	Local Restaurants
1:30 PM – 2:45 PM	Session VI: Physiology	NJSM Auditorium
2:45 PM – 3:15 PM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
3:15 PM – 4:45 PM	Special Session: Histology and Archaeology	NJSM Auditorium
5:00 PM	Shuttle to Nassau Inn, Princeton	NJSM, Trenton

PROGRAM – MAIN EVENTS

WEDNESDAY, JULY 12, 2017

Time	Event	Location
8:00 AM	Shuttle to NJSM, Trenton	Nassau Inn, Princeton
8:30 AM – 9:00 AM	Registration	NJSM Auditorium Lobby
8:30 AM – 9:00 AM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
8:30 AM – 9:00 AM	Upload talks & Poster set-up	NJSM Auditorium
9:00 AM – 10:00 AM	Keynote Lecture (Peter Dodson)	NJSM Auditorium
10:00 AM – 10:30 AM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
10:30 AM – NOON	Poster Session	NJSM West Gallery
NOON – 1:00 PM	Lunch (on your own)	Local Restaurants
1:30 PM – 2:30 PM	Keynote Lecture (Allison Tumarkin-Deratzian)	NJSM Auditorium
2:30 PM – 3:15 PM	Session VII: Phylogeny	NJSM Auditorium
3:15 PM – 3:30 PM	Concluding Remarks & Round Table Discussions	NJSM Auditorium
3:30 PM – 4:00 PM	Coffee, Tea & Snack Break	NJSM Auditorium Lobby
4:00 PM	Bus to Asbury Park	NJSM, Trenton
5:00 PM – 6:00 PM	Asbury Park Boardwalk & Beach (on your own)	Asbury Park
6:00 PM – 7:00 PM	Cocktail Hour	Tim McLoone's Supper Club, Asbury Park
7:00 PM – 9:00 PM	Closing Dinner	Tim McLoone's Supper Club, Asbury Park
9:00 PM	Bus to Nassau Inn	Tim McLoone's Supper Club, Asbury Park

THURSDAY, JULY 13, 2017

Time	Event	Location
7:30 AM – 5:00 PM	Field Trip 1	Nassau Inn, Princeton

FRIDAY, JULY 14, 2017

Time	Event	Location
7:30 AM – 7:30 PM	Field Trip 2	Nassau Inn, Princeton
7:45 AM – 6:45 PM	Field Trip 3 (Alternate and *Concurrent* to Field Trip 2)	Nassau Inn, Princeton

PROGRAM – SCIENTIFIC SESSIONS

MONDAY, JULY 10

8:00 AM	BUS TO NEW JERSEY STATE MUSEUM
8:30 AM	REGISTRATION; COFFEE, TEA & SNACKS
9:00 AM	***Welcome & Announcements***
9:15 AM	**Gregory M. Erickson** *KEYNOTE LECTURE: COMPLEX DENTAL STRUCTURE AND BIOMECHANICS IN NON-AVIAN DINOSAURS*
10:15 AM	COFFEE, TEA & SNACK BREAK

Session I: Ontogeny and Development, Part 1

Moderators: Christian Heck Sarah Werning

10:45 AM	**Oscar Cambra-Moo** EXPLORING THE HISTOMORPHOLOGY OF THE HUMAN FIRST RIB THROUGH ONTOGENY
11:00 AM	**Holger Petermann** USING OSTEOHISTOLOGY AND COMPUTED TOMOGRAPHY TO RECONSTRUCT THE ONTOGENY OF THE BASAL SAUROPODOMORPH *ANCHISAURUS POLYZELUS*
11:15 AM	**Daniel E. Barta** BONE HISTOLOGY AND GROWTH OF *HAYA GRIVA* (DINOSAURIA: ORNITHISCHIA) FROM THE LATE CRETACEOUS OF MONGOLIA
11:30 AM	**Eli Amson** TRABECULAR ARCHITECTURE IN THE XENARTHRAN (MAMMALIA) FORELIMB EPIPHYSES
11:45 AM	**Sophie Sanchez** LIFE HISTORY OF THE STEM TETRAPOD *HYNERIA*
NOON	LUNCH (on your own)

Session II: Ontogeny and Development, Part 2

Moderators: Justyna Miszkiewicz and Edina Prondvai

1:30 PM **Megan R. Whitney**
OSTEOHISTOLOGICAL SIGNATURES OF HATCHING IN MODERN RATITES WITH IMPLICATIONS FOR RECONSTRUCTING THE EARLY ONTOGENY OF DINOSAURS

1:45 PM **Mateusz Wosik**
DEFINING DINOSAUR NEONATAL BODY SIZE USING OSTEOHISTOLOGICAL EVIDENCE

2:00 PM **Edina Prondvai**
ALLOMETRIC INTRASKELETAL GROWTH PATTERNS AND THEIR FUNCTIONAL IMPLICATIONS IN DINOBIRDS

2:15 PM **Jennifer Botha-Brink**
OSTEOHISTOLOGY OF LATE TRIASSIC PROZOSTRODONTIAN CYNODONTS FROM BRAZIL

2:30 PM **Carmen Nacarino-Meneses**
IDENTIFYING BIRTH FROM BONE HISTOLOGY: A STUDY IN EXTANT *EQUUS*

2:45 PM COFFEE, TEA & SNACK BREAK

Session III: Dental Tissues

Moderators: Mateusz Wosik and Catherine Sartin

3:15 PM **Julia Audije-Gil**
AN APPROACH TO MICROPRESERVATION OF CROCODILIAN FOSSIL TEETH THROUGH HISTOCHEMICAL DATA

3:30 PM **Michael D. D’Emic**
RAPID TOOTH REPLACEMENT RATES IN THE THEROPOD DINOSAUR *MAJUNGASAURUS* FROM THE LATE CRETACEOUS (MAASTRICHTIAN) OF MADAGASCAR

3:45 PM **Yara Haridy**
TOOTH REPLACEMENT AND MIGRATION IN THE EARLIEST ACRODONT REPTILE, *OPISTHODONTOSAURUS*

4:00 PM **Aaron R. H. LeBlanc**
TOOTH ATTACHMENT IN MOSASAURIDS REVISITED: AN ONTOGENETIC PERSPECTIVE TO SQUAMATE TOOTH DEVELOPMENT AND EVOLUTION

4:15 PM **Guillem Orlandi-Oliveras**
FIRST APPROACH TO BONE AND DENTAL HISTOLOGY OF GREEK HIPPARIONINES

4:30 PM **Barbara S. Grandstaff**
OVER A CENTURY OF THIN SECTION MICROSCOPY OF THE FOSSIL FISH *CYLINDRACANTHUS*

5:00 PM BUS TO NASSAU INN

TUESDAY, JULY 11

8:00 AM BUS TO NEW JERSEY STATE MUSEUM

8:30 AM REGISTRATION; COFFEE, TEA & SNACKS

9:00 AM **Phil Manning**
KEYNOTE LECTURE: IMAGING FOSSILIZED BIOMATERIALS

10:00 AM COFFEE, TEA & SNACK BREAK

Session IV: Biomechanics

Moderators: David Parris and Rodrigo Pellegrini

10:30 AM **Alida M. Bailleul**
TYRANNOSAURUS REX SHOWS HISTOLOGICAL EVIDENCE FOR AVIAN-STYLE CRANIAL KINESIS

10:45 AM **Jordi Estefa**
CAN THE SEMI-ERECT POSTURE OF MODERN ECHIDNA BE CONSIDERED AS A PROXY FOR INTERPRETING THE POSTURE OF EARLY TERRESTRIAL TETRAPODS?

11:00 AM **Lucas Legendre**
LONG BONE HISTOLOGY OF THE AARDVARK (AFROTHERIA, TUBULIDENTATA)

Session V: Methodologies and Nomenclature

Moderators: David Parris and Rodrigo Pellegrini

11:15 AM **Marilyn Fox**
TREATMENT OF FOSSIL SPECIMENS BEFORE AND AFTER DESTRUCTIVE SAMPLING

11:30 AM **Alexandra Houssaye**
QUANTITATIVE 3D ANALYSIS OF LONG BONE SHAFT MICROANATOMICAL AND GEOMETRICAL FEATURES AMONG MAMMALS

11:45 AM LUNCH (on your own)

Session VI: Physiology

Moderators: Alida Bailleul and Allison Tumarkin-Deratzian

1:30 PM **Santiago Gomez**
PRESERVED MINERALIZED FIBERS IN OSTEONS FROM A *SPINOSAURUS AEGYPTIACUS* BONE

1:45 PM **Maïtena Dumont**
SYNCHROTRON INVESTIGATION OF THE 3D VASCULAR SYSTEM OF SAUROPOD AND MAMMAL LONG BONES

2:00 PM **Zachary M. Boles**
SHELL BONE HISTOLOGY AND HABITAT PREFERENCE OF TURTLES FROM THE K/PG HORNERSTOWN FORMATION, NEW JERSEY (USA)

2:15 PM **Rodrigo A. Pellegrini**
SKELETOCHRONOLOGY, PALEOHISTOLOGY AND LIFESTYLE OF *HYPOSAURUS ROGERSII* (CROCODYLIFORMES, DYROSAURIDAE) FROM THE EARLY PALEOGENE OF NEW JERSEY, USA

2:30 PM **P. Martin Sander**
UNIQUE CORTICAL HISTOLOGY OF GIANT LONG BONE SHAFTS FROM EUROPEAN RHAETIAN (LATEST TRIASSIC) BONEBEDS: THE ENIGMA CONTINUES

2:45 PM REGISTRATION; COFFEE, TEA & SNACK BREAK

Special Session

Microscopy of Prehistoric Bones and Teeth: Interface between Histology and Archaeology

Moderators: Vijay Sathe and Jim Moss

3:15 PM **Oscar Cambra-Moo**
PALEOHISTOLOGY OF HUMAN CREMATED BONES: A CASE FROM THE PREHISTORIC ARCHAEOLOGICAL SITE OF LAGUNITA (SANTIAGO DE ALCÁNTARA, CÁCERES, SPAIN)

3:30 PM **Orosia García-Gil**
TAPHONOMICAL AND PALEOHISTOLOGICAL DATA FROM HISPANO-MUSLIM MAQBARA OF SAN NICOLÁS (MURCIA, SPAIN)

3:45 PM **Rajeev Patnaik**
PALEOHISTOLOGICAL STUDIES ON INCISOR ENAMEL OF MODERN AND FOSSIL MURID RODENTS FROM INDIA: IMPLICATIONS FOR TAXONOMY AND PALEOECOLOGY

4:00 PM **Falguni Katkar**
MICROBIAL INFESTATION ON ARCHAEOLOGICAL BONES: A CASE STUDY OF BINJOR, RAJASTHAN

4:15 PM **Justyna J. Miszkiewicz**
CORTICAL HISTOMORPHOMETRY AND ROBUSTICITY IN ANCIENT ADULT HUMAN FEMUR – BIOMECHANICAL AND DIMENSIONAL RELATIONSHIPS?

4:30 PM **Vijay Sathe**
DENTAL HISTOLOGY AND CHEMISTRY OF PREHISTORIC LARGE MAMMALIAN FAUNA FROM INDIA

5:00 PM BUS TO NASSAU INN

WEDNESDAY, JULY 12

8:00 AM BUS TO NEW JERSEY STATE MUSEUM

8:30 AM REGISTRATION; COFFEE, TEA & SNACKS

9:00 AM **Peter Dodson**
KEYNOTE LECTURE: FIVE CENTURIES OF LOOKING THROUGH LENSES – A PALEONTOLOGIST'S PERSPECTIVE

10:00 AM COFFEE, TEA & SNACK BREAK

10:30 AM **POSTER SESSION**

NOON LUNCH (on your own)

1:30 PM **Allison Tumarkin-Deratzian**
KEYNOTE LECTURE: A REVIEW OF PALEOHISTOLOGY IN PHILADELPHIA: 1990S THROUGH PRESENT

Session VII: Phylogeny

Moderators: Barbara Grandstaff and Alexandra Houssaye

2:30 PM **John M. Rensberger**
TOTAL BONE CELL CYTOPLASM AND SURFACE AREA IN BIRDS, NON-AVIAN DINOSAURS, MAMMALS AND OTHER TETRAPODS

2:45 PM **Peter J. Makovicky**
SYNCHROTRON SCANNING REVEALS EVOLUTION OF DIVING IN HESPERORNITHIFORM BIRDS

3:00 PM **Donald Davesne**
THE EVOLUTION OF ACELLULAR BONE IN TELEOST FISHES

3:15 PM ***Concluding Remarks & Round Table Discussions***

3:30 PM COFFEE, TEA & SNACK BREAK

4:00 PM BUS TO ASBURY PARK (CLOSING DINNER)

POSTERS

1. **Eli Amson**
   LOCOMOTOR ADAPTATION IN THE FEMORAL HEAD TRABECULAR ARCHITECTURE OF SCIUROMORPHS

2. **Ashley W. Poust**
   HISTOLOGY OF THE MAMMALIAN BACULUM

3. **Yumi Asakura**
   PALEOHISTOLOGY IN PAMPATHERE OSTEODERMS: *HOLMESINA PAULACOUTOI*

4. **Julia Audije-Gil**
   NEW OBSERVATIONS ON THE HISTOMORPHOLOGICAL VARIATIONS OF THE HUMAN MIDSHAFT FEMUR

5. **Vijay Sathe**
   OSTEON ARRANGEMENT AND TAXONOMY: SIGNIFICANCE OF BONE HISTOLOGY IN ARCHAEOZOOLOGY

6. **Orosia García-Gil**
   FIRST APPROACH TO THE TAPHONOMY AND PALEOHISTOLOGY OF THE PREHISTORIC ARCHAEOLOGICAL SITE OF “CERRO DE LA ENCANTADA” (II MILLENNIUM B.C., SPAIN)

7. **Carmen Nacarino-Meneses**
   BONE HISTOLOGY OF *EQUUS* FROM STEINHEIM AN DER MURR (MIDDLE PLEISTOCENE, GERMANY)

8. **Guillem Orlandi-Oliveras**
   ENAMEL CYCLICAL MARKS OF UNKNOWN PERIODICITY IN EQUIDAE

9. **Alexandra Houssaye**
   HISTOLOGICAL AND MICROANATOMICAL CONTRIBUTION TO PALEOPHYSIOLOGICAL AND PALEOECOLOGICAL INFERENCES IN THE DICYNODONT *MOGHREBERIA NMACHOUENSIS*

10. **Yara Haridy**
    DENTICULATE CORONOIDS AND INTERNAL MANDIBULAR ANATOMY OF THE PARAREPTILE *DELORHYNCHUS*

11. **Christopher T. Griffin**
PATHOLOGICAL BONE TISSUE IN A LATE TRIASSIC THEROPOD FIBULA, WITH IMPLICATIONS FOR THE INTERPRETATION OF MEDULLARY BONE

12. **Jingmai K. O'Connor**
DEFINITIVE OCCURRENCE OF MEDULLARY BONE IN AN ENANTIORNITHINE (AVES: ORNITHOTHORACES)

13. **Rafael C.L.P. Andrade**
OSTEOHISTOLOGY AS A PROXY FOR THE UNDERSTANDING OF GROWTH STRATEGIES AND EVOLUTION IN EXTANT AND EXTINCT CAIMANINAE (CROCODYLIA, ALLIGATORIDAE)

14. **Sarah-Jane Strachan**
TO WHAT EXTENT CAN PALEOHISTOLOGY HELP US UNDERSTAND EXTINCT ANIMAL BEHAVIOR? A CONCEPTUAL FRAMEWORK APPROACH

15. **Kevin Surya**
PALEOHISTOLOGY TECHNIQUE OF SUB-FOSSILIZED BONE

16. **Christian T. Heck**
POLYESTER OR EPOXY: ASSESSING PRODUCT EFFICACY IN PALEOHISTOLOGICAL METHODS

17. **Rodrigo A. Pellegrini**
PRESSURE VS. VACUUM IN THE RESIN IMPREGNATION OF THIN-SECTION SAMPLES

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COMPLEX DENTAL STRUCTURE AND BIOMECHANICS IN NON-AVIAN DINOSAURS

GREGORY M. ERICKSON

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Reptiles rarely approached the biomechanical sophistication for feeding or dietary diversity seen in mammals. Their teeth are typically non-occluding, semi-conical structures with simplistic parallel-crystallite enamel surrounding an orthodentine core. Conversely, most mammals possess multi-cusped teeth that are drawn across one another during mastication and self-wear to their functional morphology. The most complex dental architectures are seen in herbivorous mammals. Their teeth are composed of up to four constituents (incl. prismatic enamel) that strategically wear creating coarse grinding or slicing surfaces. These allow them to comminute tough and/or abrasive plants and liberate nutrients inaccessible to other animals. Non-avian dinosaurs stand out among reptiles in that precise, mammal-like dental occlusion and self-wearing teeth evolved on at least four occasions. These topographies enabled access to myriad floral types and facilitated their respective ecological diversifications. My research group and colleagues showed that the teeth of these dinosaurs are histologically more complex than formerly appreciated. Using cutting-edge material science and tribological engineering indentation techniques we discovered that wear and fracture relevant material properties are preserved in fossil dental tissues. This led to development of the first 3D Archard's wear model from which we determined how horse-like occlusal surfaces for the grinding of plant matter occurred in hadrosaurids and fuller-like slicing surfaces developed and functioned in ceratopsians. By incorporating micro-fracture testing into our analyses we discovered how wavy enamel in grazing hadrosauroids, despite lacking enamel prisms, served to stymie fracture during the ingestion of exogenous inclusions. Notably our paleontologically-inspired wear model is seeing broad industrial application.

EXPLORING THE HISTOMORPHOLOGY OF THE HUMAN FIRST RIB THROUGH ONTOGENY

Daniel García-Martínez[1*], Oscar Cambra-Moo[2, 3], Orosia García Gil[2], María Canillas[4], Miguel Ángel Rodríguez Barbero[4], Markus Bastir[1], and Armando González Martín[2, 3]

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Human first rib morphology provides important information concerning thorax anatomy from both ontogenetic and phylogenetic perspectives. Luckily, they frequently appear well preserved in the archaeological/fossil record and are easy to assess in commingled samples because of their unique anatomy. Regarding first rib ontogeny, several studies have addressed ontogenetic macro- and micro-anatomical changes separately, but no one has previously combined both approaches.

We selected a sample of 14 first ribs from the ossuary of the *Santa María de la Soledad* medieval church (Spain), from individuals ranging from perinatal to adult (aged through a centroid size-based approach). We applied 3D morphometrics of sliding semi landmarks to quantify rib curvature and mid-shaft cross-sectional outline, then histologically processed the ribs to obtain mid-shaft thin sections. Macroscopically, the first rib changes from a low curved configuration with a rounded cross-section (perinatal) to a highly curved morphology with a "drop-shaped" section (adult). Microanatomically, we identified three patterns of compartmentalization and histological configuration: 1) small rib, cortex poorly vascularized, with a mineralized matrix configured as woven bone in which areas of paralleled-fibered and/or lamellar bone could be distinguished (perinatal cortex); 2) a medium-size cross-section in which a thicker cortex with a well-defined medullary cavity is easily identified, and with a bone matrix mainly organized as lamellar bone (infant individuals); and 3) a large cross-section, highly vascularized, with a thinner highly-remodeled cortex. These ontogenetic changes are important not only to understand rib cage ontogeny but also thorax functional anatomy and evolution.

USING OSTEOHISTOLOGY AND COMPUTED TOMOGRAPHY TO RECONSTRUCT THE ONTOGENY OF THE BASAL SAUROPODOMORPH *ANCHISAURUS POLYZELUS*

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Sauropod dinosaurs are the most gargantuan terrestrial organisms that ever lived on our planet. However, even after decades of studies, the evolutionary history of sauropods is far from being resolved. In particular, several questions regarding the origin of gigantism and body size evolution, and the phylogenetic relationships characterizing the basal branches in Sauropodomorpha, are still unanswered. Here, we present a new comprehensive study of the Early Jurassic taxon *Anchisaurus*. Peculiarities regarding *Anchisaurus* are its body size and its phylogenetic affinities. *Anchisaurus* is a slender and lightly built sauropodomorph compared to its closest relatives (Sauropodiformes such as melanorosaurs) and immediate ancestors (massospondylids). Moreover, *Anchisaurus* is usually recovered in different positions within Sauropodomorpha, but is usually nested within the more derived basal sauropodomorphs, close to Sauropoda proper. Given the combination of small body size in comparison to the closest sister taxa and its derived phylogenetic position constantly recovered in phylogenetic analyses, we hypothesize that *Anchisaurus* is a dwarfed basal sauropodomorph, the first one recovered in the basal branches of Saurischia. We performed osteohistological analyses on femora, humeri, and ribs of three specimens of *Anchisaurus* housed at the Yale Peabody Museum. We found confirmation of dwarfism in this taxon. Using microCT scan data, we were able to reconstruct the skull morphology of the youngest and oldest individuals, allowing for reinterpretation of the diagnosis of this taxon and to test, through application of morphometrics, the heterochronic event that led to dwarfism in *Anchisaurus* and shaped the general skull morphology found in Sauropoda.

BONE HISTOLOGY AND GROWTH OF *HAYA GRIVA* (DINOSAURIA: ORNITHISCHIA) FROM THE LATE CRETACEOUS OF MONGOLIA

Daniel E. Barta[1, 2*] and Mark A. Norell[1, 2]

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Haya griva is a basal neornithischian (or “hypsilophodontid”) dinosaur known from dozens of specimens, including a partial growth series, from the Upper Cretaceous Javkhlant Formation of southeastern Mongolia. Previous studies suggest skeletally mature specimens of basal neornithischian dinosaurs are rare. Given the wide size range of *Haya griva* femora in the collection, we examined growth patterns to ascertain whether any of the individuals had reached somatic maturity. These data additionally inform our work on morphological variation and the systematics of *Haya*. To investigate the maturity of individual specimens, we sampled three femora, representing the longest (162 mm) and shortest (~64 mm) presently available, as well as one intermediate in length (129 mm). Transverse sections of these bones were embedded in epoxy, mounted on glass slides, and ground and polished until transparent. Photomicrographs reveal predominantly parallel-fibered bone in the smaller two femora, and fibrolamellar bone in the largest. The smallest femur lacks growth lines (=LAGs, annuli). Growth lines are difficult to discern in the medium-sized femur because of poor preservation. The largest femur contains at least four growth lines, but lacks an external fundamental system, indicating it had not slowed growth asymptotically at the time of death. Body masses estimated from the femoral circumferences of the sectioned individuals are 0.95, 11, and 30 kg. We conclude that, as for closely related taxa, all *Haya griva* specimens discovered so far are probably skeletally immature and that the upper limit of body size for this taxon remains unknown.

TRABECULAR ARCHITECTURE IN THE XENARTHRAN (MAMMALIA) FORELIMB EPIPHYSES

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Trabecular architecture (i.e., relative number of trabeculae, their main orientation, mean thickness, spacing, etc.) has been shown experimentally to adapt with extreme accuracy and sensitivity to the loadings applied to the bone during life. However, the functional signal in trabecular parameters has only been superficially studied, as present studies are mostly limited to primates. Here we use high-resolution computed tomography to analyze the 3D architecture in the epiphyses of the forelimb of xenarthrans, i.e., sloths, anteaters, and armadillos, and their extinct relatives. Xenarthrans form a major clade of placental mammals, with modern taxa specialized in several locomotor styles and utilizing diverse hand postures: unguligrade-subunguligrade (armadillos), inverted hand (small and medium-sized anteaters), ‘knuckle-walking’ (giant anteater), and suspensory (extant sloths). They are also characterized by various degrees of digging ability. Extinct xenarthrans, “ground sloths” in particular, were also reconstructed as practicing several peculiar stances, mostly based on the gross morphology of their postcrania. Xenarthrans hence offer a suitable framework to study the response of trabecular bone to different loading regimes within a well-defined clade. Our analyses involve 3D trabecular parameters deriving from the selection of regions of interest in the epiphyses of the forelimb. We found significant differences among trabecular parameters of the extant xenarthran clades (e.g., higher degree of anisotropy in the armadillo glenoid cavity, even after size correction). These differences have the potential to help elaborate paleobiological inferences.

LIFE HISTORY OF THE STEM TETRAPOD *HYNERIA*

VIKTORIIA KAMSKA[1], EDWARD B. DAESCHLER[2], JASON P. DOWNS[2], PER E. AHLBERG[1], PAUL TAFFOREAU[3] AND SOPHIE SANCHEZ[1, 3*]

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In order to understand the ecological dimension of the fish-tetrapod transition, which occurred within the tetrapod stem group during the Devonian Period (419-359 million years ago), we need life-history data from transitional forms. Only recently have serious attempts begun to utilize limb-bone histology as a source of such data. Here we present histological life history data from a humerus (ANSP 21483) of *Hyneria lindae* obtained by propagation phase contrast synchrotron microtomography (ESRF, France). *Hyneria*, a fish member of the tetrapod stem group from the Late Devonian Catskill Formation (Pennsylvania, USA), is closely related to the better known *Eusthenopteron* but much larger (body length at least two meters). The internal structure of its humerus is similar to those of *Eusthenopteron* and the limbed stem tetrapod *Acanthostega*. The spongiosa contains primitive bone marrow processes, indicating that bone marrow was already intimately associated with long-bone elongation and endochondral ossification before the transition from fins to limbs. The humerus presents a mixture of 'juvenile' and 'adult' histological features, suggesting either that it represents a subadult individual or that *Hyneria* was in some respects paedomorphic. The latter hypothesis is supported by the unossified condition of the endocranium even in large individuals. The thin humeral cortex exhibits a relatively slow bone growth rate. Interestingly, *Eusthenopteron* and *Acanthostega* also show slow growth and late (> 6 years) sexual maturity. A broad-sample investigation of additional taxa will be needed to assess the generality of this pattern and map the reproductive trends during the early evolution of tetrapods.

OSTEOHISTOLOGICAL SIGNATURES OF HATCHING IN MODERN RATITES WITH IMPLICATIONS FOR RECONSTRUCTING THE EARLY ONTOGENY OF DINOSAURS

MEGAN R. WHITNEY[1], MATEUSZ WOSIK[2, 3], LISA DORAN[1], KRISTINA CURRY ROGERS[4], HOLLY WOODWARD[5], AND DAVID C. EVANS[2, 3]

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Circumferential zones of reduced vascularity have been proposed to represent an osteohistological indicator of hatching in a perinatal sauropod and have been used to infer an approximate hatchling body size. However, a lack of data on neonatal signals in long bone histology among extant vertebrates limits paleohistological interpretations. Here we report on the long bone histology of pre- and post-hatching ratites to detail the features of this important transitionary period between embryo and neonate. Femora and tibiotarsi from a constrained ontogenetic sample of embryonic and perinatal *Dromaius novaehollandiae* (emu) and *Struthio camelus* (ostrich) individuals (n=13) were transversely thin-sectioned at the minimum diaphyseal circumference.

All specimens display highly vascularized fibrolamellar and/or woven tissue with longitudinal primary osteon orientation in both the femora and tibiotarsi. Pre-hatching individuals show relatively uniform vascular porosity (~30%) throughout the entire cortex, with the exception of a single specimen that exhibits slightly narrower canal spaces towards the periosteal surface. Post-hatching individuals consistently have a circumferential zone characterized by a reduction in osteon diameter where the percentage of open vascular spaces within the mid-cortex is significantly smaller (~9.8%) than towards the endosteal (~18.20%) or periosteal (~28.06%) surfaces. This temporary reduction in vascular space is a result mostly of increased osteonal deposition around the canals within this zone and is similar to what has been observed in a perinatal sauropod dinosaur. Continued investigation of a neonatal signal in extant vertebrates will refine the definition of this osteohistological signature and its implications in understanding early dinosaur ontogeny.

DEFINING DINOSAUR NEONATAL BODY SIZE USING OSTEOHISTOLOGICAL EVIDENCE

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The earliest life histories of extant vertebrates are punctuated by a transition in bone deposition immediately after birth/hatching and recorded in teeth and bones as a ‘neonatal’ or ‘hatching’ line. Recent studies have noted comparable features in perinatal dinosaurs, allowing approximation of hatchling size. Here we investigate embryonic and perinatal bone histology in extant ratites (emu, ostrich) and non-avian dinosaurs (hadrosaurid, hypsilophodontid, sauropod) in order to qualitatively compare the osteohistological signal of hatching.

Ratite femora and tibiotarsi were thin-sectioned at mid-diaphysis from a series of 13 individuals with known age bracketing the hatching period. Dinosaur stylopodial and zeugopodial elements for 17 individuals were similarly thin-sectioned and categorized by size and association with eggshell material. Regardless of taxonomic identity, embryos exhibit highly cancellous and disorganized woven-fibered bone whereas perinates have fibro-lamellar bone with longitudinally or radially orientated vascular canals. Perinates preserve a narrow zone of reduced vascularity typically coinciding with a darkened band. This circumferentially oriented zone is intraspecifically consistent with known hatchling sizes for ratites and partitions the embryonic and perinatal bone regions, although with some degree of circumferential variation. Therefore, we suggest this is an osteohistological indicator for hatching and define it as the *neonatal signal*.

Clarification of the biological meaning of the neonatal signal is important because it provides an accurate neonatal size for growth rate analyses and may convey significant insight for osteohistological cues related to precocity. Further investigation is required to outline the relationships of the neonatal signal to biomechanical, nutritional, environmental, and phylogenetic effects.

ALLOMETRIC INTRASKELETAL GROWTH PATTERNS AND THEIR FUNCTIONAL IMPLICATIONS IN DINOBIRDS

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Paravian dinosaurs are usually characterized by disproportionately long and robust arms, the size of which often even exceeds that of the hind limbs. This allometry can be achieved by differential growth rates of limb elements in different phases of ontogeny. To get insight into intraskeletal growth dynamics, we studied the osteohistology of limb bones in five paravian dinosaurs from the Middle/Late Jurassic and Early Cretaceous of China, *Anchiornis*, *Aurornis*, *Eosinopteryx*, *Jeholornis* and a yet unnamed taxon, with qualitative and various quantitative methods. Our results show that despite their largely uniform 'dinobird' bauplan, different bones reveal diverse growth dynamics with no element-specific consistent pattern across taxa. Furthermore, ontogenetic stages combined with intraskeletal growth dynamics explain osteohistological diversity patterns better than pure taxonomic status in these paravian dinosaurs. The only possible exception is the avian *Jeholornis* which, besides being larger, had superior aerial skills compared to the other studied non-avian taxa. However, locomotion-related and phylogenetic influences resulting in the distinct histology of this taxon cannot currently be separated. Histology also provided independent evidence of restored hand bones in this *Jeholornis* specimen. Nevertheless, ≥50% of variance remains consistently unexplained, which implies the importance of unexplored factors, including possibly locomotor adaptations, in shaping the investigated histological characters. As allometric intraskeletal development in these paravian taxa involves significant and diverse proportional changes in limb bones during ontogeny, our study reveals the importance of exploring ontogenetic stage and postnatal intraskeletal growth dynamics when studying aerodynamic performance of dinosaur-bird transitional forms to reconstruct the evolution of avian flight.

OSTEOHISTOLOGY OF LATE TRIASSIC PROZOSTRODONTIAN CYNODONTS FROM BRAZIL

JENNIFER BOTHA-BRINK[1, 2*], MARINA BENTO SOARES[3],
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The Prozostrodontia was a group of Triassic eucynodonts, the derived members of which gave rise to the Mammaliaformes, in which Mammalia is nested. Analyzing their growth patterns is thus important for understanding the evolution of mammalian life histories. Obtaining material for osteohistological analysis is difficult due to the rare and delicate nature of most of the prozostrodontian taxa much of which comprises only crania or sometimes even only teeth. Here we present a rare opportunity to observe the osteohistology of several postcranial elements of the basal prozostrodontid *Prozostrodon brasiliensis*, the tritheledontid *Irajatherium hernandezi*, and the brasilodontids *Brasilodon quadrangularis* and *Brasilitherium riograndensis* from the Late Triassic of Brazil (Santa Maria Supersequence). *Prozostrodon* and *Irajatherium* reveal similar growth patterns of rapid early growth with annual interruptions later in ontogeny. These interruptions are associated with wide zones of slow growing bone tissue. *Brasilodon* and *Brasilitherium* exhibit a mixture of woven-fibered bone tissue and slower growing lamellar bone. The slower growing bone tissues are present even during early ontogeny. The relatively slower growth in *Brasilodon* and *Brasilitherium* may be related to their small body size compared to *Prozostrodon* and *Irajatherium.* These brasilodontids also exhibit osteohistological similarities with the mammaliaform *Morganucodon.* This may be due to similar small body sizes, but may also reflect their close phylogenetic affinities as *Brasilodon* and *Brasilitherium* are the closest relatives to the Mammaliaformes.

IDENTIFYING BIRTH FROM BONE HISTOLOGY: A STUDY IN EXTANT *EQUUS*

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The study of bone microstructure is known to provide key insights about the growth and life history strategy of extant and extinct vertebrates. Because bone growth marks usually register annual cycles of growth, they have been used to reconstruct important life history traits of the species such as longevity or age at maturity. However, non-cyclical bone growth marks can also be identified in the bone cortex. Although the ultimate causes of deposition of this kind of features are poorly known, they are supposed to record moments of physiological stress in the organism.

Here, we aim to investigate the relationship between non-cyclical bone growth marks and stressful biological events. To achieve that objective, histological slices of femora, tibiae and metapodial bones have been prepared from individuals of known age and sex of *Equus hemionus*, *E. quagga* and *E. grevyi*. Several of the specimens lived captive in the Hagenbeck Zoo (Hamburg, Germany), while others lived semi-captive in the Réserve Africaine de Sigean (Sigean, France). The results obtained reveal the presence of a non-cyclical bone growth mark that is deposited around birth, analogous to the neonatal line described for teeth. This neonatal line in bones, which is accompanied by other histological changes in femur and tibia, has been identified in various bones of all age groups. Our findings of an important disruption in the deposition of perinatal bone tissue and an associated change in tissue type, are essential for future skeletochronological studies in extant and extinct equids.

AN APPROACH TO MICROPRESERVATION OF CROCODILIAN FOSSIL TEETH THROUGH HISTOCHEMICAL DATA

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The fossil site of "Lo Hueco" is an Upper Cretaceous Konzentrat-Lagerstätte located in Cuenca (Spain) in which microstructure of bones and teeth is exceptionally preserved due to possible differential micropreservation events. In order to enrich fossilization and paleobiological knowledge, paleohistological and physicochemical analyses of several teeth from this outcrop were performed. First, after preparing thin sections of two Eusuchian crocodyliform teeth from two marly mudstone levels of the site, their structure was observed and photographed, using polarized light microscopy. Second, we contrasted the information of the composition and structure from seven points of the complete tooth length by two means: Fourier Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscope (SEM). As previously described in the literature, two sort of periodic layers, representing long and short depositional periods, have been identified in the dentine microstructure. The analysis of the nanometric texture of the tooth reveals also two rugosity levels and surface unevenness on the mineral phase. Concerning the chemical analysis, an alteration of the original bioapatite of the tooth was observed and photographed, but no important variations on the composition of each layer (no significant changes in the Ca/P ratio along the tooth) were observed. Finally, Fe was detected between some layers, as well as a slight degree of sample carbonation. These biomineralized tissue studies, through the combination of microstructure data and geochemical analysis, offer accurate insights to the preservation processes and paleobiological interpretations of the fossil biotas.

RAPID TOOTH REPLACEMENT RATES IN THE THEROPOD DINOSAUR MAJUNGASAURUS FROM THE LATE CRETACEOUS (MAASTRICHTIAN) OF MADAGASCAR

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Majungasaurus crenatissimus is an abelisaurid theropod dinosaur known from abundant material from the latest Cretaceous (Maastrichtian) of Madagascar. The species was cannibalistic; lived in a harsh, seasonal paleoenvironment; and underwent unusually slow somatic growth to achieve a modest body size. Like other abelisaurids, *Majungasaurus* had smaller teeth and a dorsoventrally tall, anteroposteriorly short skull relative to other theropods. In order to investigate the unusual anatomy of *Majungasaurus*, we thin-sectioned a sample of over 20 isolated teeth and CT scanned over a dozen dentigerous elements collected across the large exposures of the Maevarano Formation in northwest Madagascar. We contextualize our findings with novel CT and histological data from *Allosaurus* and *Ceratosaurus*. Daily-deposited incremental lines of von Ebner in *Majungasaurus* have thicknesses in the range seen in other dinosaurs. Owing to their small size *Majungasaurus* teeth formed relatively quickly. CT scans reveal multiple generations of replacement teeth in each alveolus. There is only a small size discrepancy between successive replacement teeth, indicating rapid tooth replacement rates relative to other theropods. This is perhaps related to a specialized diet and/or feeding style in *Majungasaurus*.

TOOTH REPLACEMENT AND MIGRATION IN THE EARLIEST ACRODONT REPTILE, *OPISTHODONTOSAURUS*

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Almost all extant squamates possessing acrodont dentition are grouped within the clade Acrodonta. Extant members of Acrodonta do not replace their teeth (monophyodonty) and other acrodont lepidosaurs exhibit reduced tooth replacement; this shared reduction of replacement within the clade has resulted in oligophyodonty becoming associated with the evolution of acrodont implantation. In this study we present new histological data and an ontogenetic series of the earliest acrodont amniote, *Opisthodontosaurus*, from the early Permian. *Opisthodontosaurus* is unusual in exhibiting continuous tooth replacement and migration of tooth positions through ontogeny. This suggests that acrodonty is not universally associated with reduced tooth replacement, but rather that acrodonty predates the evolution of oligophyodonty. Moreover, multiple superimposed generations of alveolar bone and dentine are present at each tooth position in thin section. These layered remnants of teeth track the migration of tooth positions through ontogeny. The vasculature and tooth remnants show an incremental migration posteriorly. This is likely caused by allometric growth of the jawbone that resulted in migration of the tooth positions, whereas the corresponding dental lamina remained in place within the soft tissue. In many other reptiles, this growth is correlated with an increase in tooth count; however in *Opisthodontosaurus,* there is a reduction in tooth count through ontogeny that is likely caused by allometry in tooth size. With this new evidence we offer insights into the supposed link between acrodonty and oligophyodonty, and use *Opisthodontosaurus* as a model organism to describe the mechanisms underlying tooth migration in non-mammalian amniotes.

TOOTH ATTACHMENT IN MOSASAURIDS REVISITED: AN ONTOGENETIC PERSPECTIVE TO SQUAMATE TOOTH DEVELOPMENT AND EVOLUTION

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Mosasaurids were giant marine squamates that roamed the world's oceans during the Late Cretaceous. Their tooth attachment and implantation have been studied extensively in order to determine their affinities within Squamata as well as to compare squamate tooth attachment to that of other amniotes. Mosasaurids provided the first evidence of "mammal-like" tooth attachment in a lizard and have been the focus of renewed interest in the evolution and development of teeth. What remains to be determined, however, is if a lizard is capable of attaching its teeth to the jaws by way of a ligament, a condition elsewhere only seen in mammals and archosaurs. We re-examine tooth attachment tissue histology and development in mosasaurids and show that their teeth were initially held in place by a network of collagen fiber bundles forming a periodontal ligament. Fiber bundles extend through the entire length of the osteocementum of the tooth root. A ligament therefore forms the initial attachment of the tooth to the alveolus and calcifies from the root surface outwards before fusing the tooth in place. The presence of a periodontal ligament in a squamate and its capacity to fully calcify provide new insights into the evolution of tooth attachment in amniotes. What were previously thought to be different tooth attachment tissues in squamates, mammals, and archosaurs are confirmed to be homologous tissues that differ in the extent and timing of the mineralization of the soft tissues supporting the tooth.

FIRST APPROACH TO BONE AND DENTAL HISTOLOGY OF GREEK HIPPARIONINES

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The rich late Miocene fossil assemblages of Greece have provided numerous hipparionine remains that have been the object of several studies. The baseline research on the systematics of these hipparionines, has contributed to set a perfect background for conducting paleohistological analyses on an evolutionary framework. Considering the taxonomic and body size diversity of Greek hipparionines from the late Vallesian (MN10) to the late Turolian (MN13), we aim to characterize their bone and dental histology to infer about their life history strategies.

Metapodials and inferior molars of four distinct species (*Hipparion* cf. *H. sebastopolitanum*, *Hipparion macedonicum*, *Hipparion sithonis,* and *Hipparion philipus*) from five fossil sites were analyzed. From each tooth, we estimated growth patterns and parameters like daily secretion rate (DSR), enamel extension rate (EER) and total crown formation time (CFT). Growth marks and tissue types were used to describe and reconstruct the bone growth of the metapodial bones.

Primary bone tissue types of the hipparionines studied are similar to those observed in extant equids, mainly characterized by a fibrolamellar complex (FLC) with longitudinal primary osteons oriented in circular rows. Regarding dental histology, differences between species were found in several of the parameters studied. Both bone growth marks and dental growth patterns allowed the reconstruction of growth curves for each taxon. The differences observed should be set on an evolutionary, stratigraphic and environmental context.

OVER A CENTURY OF THIN SECTION MICROSCOPY OF THE FOSSIL FISH *CYLINDRACANTHUS*

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Study of the microscopic anatomy of *Cylindracanthus* dates to the nineteenth century. This was continued in the early twentieth century using thin sections of Nigerian specimens. This remarkable genus, known only from its distinctive rostral spines, remains enigmatic. We have reviewed the historical slides of Nigerian specimens in the collections of the British Museum of Natural History and expanded the histologic study of *Cylindracanthus* to include the first detailed description of the tooth bases, examination of possible lesions and healed tissue, petrography of the fossil, and probable functional anatomy. We have repeated the historical comparative studies between *Cylindracanthus* and modern billfish. Billfish rostral structure has no real resemblance (structural or mineralogical) to *Cylindracanthus*. Tooth base attachments in billfish are subdermal. The tooth base structures, lesions, and damaged surfaces in *Cylindracanthus* give no evidence of having been subdermal. We have expanded comparative histological research to include comparisons between *Cylindracanthus* and *Polyodon* (paddlefishes) and *Acipenser* (sturgeons).

Although fish teeth are typically acrodont (i.e., fused to the oral surfaces of the jaw and palatal elements), the teeth of *Cylindracanthus* are functionally pleurodont. They are attached along (in fact, within) a groove, from which they protrude only slightly. The teeth point backwards toward the mouth (away from the tapered end). Hypothetically, the teeth could function in predation by acting as barbs that could cause damage during a stab-and-withdraw motion of the rostral spine; they would be useless in a lateral striking and/or slapping motion. They could have been highly effective during head-on attacks on shelled cephalopods such as ammonites. This would have been advantageous during the Cretaceous Period but of little value during the Eocene, after ammonites had become extinct. We conjecture that the teeth became vestigial after the K-Pg event, as they are unknown in Cenozoic specimens.

IMAGING FOSSILIZED BIOMATERIALS

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Quantitative chemical analyses are rarely undertaken on fossils, despite the potentially valuable information. Trace metal biomarkers have shown that discrete elemental inventories can be identified and mapped in fossil organisms that correlate to specific anatomical structures. Infra-red mapping (FTIR) of organic functional groups also helps in the identification of organometallic compounds that map within discrete biological structures. Additionally, Pyrolysis Gas Chromatography Mass Spectrometry (Py-GCMS) and Matrix Assisted Laser Desorption/Ionization (MALDI) mass spectrometry further constrain the macromolecular composition and endogeneity of samples being mapped. Such elemental inventories and macromolecular data provide insight to specific biosynthetic pathways. Ideally such analyses measure and map the chemistry of bone, soft tissue structures and embedding rock matrix. Mapping fossils *in situ* helps place constraints on mass transfer between the embedding matrix and fossil, aiding in distinguishing taphonomic processes from original chemical zonation remnant from the fossil itself. Conventional non-destructive analytical methods face serious problems in this case and most recent technological advances have been targeted at developing nanometer-scale rather than decimeter-scale capabilities. However, the development of Synchrotron Rapid Scanning X-ray Fluorescence (SRS-XRF) at the Stanford Synchrotron permits large specimens to be non-destructively analyzed (1-100 µm resolution) and imaged using major, minor and trace element concentrations. Fossil and extant samples are mounted in a purpose-built sample chamber held on a computerized x-y-z translational stage. For light-element XRF imaging, an X-ray-transparent ∼30-µm thick polyethylene film was placed on the sample chamber, and purged of air with He to minimize scattering and increase signal to the detector. X-ray Absorption Spectroscopy (XAS) constrains oxidation state and coordination chemistry of key elements (S, Ca, Cu, Zn, Sr, etc.), providing key insight to the endogeneity of chemistry mapped to PPM sensitivity. The combination of precise, repeatable and quantitative techniques build upon decades of research at synchrotron and lab-based facilities, shedding new light on the chemistry and evolution of life.

TYRANNOSAURUS REX SHOWS HISTOLOGICAL EVIDENCE FOR AVIAN-STYLE CRANIAL KINESIS

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Avian cranial kinesis played a significant role in the adaptive radiation of birds, as they evolved from less kinetic, non-avian theropod ancestors. This phenomenon is mediated by synovial joints, which differ from those of other extant sauropsids by forming secondary articular cartilage on membranous elements. This tissue is systematically associated with a synovial cavity, hence kinesis, within the heads of modern birds, and therefore can serve as a diagnostic character for cranial kinesis in non-avian theropod joints.
For the first time, we investigate the presence of secondary articular cartilage in a non-avian theropod dinosaur, Tyrannosaurus rex (MOR 1125). We compare the jaw joint and the otic joint, which are responsible for streptostyly in modern birds. Five extracted fragments of articular surfaces from the surangular, quadrate and squamosal were microCT-scanned and serially sectioned via paleohistology. Complementary data from two extant archosaurs (ducks and American alligators) were also examined.
The squamosal and surangular of T. rex possess a layer of secondary articular cartilage above their subchondral bone, and the quadrate fragments possess primary articular cartilage. These results suggest that the jaw and otic joints of T. rex were both synovial, and identical in structure to those of modern birds, but substantively different from those of alligators. This study provides for the first time clear paleohistological evidence for a synovial otic joint, which bolsters hypotheses of avian-style streptostyly in a theropod dinosaur. It also suggests that birds inherited secondary cartilage from their dinosaurian ancestors, and improves our understanding of dinosaurian cranial kinesis.

CAN THE SEMI-ERECT POSTURE OF MODERN ECHIDNA BE CONSIDERED AS A PROXY FOR INTERPRETING THE POSTURE OF EARLY TERRESTRIAL TETRAPODS?

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Since terrestrial tetrapods' appearance during the Paleozoic, their posture and gait have diversified in response to biomechanical constraints and other evolutionary pressures. The close relationship between locomotion and limbs has made possible the use of limb bone morphology and microanatomy to infer lifestyle, posture, gait, ecology, and other traits of fossil species. The sprawling posture and gait of modern salamanders has commonly been used as a proxy to infer the posture of early terrestrial tetrapods although the gait of early amniotes evolved similarly to that of modern lizards, and diversified later on within the mammalian lineage. Stem mammals present humeri with wide metaphyses and a spongy diaphysis. From an extensive review of 250 mid-shaft thin sections from the literature, the only humeral compactness profile resembling that of *Seymouria* is the profile of the short-beaked echidna. The humeral morphology of the echidna exhibits broad metaphyses and differs substantially from the tubular shape of the humerus of modern salamanders, suggesting different locomotion types. We performed Finite Element Analyses (FEA) on 3D models from propagation phase-contrast synchrotron X-ray microtomographic data of the humeri of the Palaeozoic tetrapod *Seymouria sanjuanensis*, the modern short-beaked echidna and the Japanese giant salamander. Their comparisons suggest that the humeral morphology and microanatomy of the modern echidna would be a better proxy than modern salamanders for studying the posture and gait of Paleozoic terrestrial tetrapods.

LONG BONE HISTOLOGY OF THE AARDVARK (AFROTHERIA, TUBULIDENTATA)

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The aardvark (*Orycteropus afer*) is a large mammal endemic to sub-Saharan Africa. As an insectivore living in a semi-arid environment, it has developed a series of unique abilities, including a highly specialized fossorial lifestyle. Its anatomical and physiological adaptations linked with fossoriality, including the role of its limb bones, have been extensively described in many comparative studies. The bone microstructure of the aardvark limb bones, however, has never been studied, despite an increasing number of publications on the bone histology of mammals in recent years.
Here we describe the histology of all six limb bones in the aardvark, from transverse and longitudinal sections, with a focus on their functional role in fossorial activity for each of them. All bones show extensive remodeling during the last stages of bone growth, and display histological profiles compatible with a strong resistance to bending torsion. Most bones also present a high number of Sharpey's fibers, corresponding to specific muscular insertions, showing a strong functional link between myology and bone microstructure.
The bone histology of the aardvark thus reflects a highly derived burrowing strategy, unique to Tubulidentata. The arrangement of secondary osteons in the outer region of the cortex differs completely from that of all other burrowing mammals, and likely reflects structural constraints linked with large body size. These preliminary results show that bone histology can reflect adaptations to fossorial lifestyle in mammals, and could potentially be used in future studies to infer burrowing strategies in fossil synapsids.

TREATMENT OF FOSSIL SPECIMENS BEFORE AND AFTER DESTRUCTIVE SAMPLING

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Best practices call for sampling a fossil specimen while causing the least amount of damage to rare and irreplaceable resources. Thought should always be given to future use of the specimen and whether current treatments will interfere with future studies, such as isotope or surface studies. Common practices include consolidation, molding and casting. This requires a familiarity with adhesives and molding materials and with effective techniques for their use. Molding is done to retain the morphological information in the original specimen. Molding protocols call for a thin, conservationally sound, barrier layer to protect the bone from rubber oils, filling holes with an easily removable material, such as Carbowax, and careful mold set-up and molding that accurately captures all morphological details. If the specimen is covered with a heavy consolidant or molding is not done with skill, critical information can be forever lost - there may be no record of the original anatomy if sampling damages or destroys those features. After sampling, when reconstructing the element, it is important to show the reconstructed area. Inpainting to conceal the damage only confuses future researchers. It is essential that all materials that are now an irremovable part of the specimen be documented, including specific brand and grade names. Rather than viewing the histological study in isolation, researchers must understand that everything that happens to the specimen during the process is a permanent part of the history of that specimen. Following best practices in treatment will maintain the specimen for future research.

QUANTITATIVE 3D ANALYSIS OF LONG BONE SHAFT MICROANATOMICAL AND GEOMETRICAL FEATURES AMONG MAMMALS

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Long bone inner structure and cross sectional geometry have been assumed to display a strong functional signal, leading to convergences, and are widely analyzed in comparative anatomy at small and large taxonomic scales. Long bone microanatomical studies have been conducted essentially on transverse sections but also on a few longitudinal ones. Recent studies highlighted the interest of analyzing variations of the inner structure all along the diaphysis and with a qualitative but also quantitative approach. The development of microtomography enables to non-destructively access bone inner structure and to develop three-dimensional virtual bone microanatomy, which offers new types of investigations. We analyzed the diaphysis of humeri and femora representing a large ecological and systematic diversity among mammals, resorting to X-ray microtomography and image processing. We selected the quantitative parameters we can use to describe at best the shape changes and distribution of the osseous tissue all along the diaphysis. We notably discussed if some parameters co-vary and their historical (phylogenetic), structural (notably linked to size and allometry), and functional (linked to animal's ecology) signals. This enabled us to select the relevant microanatomical and geometrical parameters to use in a comparative analysis of bone diaphyseal structure in three dimensions.

PRESERVED MINERALIZED FIBERS IN OSTEONS FROM A *SPINOSAURUS AEGYPTIACUS* BONE

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Types of bone tissue in fossilized dinosaur bone are in general well characterized microscopically, whereas the mineralized collagen fiber organization is not often identified. In the present investigation we imaged, at the micron scale, the fossil traces of mineralized fibers preserved in the osteons of a dinosaur bone and compared these traces with fibers observed in ostrich bone.
The specimen examined was a portion of a limb bone of *Spinosaurus aegyptiacus* from Kem Kem beds, Morocco. The fossil bone was cut into several blocks which were embedded in poly-methyl methacrylate. Polished block surfaces were analyzed using backscattered electron microscopy and energy dispersive X-ray microanalysis in the SEM. Thin ground sections were examined by polarization microscopy and by green polarization microscopy, a method which uses green interference color to form a high resolution monochromatic image. The *Spinosaurus* specimen consisted mostly of secondary osteonal bone. Osteons varied in size (320 ± 127 μm in diameter) and were mainly composed of apatite mineral, confirmed by a predominance of phosphorous and calcium and the polarization color when using a 1 λ-plate. Examination of the thinnest sections with green polarization microscopy revealed a mesh of mineralized fibers, stained by green color, against a black background. The mineralized fiber traces had a diameter of about 0.7 μm and formed a rather tight fabric. Size and organization of these fiber traces were similar to those found in ostrich osteons. Interestingly, when *Spinosaurus* sections were decalcified by acid solutions, permineralized fiber traces remained visible.

SYNCHROTRON INVESTIGATION OF THE 3D VASCULAR SYSTEM OF SAUROPOD AND MAMMAL LONG BONES

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Bone is, in general, a vascularized hard tissue, for which the organization is used in histology to classify the different bone tissue types. The interconnected network formed by the canals is an integral component of its microstructure and undergoes continual change throughout life. Its development in the sauropod bones is of particular interest to understand the establishment of their heavy body mass and late ontogenetic remodeling. We used propagation phase-contrast synchrotron microtomography to characterize and quantify the vascular cortex system of an ontogenetic series of sauropod long bones in 3D and compare it to those obtained for large mammals. The vascular volume, orientation and connectivity permit understanding of the impact of growth and bone remodeling on bone biomechanics. Sauropods present in their early stages of development, a laminar vascular organization made of circumferential plates, similar to those observed in juvenile mammals. This organization rapidly fades in mammal bone, and is replaced by a secondary Haversian architecture. The late bone remodeling in sauropod bones has the consequence of keeping the laminar organization at the cortex periphery at the adult stage with a progressive narrowing of the plates and a consecutive enlargement of the radial canals. The bone remodeling results subsequently in both groups in an obvious change of the microstructure with a general reduction of the canal size, a different vascular connectivity, and a more tubular longitudinal orientation. Therefore the specific vascular arrangement observed in adults seems to be highly related to the bone biomechanics to support the heavy mass of giant dinosaurs.

SHELL BONE HISTOLOGY AND HABITAT PREFERENCE OF TURTLES FROM THE K/PG HORNERSTOWN FORMATION, NEW JERSEY (USA)

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Study and description of the bone microstructure of turtle shells has become common in the past decade, as these details can provide important phylogenetic and ecological insights. At least eight turtle species exhibiting various shell morphologies and sizes are known from the Main Fossiliferous Layer (MFL) of the Hornerstown Formation in New Jersey. This diversity may reflect varying niches or degrees of aquatic adaptation among the turtle taxa. As part of a taphonomic and paleoecological study of the MFL, we studied the shell bone microstructure of six of the eight taxa to assess their degree of aquatic adaptation and to infer their habitat preference. Comparisons were made with published descriptions of the seventh taxon (*Osteopygis emarginatus*); the eighth taxon (*Euclastes wielandi*) could not be included because it is only known from cranial material. All specimens displayed the plesiomorphic diploe structure. Primary differences in bone structure among the examined turtles related to thickness of the cortices and the degree of remodeling and expansion of the cancellous region. *Adocus beatus* and *Agomphus pectoralis* are here regarded as semi-aquatic turtles that likely inhabited onshore freshwater environments. *Taphrosphys sulcatus*, *Bothremys* sp., and *Peritresius ornatus* were found to be fully aquatic turtles, with *P. ornatus* exhibiting a shell morphology similar to more pelagic marine forms. The shell bones of *Catapleura repanda* have extremely thin cortices and expansive cancellous bone regions. Combined with its overall shell morphology, this taxon was regarded as well adapted to a pelagic lifestyle.

SKELETOCHRONOLOGY, PALEOHISTOLOGY AND LIFESTYLE OF *HYPOSAURUS ROGERSII* (CROCODYLIFORMES, DYROSAURIDAE) FROM THE EARLY PALEOGENE OF NEW JERSEY, USA

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Although dyrosaurids are common in the fossil record, and are among the few lineages of crocodylomophs that survived the K-Pg extinction, their bone histology is only known from a small sample. Previous workers have made lifestyle inferences for the group from sections of the snout, vertebrae, partial femur, and tibia. To test and improve previous conclusions, we conducted a skeletochronological and paleohistological study of midshaft cross sections of both femora and humeri of NJSM 23368, a nearly complete *Hyposaurus rogersii* skeleton recovered from just above the K-Pg boundary in mid-Danian (early Paleocene) strata of New Jersey.

Histology revealed many closely-spaced LAGs in lamellar-zonal bone that underwent a good measure of remodeling, as evidenced by abundant secondary osteons and small resorption cavities. The completely open medullary cavity is slightly smaller than an extant alligator's. No trabeculae exist, and endosteal deposition appears limited to a very thin lamellar layer that varies in thickness around the medullary cavity. Periosteally, a dark band obscures the bone surface and makes an EFS difficult to confirm. However, at least 4 closely spaced LAGs are visible within it, supporting its presence.

Whether the closely spaced LAGs are annual or double LAGs, the histology proves NJSM 23368 was a fully grown adult. Absence of evidence for osteosclerosis, osteoporosis, and pachyostosis indicates *H. rogersii* was not a fast swimmer in the open ocean, and supports the traditional interpretation: a near-shore marine predator that swims in the axial manner of extant crocodylians, aided by a more powerful undulatory tail.

UNIQUE CORTICAL HISTOLOGY OF GIANT LONG BONE SHAFTS FROM EUROPEAN RHAETIAN (LATEST TRIASSIC) BONEBEDS: THE ENIGMA CONTINUES

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The Rhaetian bonebed of Aust Cliff, U.K., is a classical source of a wide variety of latest Triassic vertebrate fossils. The largest bones from this bonebed are shafts of presumable femora. The straightness and great diameter (>16 cm) of the shaft suggest a total length of these bones of >1 m. Such femora or other large, straight long bones can reasonably be attributed only to Archosauriformes, pertaining either to giant rauisuchian Crurotarsi or to dinosaurs (Sauropoda, Stegosauria, and Ankylosauria - although the latter two taxa do not appear in the fossil record before the Middle Jurassic). Cortical histology of the Aust Cliff bones is dominated by longitudinal vascular canals that are primary in origin, but with secondary osteons deeper in the cortex. In addition the bone matrix shows an abundance of randomly-organized structural fibers (not to be confused with woven bone) and closely-spaced growth marks. Over the past decades, bone histology of Archosauriformes has been comprehensively sampled, and has been shown to be clade-specific. The histology of the Aust Cliff bones does not match any known histology. While size would favor sauropod affinities, histology of these bones shows the least resemblance to the laminar fibrolamellar bone of this clade. Cortical fragments of very large bones are common in a newly discovered Rhaetian bonebed in Germany, and these show the same histology as the Aust Cliff shafts. The unique histology of giant bone shafts from European Rhaetian bonebeds hints at a previously unrecognized experiment in gigantism in Archosauriformes of the latest Triassic.

PALEOHISTOLOGY OF HUMAN CREMATED BONES: A CASE FROM THE PREHISTORIC ARCHAEOLOGICAL SITE OF LAGUNITA (SANTIAGO DE ALCÁNTARA, CÁCERES, SPAIN)

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Burnt bones are typically found in secondary deposits in which remains appear most times partially preserved or fragmented. Complete or articulated bones are quite unusual. Despite many researchers having attempted the analysis of burnt skeletal remains to infer cremation effects on bones, depositional and post-depositional taphonomical events introduce a huge variety of alterations that are difficult to discriminate from cremation effects. Most times anatomical description is not possible due to the alterations, and multidisciplinary approaches become crucial to correctly interpreting changes in volume (shrinkage), weight, coloration, or even microstructure and crystallinity. In this sense, paleohistological approaches have contributed interesting data which assists investigation of the possible pyre conditions.
In the present report we present the results of the histomorphological investigation of burnt bones from the prehistoric archaeological site of Lagunita I (Cáceres, Spain). We analyzed two humeral fragments that were meticulously excavated from a funerary urn and anatomically attributed to a young-adult individual. The two fragments were analyzed histomorphologically, permitting not only description of their stage of preservation but also of their microanatomical characteristics. The humerus metaphysis fragment, in which the cortical bone was thinner, presented white color and heavily altered microstructure. By contrast, the humerus mid-shaft fragment preserved some microanatomical details (the bone matrix was still identifiable). Both fragments confirmed high temperature for pyre conditions. Analysis of tissue compartmentalization in the mid-shaft fragment permitted us to discuss the possibility that the cremated individual was younger that inferred from macroscopic analysis.

TAPHONOMICAL AND PALEOHISTOLOGICAL DATA FROM A HISPANO-MUSLIM *MAQBARA* OF SAN NICOLÁS (MURCIA, SPAIN)

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The Hispano-Muslim archaeological site of San Nicolás (Murcia, Spain) was used as a cemetery (maqbara) during the Islamic occupation of the Iberian Peninsula (11th to 13th centuries). Following Muslim funerary rite, all burials were simple, with the body deposited on its right lateral side, in contact with the sediment and oriented towards the Qibla (facing the Kaaba in Mecca). The site excavation exposed 823 individuals of which 233 were non-adults. Preliminary evaluation of the macro-preservational patterns shows that human remains were in general well preserved, but highly affected by body position (skeletal completeness varied considerably from right to left side, with the left more poorly preserved). We performed a paleohistological analysis to evaluate bone tissue quality or micro-preservation. Thin sections of left humeri at mid-shaft, and three cranial bones (frontal, parietal, occipital) of seven individuals, ranging from infant to young-adult, were histologically analyzed.

Our results show that the microstructure of bone tissues was generally poorly preserved (there is extensive alteration from microorganisms). Nevertheless, we observed that bone tissue preservation varies between bones of the same individual and this does not correlate with macroscopic completeness or with individual age. We also observed that cortical bone section compartmentalization proportions remained similar to those described in previous research on bones of similar individuals from an archaeological site of different age. Thus, quantitative analyses can be used to extract biological data despite bad preservation. Further analysis is necessary to more deeply understand micro-preservational patterns and the manner they can relate to biological characterization of past populations.

PALEOHISTOLOGICAL STUDIES ON INCISOR ENAMEL OF MODERN AND FOSSIL MURID RODENTS FROM INDIA: IMPLICATIONS FOR TAXONOMY AND PALEOECOLOGY

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Rodents in archaeological and paleontological sites are primarily identified on the basis of their molar morphology, cranial and post-cranial characteristics. However, molars are less abundant in the fossil record compared to the ever-growing incisors. Rodent incisors exhibit all the stages of tooth formation simultaneously, and this characteristic makes them an ideal subject for the study of enamel formation and taxonomy.

We carried out preliminary paleohistological studies on incisors of fossil murid rodents collected from Siwaliks (ranging in age from ~14 to 1 Ma), Kutch (~11 Ma), Narmada Valley (~ 150 Ka) and Kurnool Caves (~ 20 Ka). The teeth were compared with those of modern murid rodents from India for taxonomic identification and to understand their biomechanical properties. The results obtained so far indicate that these taxa can be identified in the fossil assemblages at least up to the genus level. The decussation angles observed among rats are larger than those of mice. The incisal inclination of prisms in lower incisors of rats is less than that in mice. Upper incisors have thicker overall enamel and outer enamel compared to lower incisors. Fossil and field mice and rats show slightly thicker outer enamel, compared to the teeth of their extant and domestic counterparts. Those with fossorial adaptation also show thicker outer enamel in their incisors.

MICROBIAL INFESTATION ON ARCHAEOLOGICAL BONES: A CASE STUDY OF BINJOR, RAJASTHAN

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Survival of bones in archaeozoological deposits and change in their histology is primarily dependent on pre and post burial conditions. The process of diagenesis takes place through chemical deterioration of collagen (the organic phase), hydroxyapatite (the mineral phase), and microbial attack on the composite of both. Physical factors like temperature, pH, and active hydrology also govern the process of diagenesis. This study focuses on the microbial alterations on mammalian bones from the proto historic site 4MSR- Binjor in Rajasthan, India. The site is dated to approximately 2200 B.C. Bones of large mammals, fish and reptiles are abundantly found in the habitation area.

This comparative study of sections of archaeological samples and fresh bones infested with pure cultures of bacteria and fungi, sheds light on the process of bone penetration and exploitation of organic contents of bone tissue. Fresh bones of chicken, goat and kingfish were infested with pure cultures of *Bacillus sp.* and *Cladosporium sp*. Pure culture microorganisms, as well as those inherent with the bone, started scavenging the nutrients from the bone upon consumption of organic nutrients from supporting media, thus changing its physical appearance. Microscopic fractures, changes in porosity and surface pigmentation might indicate microbial interactions, and could be used for visual identification in archaeozoological deposits.

CORTICAL HISTOMORPHOMETRY AND ROBUSTICITY IN ANCIENT ADULT HUMAN FEMUR – BIOMECHANICAL AND DIMENSIONAL RELATIONSHIPS?

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Limb bone paleohistology is an insightful tool when reconstructing ancient human behavior. While it is known that biological relationships exist between a range of cortical histology parameters, their association with gross bone anatomy remains largely unexplored. Using quantitative data from English Medieval adult human midshaft femora, we assess how micro- and macroscopic bone structures affect one another from the perspective of tissue form and function. Parameters that included geometry and density of secondary osteons, osteocyte lacunae, and Haversian canals recorded in thin sections from posterior midshaft femur were correlated with the corresponding width of cortex and an estimated bone robusticity in young (n = 49) and middle-aged males (n = 180), and young (n = 77) and middle-aged females (n = 139). A series of statistically significant relationships accounting for moderate portions of data variation were observed. There was an overall positive trend of an increase in cortical width and robusticity with osteon and osteocyte lacunae densities. Diameter and area of osteons and Haversian canals decreased as the width of cortex and robusticity increased. However, these patterns were not consistent across the whole sample. Data indicate that thicker cortex and higher femur robusticity present corresponding variation in histological products of bone remodeling, in agreement with biomechanical principles. However, we do not rule out a bone anatomy dimensional macro-microscopic relationship. Future paleohistology studies utilizing ancient human femora may benefit from undertaking complementary histology and macrostructural analyses.

DENTAL HISTOLOGY AND CHEMISTRY OF PREHISTORIC LARGE MAMMALIAN FAUNA FROM INDIA

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Until recently not much has been explained about proxies of climate change based on histological and chemical analyses of calcified tissues, especially with regard to the Indian Pleistocene. The significant increase in Hunter-Schreger Bands in the enamel of large bovine teeth, suggesting possible shifts in dietary regime of initial early Holocene domesticates, and higher saline levels suggested in the habitats of hippos, are some of the few attempts undertaken so far. The paucity of substantial data with regard to climate change and megafaunal extinction in Indian subcontinent has prompted a fresh enquiry into tooth enamel microstructure and into elemental analyses of calcified tissues of large mammals like rhinos, elephants, large bovines etc. - including climatically sensitive hippopotami, which are known to have perished towards the end of the Pleistocene. The fossil materials in the present study come from three Late-middle to Terminal Pleistocene localities in Peninsular India whose association with prehistoric stone tools are well documented. Age of the fauna ranges between ~150k to ~18k before the present.
The paper is structured in two parts, a) Tooth enamel microstructure, which investigates functional and evolutionary trends, and b) Elemental profiles of the bioapatite, for habitat and environmental interpretations. The results offer fresh information regarding the distribution of different enamel types and an array of elements in dental tissues for a better interpretation of climatic conditions. This method has been employed on large mammals in Europe, Africa and the Americas. The diverse faunal population in the Indian Subcontinent offers great potential for testing the same hypothesis, but in the Indian context which has not hitherto been done.

FIVE CENTURIES OF LOOKING THROUGH LENSES – A PALEONTOLOGIST'S PERSPECTIVE

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Microscopic studies of fossil bone are a commonplace today, a standard practice. Indeed, Horner's dictum succinctly states "Cut absolutely everything." As recently as 25 years ago this was not true. We can recognize modern innovators who explored dinosaur bone histology in the 1960s, such as Armand de Ricqlès who was a lonely pioneer for many years. It is surprising perhaps to learn that studies of fossil bone have a deep history especially in the 19th century. Richard Owen's monograph on Comparative Odontology of 1846 stands out as a beacon. In this study we review seminal studies of the past and document the current bibliographic explosion.

A REVIEW OF PALEOHISTOLOGY IN PHILADELPHIA: 1990S THROUGH PRESENT

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Philadelphia is widely known as a historically significant contributor to North American paleontology, with the continent's oldest natural history museum, the Academy of Natural Sciences, housing the first named North American dinosaur specimens (named by Joseph Leidy in 1856) and the first reasonably complete dinosaur skeleton, *Hadrosaurus foulkii* (named and described by Leidy in 1858). Philadelphia's impact on the field of paleohistology is perhaps less well known, as its contributions have originated not from a single institution, but from a web of interactions including research groups at the University of Pennsylvania, Temple University, and Drexel University. Faculty and student collaboration across institutions, and students and post-docs retaining strong ties to their former research groups, has resulted in a sizable volume of significant contributions over the last three decades. Here I review and highlight the notable output of paleohistological research in Philadelphia since the early 1990s, emphasizing the interconnected and interdisciplinary nature of the city's former and current research community. Research foci have concentrated in four areas: (1) ontogeny and growth dynamics, primarily of crocodilians, non-avian dinosaurs, and birds; (2) paleopathology, primarily of non-avian dinosaurs and birds; (3) paleoecology; primarily of non-avian dinosaurs and turtles; and (4) effects of bone microstructure on geochemistry of fossilization, in diverse taxa from the Cretaceous to Neogene. Together, these three institutions, with additional connections to the Academy of Natural Sciences of Drexel University and the New Jersey State Museum, have created a vibrant local academic community for paleohistological research, now and for the foreseeable future.

TOTAL BONE CELL CYTOPLASM AND SURFACE AREA IN BIRDS, NON-AVIAN DINOSAURS, MAMMALS AND OTHER TETRAPODS

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Dinosaurs contain taxa with the largest body sizes known among terrestrial tetrapods and their modern descendants, birds, have the highest postnatal growth rates among extant terrestrial tetrapods. Recent measurement of the spaces within bone tissue (osteocyte lacunae and canaliculi) in diverse tetrapods indicated that a denser organization of the cell cytoplasm occurs in birds and their saurischian dinosaur relatives than in other groups. Because osteocyte cell bodies are smaller in the saurischians, this raises the question whether there may be a constraint on the total mass of cytoplasm and that this is what causes the cell bodies to be smaller in taxa with increased density of osteocyte extensions. To assess this question, the total area of cytoplasm in the cell bodies and their extensions in taxa with denser canaliculi and small osteocyte cell bodies are compared with that in taxa having larger osteocyte cell bodies. The results indicate that the total cytoplasmic area in thin-sections is relatively constant among major groups, supporting the existence of a constraint on the total cytoplasmic mass.

SYNCHOTRON SCANNING REVEALS EVOLUTION OF DIVING IN HESPERORNITHIFORM BIRDS

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Hesperornithiformes are a clade of extinct stem-group birds from the Cretaceous of Laurasia. The anatomy and skeletal pachyostosis of derived hesperornithiformes indicate they were flightless, foot-propelled divers. However, recent discoveries from Asia and North America led to the recognition of a new sub-clade, Brodavidae, whose members were thought to lack pachyostosis, and therefore may have been volant. To infer the ecological history of the clade, we conducted a virtual histological study on hindlimb bones of hesperornithiform taxa, including recently identified brodavid specimens, and a comparative sample of fossil and extant bird species at the Advanced Photon Source synchotron at Argonne National Laboratory. Three parameters for bone wall thickness and density was quantified in Boneprofiler and optimized on a consensus phylogeny of birds. Brodavid femoral and tarsometatarsal bones are pachyostotic with bone thickness ratios comparable to other hesperornithiformes, but significantly greater than in non-diving extant and fossil outgroups. These results support phylogenetic studies positing that diving habits, and likely flight loss, evolved early in the history of the clade, and that these ecological traits were not secondarily reversed in brodavids.

THE EVOLUTION OF ACELLULAR BONE IN TELEOST FISHES

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Acellular bone – bone lacking enclosed osteocytes – is widespread in teleosts, a clade of ray-finned fishes (Actinopterygii) that accounts for roughly half of extant vertebrate diversity. This feature has been recognized since the mid-19th century in a variety of taxa across teleost diversity. Distribution of acellular bone is tightly linked with phylogeny: it is almost always found in Neoteleostei, a clade including the highly diverse spiny-rayed fishes (Acanthomorpha). However, acellular bone is also found in other teleosts, such as pikes (Esocidae) and smelts (Osmeridae), implying a more complex evolutionary history. Past studies on the distribution of acellular bone largely lack a formal phylogenetic framework. Here, we use a dated super-tree built from recent molecular topologies to reconstruct the history of acellular bone in teleosts. The inclusion of key fossil taxa from different extant lineages increases our understanding of the timing and distribution of this character in the phylogenetic tree. Our results suggest that acellular bone first appeared in a larger clade, Euteleostei. However, this clade also includes taxa with cellular bone, such as salmons and trouts (Salmonidae) and marine smelts (Argentinidae). This fact, combined with persistent uncertainty in the phylogenetic relationships at the base of the euteleost tree, makes interpretation of the results ambiguous. A more systematic survey of the distribution of acellular bone in non-acanthomorph euteleost groups, along with a consolidation of topologies near the base of the teleost tree, are necessary in order to constrain the evolution of this peculiar histological character.

LOCOMOTOR ADAPTATION IN THE FEMORAL HEAD TRABECULAR ARCHITECTURE OF SCIUROMORPHS

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Trabeculae, as part of bone inner structure, build a network of thin bony struts that is constantly remodeled and therefore reflects changes in loading during life (Wolff's law). This adjustment affects both the orientation and the dimensions of the trabeculae. In order to investigate how trabecular architecture reflects different locomotor types, we analyzed the 3D inner bone microstructure of femoral heads in Sciuromorpha. This taxon is diverse in terms of body size and adopted different lifestyles and locomotor types (aerial, arboreal, fossorial). In this study we investigate the effect of locomotor type on trabecular structure while taking body size into account. Analysis was done on high resolution computed tomography scans. A cubic volume of interest was selected in the center of each femoral head and analyzed by extraction of various parameters that characterize trabecular architecture. Some parameters (bone surface density (*BS/BV*), connectivity density (*ConnD*), trabecular thickness (*TbTh*) and trabecular separation (*TbSp*)) are subject to strong allometry. Degree of anisotropy (*DA*) and bone volume fraction (*BV/TV*) show weak allometry. For all parameters except *BS/BV* and *TbTh* the size-corrected data show to some extent adaptive signal to the different locomotor types. The methodology of this study can be applied in a paleobiological framework and enable us to gain information about the lifestyle of extinct sciuromorph taxa.

HISTOLOGY OF THE MAMMALIAN BACULUM

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The baculum is a bone with high morphological variation found in the penis of some placental mammals. It is widely and unevenly distributed across the placental tree, originating multiple times. The utility of bacular gross morphology for relative age assessment has been demonstrated in some taxa, but histological studies remain rare.
In this pilot study, I sample baculum mid-shafts in five taxa from two orders (Carnivora and Rodentia) using standard histological methods. Histovariability among these taxa is high: bacula vary in presence of a medullary cavity, distribution of endosteal lamellae, vascularity, and abundance of secondary osteons. Periosteal erosion and remodeling is suggested by cementing lines between dense Haversian tissue and outer lamellar bone in *Castor canadensis* (beaver), *Neovison vison* (mink), and *Canis latrans* (coyote). From *Lontra canadensis* (otter), I report the first lines of arrested growth (LAGs) in a baculum. The three LAGs are more closely spaced near the urethra showing that growth is primarily dorsal. Similar differential dorsal growth in *Castor* is instead achieved by resorption and addition of avascular lamellar bone suggesting convergent processes.
The variation present suggests that an expanded dataset could reveal correlations with functional and life-history traits. Bacula are often kept with harvested furs and are present in taxa where other bones (i.e. femora) may be influenced by unique functional factors. Bacular histological structure and variation may elucidate heterochronic patterns underlying independent origins of the baculum and its variable morphology, and may provide a novel skeletochronologic tool in animals where other methods are problematic or unavailable.

PALEOHISTOLOGY IN PAMPATHERE OSTEODERMS: *HOLMESINA PAULACOUTOI*

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Xenarthran osteoderms are integumentary bones with high fossilization potential presenting a high degree of morphological and histological diversity. Pampatheres are extinct, large-bodied cingulates that share morphological characters with both armadillos and glyptodonts, but are more closely related to the latter. Here, we present for the first time the histological description of an isolated buckler osteoderm from the South American pampatheriid *Holmesina paulacoutoi* (DGEO-UFPE 5964). The osteoderm presents the classic diploe conformation, but unlike the heavily remodeled osteonal tissues in the osteoderms of large glyptodonts, *H. paulacoutoi* presents a mainly primary compact bone in both the superficial and deep zones. Osteocyte lacunae appear rounded, and sometimes flattened and elongate. They are irregularly and loosely distributed in the deeper zone, but superficially become increasingly densely spaced and arranged in surface-parallel layers. Vascularization is generally low within the superficial and deep zones, consisting of a few primary osteons and some rare secondary osteons. Orientation of the collagen fiber bundles ranges from radial to, to parallel with, the osteoderm surface. The compact bone at the osteoderm margins is marked by abundant Sharpey's fibers arranged in thick but rather loose bundles, which has been interpreted as a synapomorphy of pampatheres. The central trabecular zone exhibits extensive remodeling characterized by numerous large resorption areas, surrounded by concentric bone lamellae with abundant and evenly spaced osteocyte lacunae. The histological pattern described here corroborates the idea of a highly uniform histological organization for osteoderms of pampatheres already described in the literature.

NEW OBSERVATIONS ON THE HISTOMORPHOLOGICAL VARIATIONS OF THE HUMAN MIDSHAFT FEMUR

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Bone undergoes changes in shape, size and tissue typologies through ontogeny. The mapping of bone compartmentalization allows for quantification of these changes in order to understand bone microstructure and growth process. In this work we integrate data concerning the histological description and compartmentalization. We analyzed the microstructure of 6 human mid-shaft femora of different age stages. These femurs came from an archaeological context and were classified in four age groups: 2 perinatals (P1, P2; <1 year), 1 early childhood (I; 2-3 years), 1 juvenile (J; 14-15 years) and 2 adults (A1, A2; >20 years). Thin sections were observed and photographed using brightfield and linearly polarized light microscopy. Histology was described and photomontages were mapped to study the spatial distribution of the bone compartments. We implemented a methodology based on geographic information systems to map the extent of the mineralized area, medullary cavity and vascularization. In relation to histological description, our results are in concordance with the idea of a faster bone growth during early age stages. We have identified different typologies of bone tissue, previously described in the literature, for these stages. Concerning the compartmentalization results, we observe a decrease in the extent of the mineralized area during the early stages (P1, P2, I), while the medullary cavity and vascularization increase. In contrast, juveniles and adults present the opposite pattern, giving evidence of a change during late childhood. Our research provides new insights into human limb bone histomorphology which could contribute to the knowledge of normal growth and bone complexity.

OSTEON ARRANGEMENT AND TAXONOMY: SIGNIFICANCE OF BONE HISTOLOGY IN ARCHAEOZOOLOGY

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Bones and teeth are generally found in abundance at an archaeological site and are a rich source of information for animal-based subsistence, ecology and socio-economic and religious history of ancient civilizations. However, inherent taphonomic bias leaves a series of questions like the precise identification of animal species, provenance, and diagenetic record that are frequently confronted in archaeo-faunal studies. In recent years the focus of osteology has extended beyond the macroscopic observations into the world of microanatomy of bones and teeth.

The present paper describes bone histology with special reference to the Holocene faunal record, taxonomy and biomechanics. This plays a significant role in identification of bones from archaeological sites that may represent part of the food refuse, or that may have been raw materials intended for shaping into different tool types or objects of adornment.

The micromorphological and morphometrical features of bone tissue, focusing upon various issues of osteons among horses, cows, sheep, goats, cats, and dogs are discussed. A relationship has been observed between osteon density and different bone areas subjected to different mechanical forces. Osteon density is higher in medial and caudal areas, where forces of compression prevail, whereas it is lower in cranial and lateral areas, where forces of extension are dominant. Most osteons are elliptical in shape, rather than circular, with their major axis oriented towards the directions of prevailing forces. Biomechanical properties offer useful insights into the issues of taxonomy, as they offer an alternative method to identification of bones through osteon morphology.

FIRST APPROACH TO THE TAPHONOMY AND PALEOHISTOLOGY OF THE PREHISTORIC ARCHAEOLOGICAL SITE OF “CERRO DE LA ENCANTADA” (II MILLENNIUM B.C., SPAIN)

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Preserved bones retain in their microanatomy not only paleobiological reminiscences but also information concerning taphonomic modifications during postdepositional processing. Previous studies have shown the importance of paleohistology in the interpretation of preservational patterns in archaeological human bones. The aim of this study is to use the paleohistological approach to enrich the investigation of bone remains from prehistoric sites with different funerary practices. For that purpose, two adult skeletons with similar age at death and recovered from different types of burials in the “Cerro de La Encantada” archaeological site (II millennium B.C., Granátula de Calatrava, Ciudad Real, Spain), have been taphonomically and paleohistologically analyzed.

Taphonomic analysis of the skeletal remains shows that macro-preservation patterns could be influenced by the different funerary practices described at the archaeological site. In this sense, a better quality of preservation has been described for the individual buried in a masonry tomb than for the one buried in a slab tomb. In contrast, the paleohistological analysis, carried out through thin sections of rib fragments of both individuals, shows that the microstructure of bone tissues of both individuals was well preserved, and no significant differences were observable between them. Bone matrix was easily observable in both thin sections and typical adults’ microanatomical configuration previously described in the literature was identifiable. Further analyses will be needed to explore in detail how taphonomic processes act over the macro- and microstructure of individuals recovered from the same archaeological site but with different biological characteristics (age at death and/or sex).

BONE HISTOLOGY OF *EQUUS* FROM STEINHEIM AN DER MURR (MIDDLE PLEISTOCENE, GERMANY)

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The family Equidae has been extensively studied because it offers important insights into the mechanisms that drive evolution. A large-scale trend towards ever-increasing body size is observed during the evolutionary history of the group, interrupted by repeated size decreases, particularly during the European Pleistocene. Body size is an important life history (LH) trait that not only depends on the ecological conditions of the ecosystem but also correlates with other biological traits such as longevity and growth rate. Over the last few years, paleohistology has been shown to be a key tool to infer these traits in fossil taxa. However, little has been done yet to understand the relation between body size and other LH traits in fossil equids.

Here, paleohistology and body sizes of *Equus* cf. *steinheimensis* from Steinhem an der Murr (Baden-Württenberg, Germany) are studied to settle certain LH traits of the species in relation to its body size. Body mass was calculated from measurements in dental and postcranial elements while histological analyses were performed using metapodials. An estimated weight of about 470 kg was obtained for this fossil species. Bone histology reveals similar bone tissue types as in extant equids, although the deposition of the external fundamental system is delayed in the metacarpals of *E.* cf. *steinheimensis*. Our analysis of cyclical bone growth marks suggests a growth pattern like that of extant *E. hemionus* for *E.* cf. *steinheimensis*. E*quus.* cf. *steinheimensis* hence had a slow LH in relation to body mass, comparable to that of extant asses.

CYCLICAL ENAMEL MARKS OF UNKNOWN PERIODICITY IN EQUIDAE

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Dental histology has predominantly been performed in primate teeth; generally focused on the description and analysis of the main enamel incremental features (circum-weekly striae of Retzius and circadian cross-striations). While striae of Retzius have been observed in all mammalian groups, recent studies on ungulate teeth show that the most conspicuous daily incremental patterns are not cross-striations, as in primates, but laminations.

Here, we describe the presence of a set of enamel marks that do not seem to correspond with any of the aforementioned periodicities. We identified these lines in a first-second lower molar of *Hipparion macedonicum* from the Greek fossil site of Ravin de la Pluie (MN10). In this tooth, the obtained distance between laminations is about 15 µm (Daily Secretion Rate), whereas the Retzius lines are spaced approximately 75 µm. In addition, the unknown increments are spaced around 30 µm.

In extant *Equus*, marks of similar periodicity have also been observed. However, in the studied molar, these lines are grouped in a continuous and localized set that can be followed from the outer to the inner enamel. Different hypotheses are raised to explain the presence of these marks of unknown periodicity. On the one hand, the occurrence of these lines could be explained as an optical phenomenon caused by the overlap of laminations and influenced by the sectioning plane. On the other hand, they could be the consequence of an alteration of the enamel secretion rate due to intrinsic or extrinsic factors of the organism.

HISTOLOGICAL AND MICROANATOMICAL CONTRIBUTION TO PALEOPHYSIOLOGICAL AND PALEOECOLOGICAL INFERENCES IN THE DICYNODONT *MOGHREBERIA NMACHOUENSIS*

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The structural bone organization of extinct organisms can help to reveal their growth rate, metabolic rate, the biomechanical constraints they underwent, and their lifestyle. Here we report on stylopod bones of the Upper Triassic (Carnian) kannemeyeriiform *Moghreberia nmachouensis* from Morocco. First, the histological analysis of its bones shows well-vascularized incipient fibrolamellar bone evidencing a moderately high growth rate. This particular bone organization, consisting in an alternation of zones of woven bone and annuli of parallel-fibered bone, characterizes cyclical growth. Parallel-fibered bone deposits in the periphery indicate a growth decrease and thus suggest the onset of sexual maturity. Remodeling is high and differs between the femur and the humerus, suggesting different biomechanical constraints perhaps linked with the bimodal posture hypothesized in some dicynodonts. The high remodeling activity and the growth pattern suggest that the individuals were at least subadults. Qualitative histology being insufficient to rather precisely infer resting metabolic rates or physiological thermoregulation, we performed the first quantitative estimation of metabolic rate on fossil synapsids (*Moghreberia*, and the dicynodonts *Oudenodon* and *Lystrosaurus* for comparative purpose) using bone histological features and phylogenetic eigenvector maps. The results infer endothermy in the three dicynodonts analyzed. The acquisition of mammalian endothermy thus probably occurred at the Neotherapsida node, more than 260 Myr ago. Concerning the bone microanatomical structure, it is very compact with a trabeculae-filled medullary cavity. By comparing with other dicynodonts, extant organisms and paleoenvironmental data, we infer a probably semi-aquatic lifestyle for *Moghreberia*. Moreover, based on the microanatomy, anatomy, and size of this dicynodont, posture of the hindlimbs would have been graviportal.

DENTICULATE CORONOIDS AND INTERNAL MANDIBULAR ANATOMY OF THE PARAREPTILE *DELORHYNCHUS*

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The Richards Spur locality has yielded an abundance of pristinely preserved specimens that allow us to recognize the presence of the two-coronoid ossification in a Paleozoic parareptile, *Delorhynchus*. Additionally, both coronoids bear numerous small teeth, a feature commonly found in anamniotes, but rare in amniotes. These coronoid teeth are normally described as 'denticles', which is a problematic term often used to describe scales, serrations and other features. With new histological data, a more accurate identification of the dental tissues can be recognized, which reveals that the coronoid dentition is both morphologically and histologically indistinguishable from the marginal dentition. Additionally, through serial sectioning of the mandibular ramus, we can further understand the internal morphology of the parareptile mandible, and the biomechanical interactions between the various elements. Remarkably, we can see that the denticulate coronoids are well reinforced internally via a unique anterior extension of the prearticular and thickening of the dentary; this is presumably favorable for force distribution during feeding. The histological sampling of this parareptilian mandible provides a novel basis for comparison with that of the co-occurring eureptile *Captorhinus*, the only other histologically sampled reptilian lower jaw from this period. *Captorhinus* and *Delorhynchus* were likely insectivorous, but they feature different adaptations for increasing the prey-capture surface area. While captorhinids utilize multiple tooth rows effectively increasing their dentulous surface area, *Delorhynchus* and other lanthanosuchoids have integrated coronoid dentition into their feeding strategy. This difference in feeding adaptation is reflected in the internal morphology of the mandibles.

PATHOLOGICAL BONE TISSUE IN A LATE TRIASSIC THEROPOD FIBULA, WITH IMPLICATIONS FOR THE INTERPRETATION OF MEDULLARY BONE

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Typical archosaurian bone tissues and the broad biological features they indicate (e.g., growth rate, basic metabolic strategy) are now well understood from both paleontological and neontological studies. However, definitions, diagnoses, and the paleobiological implications of uncommon osteohistological features, such as medullary bone (MB; indicative of female reproductive activity) or pathological tissues, remain contentious. Here, I describe unusual bone tissue from the shaft of a theropod fibula from the Upper Triassic of New Mexico. Most of the interior portion of the cortex of this element consists of normal primary woven bone. However, nearly the entire outer portion of the cortex is composed of a woven network of spicules, with large longitudinally- and radially-oriented vascular canals and abundant osteocyte lacunae. This unusual tissue is separated from the normal tissue by an annulus. In two places the unusual bone "invades" the inner cortex and extends to the endosteal surface. Tissue stratification indicates that this invading bone was deposited after the normal primary bone. The unusual bone was deposited within the medullary cavity internal to the endosteal lamellae in several regions, and a second endosteal lamella is present in these regions. Surprisingly, the unusual bone grades into normal woven primary bone ~1 mm beneath the subperiosteal surface, and the bone remains vascularized to this surface. I interpret this unusual tissue as pathological. Because the internal portions of this tissue also fulfill diagnostic criteria of MB (i.e., tissue type, position, and endosteal origin) care should be taken when interpreting similar tissues.

DEFINITIVE OCCURRENCE OF MEDULLARY BONE IN AN ENANTIORNITHINE (AVES: ORNITHOTHORACES)

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Medullary bone (MB) is an ephemeral type of bone tissue, found today only in reproductively active female birds, that provides a calcium reservoir for eggshell formation. The identification of MB in non-avian theropod dinosaurs provided biological evidence that further supported an ancestral link between birds and dinosaurs. However, the discovery of similar tissue in dinosaurs only distantly related to birds and in pterosaurs, as well as studies on bone pathologies in extant birds, has led to the reinterpretation of these tissues as pathological tissues not associated with reproductive activity. This lead to the hypothesis that MB evolved with the rapid growth strategy present in derived members of Ornithuromorpha, the clade that includes all living birds nested within it. Here we describe the histology of a previously unreported pengornithid enantiornithine (Aves: Ornithothoraces) IVPP V15576. Although incomplete – the specimen consists only of an isolated left hindlimb - its excellent three dimensional preservation contrasts with the typically crushed Jehol specimens. Histology suggests that this unusual preservation is due to the presence of a thick layer of MB filling the bone cavity. Unlike previous reports of medullary bone in Cretaceous fossils, the morphology of the endosteal tissue is nearly identical to observations from neornithine birds. This represents the first definitive record of medullary bone in a non-neornithine avian and shows that this feature was present in birds with more prolonged growth strategies.

OSTEOHISTOLOGY AS A PROXY FOR THE UNDERSTANDING OF GROWTH STRATEGIES AND EVOLUTION IN EXTANT AND EXTINCT CAIMANINAE (CROCODYLIA, ALLIGATORIDAE)

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Caimaninae are a South American lineage of crocodylians well represented in Brazil. They are composed of six species within three genera: *Caiman, Melanosuchus* and *Paleosuchus*. Many points about their growth strategies have been questioned, as if they present different growth rates and skeletal specializations for a certain ecology. Previews osteohistological studies in extant crocodylians were conducted in long bones and osteoderms of *Alligator mississippiensis, Caiman crocodilus* and *Crocodylus niloticus* and provide substantial data about microstructure and physiology regarding Alligatoridae. Herein, we gather osteohistological description among long bones of a fossil *Caiman* sp. from Solimões Formation (Acre Basin) and in extant species of *Caiman yacare* and make comparisons, to the data already published. The thin sections revealed three types of primary cortex, confirming that the Alligatoroidea have distinct growth rates caused by endogenous rhythms since the Miocene. The presence of cyclical growth marks and some microstructures indicates the maintenance of the inner cortex that could be related to buoyancy control. The skeletal variability found in *Caiman yacare* reinforces that humerus, femur and tibia are a good source to investigate the growth rates, and the radius is better for skeletochronology. The clade Crocodylia seems to retain the plesiomorphic characteristic observed in basal archosaurs, forming fast-growing tissue. This goes against the hypothesis that crocodiles lost the capacity of high growth rates in relation to some Triassic Crurotarsi.

TO WHAT EXTENT CAN PALEOHISTOLOGY HELP US UNDERSTAND EXTINCT ANIMAL BEHAVIOR? A CONCEPTUAL FRAMEWORK APPROACH

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Many authors have cited the synergistic nature of development and evolution of animal behavior and morphology, and the benefits (and indeed necessity) of considering form and function at different levels of the biological hierarchy. The use of histology to understand extinct animal behavior transcends this hierarchy but faces particular challenges when drawing conclusions regarding certain types of behavior. To consider this issue, a conceptual framework was constructed to visually illustrate the relationship between form, function, behavior and morphology. The historical, functional, and structural components of paleohistology were then mapped onto this framework.

The framework is based on several basic premises. Morphology (including histological structures) enables behavior, and the same morphology may be 'co-opted' for different behaviors. Form (encompassing both behavior and morphology) achieves a particular function, altering plastically in response to internal influences (such as ontogeny) and external influences (such as the environment) within historical constraints. Of the many definitions of behavior, the distinction between simple, often instinctive behaviors (locomotion, ingestion, reproduction, elimination) and complex behaviors (requiring a functional interpretation) proved critical. Paleohistology offers important insights into simple behaviors, often connected with locomotory style and mechanics, but in general comments regarding complex behaviors are limited due to the temporal and spatially defined nature of these behaviors.

It is hoped that this pluralistic approach will provide an initial reference point to both better understand and position paleohistology research within the key themes of evolutionary biology, and prompt further discussion on the ability of paleohistology to inform on extinct animal behavior.

PALEOHISTOLOGY TECHNIQUE FOR SUB-FOSSILIZED BONE

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Bone histology techniques for fully fossilized and modern bones are well established. However, there is to date no specific method for use on sub-fossilized bones. Here, we subject four sub-fossilized humeri of Quaternary iguanid from Cuba (*Cyclura nubila* and *Cyclura sp.*) to a protocol suited for fossilized bone and another two to a protocol for modern bone. Mid-shaft portions of all humeri were cut after the bones had been stabilized with a cyanoacrylate penetrant stabilizer. In the fossilized bone protocol, the cut sections were embedded in polyester resin and sectioned on a wet-saw with a diamond-edged wheel. In the modern bone protocol, the humeri were first fixed with 10% neutral buffered formalin, dehydrated using ethanol with increasing concentrations (70%, 85%, 95%, and 100%), stabilized with a polyvinylalcohol-vinylacetate stabilizer during dehydration to mitigate crack expansions, and cleared using citric acid. Then, the mid-shaft portions were embedded in low-viscosity epoxy resin and sectioned in the same way as in the previous protocol. Specimens from both protocols were mounted on either pre-ground plastic or glass slide using superglue or epoxy glue respectively. Lastly, all sections underwent toluidine blue staining. Besides observed cracks in the sections that were produced from the modern protocol dehydration phase, we found no other differences in: how effectively the bones embedded; section adherence to slide; histological tissue clarity, and staining signal. Therefore, the fossilized bone protocol is the more appropriate choice for sub-fossilized bone since this method prevents cracks, requires less time for processing, and less expense for materials.

POLYESTER OR EPOXY: ASSESSING PRODUCT EFFICACY IN PALEOHISTOLOGICAL METHODS

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Examination of bone microstructure provides insights into the physiology of vertebrates. Standard fossil material embedding procedure involves inexpensive polyester resin while small fossils and modern bones are embedded in higher priced epoxy resin. Modern bone and small fossils often require polishing near or below 100 micrometers in thickness. Anecdotal evidence suggests polyester resin polished thinner than 100 micrometers increases likelihood of sample peeling, material loss, and is unsuitable for modern bone and small fossil embedding. To test this assumption, three fossil bones and two modern bones were embedded in epoxy resin, while five fossil bones and four modern bones were embedded in polyester. Multiple sections from embedded specimens were mounted and polished following standard protocol. Additionally, two slides, one with a polyester embedded specimen and one with an epoxy embedded specimen, were ground until peeling occurred. Slide thickness at point of peeling was measured for comparison of resins and timing of specimen loss. Finished slide thickness ranged from 23-230 micrometers. We found no appreciable difference in microstructure visibility between resin types, and none of the 35 slides exhibited signs of peeling. For the two additional slides ground until peeling occurred, there was no observable difference in timing of specimen peeling. The specimen embedded in epoxy peeled at 77 microns while the specimen in polyester peeled at 55 microns. Our results suggest that epoxy resins can be replaced by polyester in histological preparation of modern bone and small fossil material, but long-term integrity needs to be addressed in future studies.

PRESSURE VS. VACUUM IN THE RESIN IMPREGNATION OF THIN-SECTION SAMPLES

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Sample impregnation in resin under vacuum is not 100% effective at displacing air in the mixture when using the lower technology, low-cost method of repeatedly applying a vacuum while tapping the bottle containing the sample. Molding and casting techniques historically used a vacuum to diminish the size and number of bubbles until pressure experiments yielded better results. A literature search found no references for the use of pressure in the impregnation of thin-section samples, prompting this experiment.
Two fish coprolites from the Hornerstown formation of central New Jersey (NJSM 11266) were selected as subject samples due to their porosity and consistent composition. Each sample was cut into four sections, and then two of each four were impregnated with resin under vacuum, and two under pressure (30 PSI). Thin sections were prepared and studied, comparing the occurrence and size of bubbles in each pressure section to its mirror vacuum section. Unexpectedly, the resulting sections show very few bubbles within the resin in both vacuum and pressure-impregnated sections. Both types are comparable in area and occurrence of bubbles to the point of indifference. Further experimentation under higher pressure (65 PSI) is expected to produce more distinct results.

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