PROGRAM - MAIN EVENTS

THURSDAY, JULY 2, 2015		
Time	**Event**	**Location**
8:00 AM - 12:00 PM	Beginner's Workshop	Übungsraum & Labor, Steinmann-Institut (Nussallee 8, rear building)
1:00 PM – 5:00 PM	Advanced Workshop	Übungsraum & Labor (Nussallee 8, rear building)
5:00 PM -	Lab Tour with preparator Olaf Dülfer	Labor (Nussallee 8, rear building)
6:00 PM – 7:30 PM	Registration	Entrance to Goldfuß Museum, (Nussallee 8, front building)
7:00 PM – 10:00 PM	Ice Breaker	Goldfuß Museum (Nussallee 8, front building)

FRIDAY, JULY 3, 2015		
Time	**Event**	**Location**
8:00 AM – 9:00 AM	Registration	Gartensaal, Poppelsdorf Palace
8:00 AM – 9:00 AM	Upload Talks	Hörsaal Zoologie, Poppelsdorf Palace
8:00 AM – 9:00 AM	Poster Setup	Stucksaal, Poppelsdorf Palace
9:00 AM – 9:15 AM	Welcome	Hörsaal Zoologie, Poppelsdorf Palace
9:15 AM - 9:45 AM	Keynote H. Woodward Session I	Hörsaal Zoologie, Poppelsdorf Palace
9:45 AM – 10:30 AM	Session I	Hörsaal Zoologie, Poppelsdorf Palace
10:30 AM – 11:00 AM	Coffee Break	Gartensaal and Stucksaal, Poppelsdorf Palace
11:00 AM – 12:00 PM	Session I (continued)	Hörsaal Zoologie, Poppelsdorf Palace
12:00 PM - 1:30 PM	Lunch Break (Upload Talks)	
1:30 PM – 2:00 PM	Keynote K. Mikhailov Session II	Hörsaal Zoologie, Poppelsdorf Palace
2:00 PM – 3:15 PM	Session II	Hörsaal Zoologie, Poppelsdorf Palace
3:15 PM – 3:45 PM	Coffee Break	Gartensaal and Stucksaal, Poppelsdorf Palace
3:45 PM – 4:15 PM	Keynote W. Dirks Session III	Hörsaal Zoologie, Poppelsdorf Palace
4:15 PM – 5:30 PM	Session III	Hörsaal Zoologie, Poppelsdorf Palace
6:00 PM – 8:00 PM	Troubleshooting Workshop and Core Drilling Demonstration	Labor and Übungsraum (Nussallee 8, rear building)

SATURDAY, JULY 4, 2015		
Time	**Event**	**Location**
8:00 AM – 9:00 AM	Upload Talks	Hörsaal Zoologie, Poppelsdorf Palace
8:00 AM – 9:00 AM	Poster Setup	Stucksaal, Poppelsdorf Palace
9:00 AM – 9:30 AM	Keynote E-M. Griebeler Session IV	Hörsaal Zoologie, Poppelsdorf Palace
9:30 AM - 10:45 AM	Session IV	Hörsaal Zoologie, Poppelsdorf Palace
10:45 AM – 11:15 AM	Coffee Break	Gartensaal and Stucksaal, Poppelsdorf Palace
11:15 AM – 12:45 PM	Session IV (continued)	Hörsaal Zoologie, Poppelsdorf Palace
12:45 PM – 2:15 PM	Lunch Break (Upload Talks)	
2:15 PM – 3:30 PM	Session V	Hörsaal Zoologie, Poppelsdorf Palace
3:30 PM – 5:30 PM	Poster Session	Stucksaal, Poppelsdorf Palace

SUNDAY, JULY 5, 2015		
Time	**Event**	**Location**
8:00 AM – 9:00 AM	Upload Talks	Hörsaal Zoologie, Poppelsdorf Palace
9:00 AM – 9:30 AM	Keynote S. Sanchez Session VI	Hörsaal Zoologie, Poppelsdorf Palace
9:30 AM - 10:15 AM	Session VI	Hörsaal Zoologie, Poppelsdorf Palace
10:15 AM – 10:45 AM	Coffee Break	Gartensaal and Stucksaal, Poppelsdorf Palace
10:45 AM – 11:15 AM	Keynote J. Vinther Session VII	Hörsaal Zoologie, Poppelsdorf Palace
12:15 PM – 1:45 PM	Lunch Break (Upload Talks)	
1:45 PM – 3:30 PM	Session VIII	Hörsaal Zoologie, Poppelsdorf Palace
3:30 PM – 4:00 PM	Coffee Break	Gartensaal and Stucksaal, Poppelsdorf Palace
4:00 PM – 5:30 PM	Session IX	Hörsaal Zoologie, Poppelsdorf Palace
6:15 PM	Meet to walk to port for Dinner Cruise	Entrance of Poppelsdorf Palace
7:00 PM – 11:00 PM	Dinner Cruise along the Rhine	Depart Bonn Port 'Alter Zoll'

Please note all posters must be taken down by **5:30 PM Sunday**

PROGRAM – SCIENTIFIC SESSIONS

FRIDAY, JULY 3

9:00 AM ***Welcome & Announcements***

Session I: Testing Assumptions in Paleohistology

Moderators: Xavier Jordana, Aurore Canoville

9:15 AM **Holly Woodward**

KEYNOTE: BACK TO BASICS AND TESTING ASSUMPTIONS IN PALEOHISTOLOGY

9:45 AM **Alexandra Quilhac**

GLOBULI OSSEI IN TETRAPODS LONG BONES

10:00 AM **Aurore Canoville**

MICROANATOMICAL DIVERSITY OF THE RIBS OF AMNIOTES AND CONSIDERATIONS FOR PALEOECOLOGICAL INFERENCES

10:15 AM **Filippo Bertozzo**

HISTOLOGICALLY DETECTING POSTCRANIAL PNEUMATICITY IN SAUROPODOMORPHA: IMPLICATIONS FOR THE EVOLUTION OF THE DINOSAURIAN RESPIRATORY SYSTEM

10:30 AM COFFEE BREAK

11:00 AM **Holger Petermann**

STUDY OF THE TEIID LIZARD *ASPIDOSCELIS TIGRIS* REVEALS ENVIRONMENTALLY CONTROLLED GROWTH IN SQUAMATES

11:15 AM **German Montoya**

BONE MICROSTRUCTURE OF *BATHYERGUS SUILLUS* (RODENTIA: BATHYERGIDAE); CORTICAL BONE THICKENING AND SEXUAL DIMORPHISM

11:30 AM **Meike Köhler**

CALIBRATION OF BONE GROWTH WITH METABOLIC RATE AND LIFE HISTORY EVENTS IN *LEPUS EUROPAEUS*: A LABELING EXPERIMENT

11:45 AM **Xavier Jordana**

BONE HISTOLOGY OF RED DEER (*CERVUS ELAPHUS*) AND IMPLICATIONS FOR LIFE-HISTORY INFERENCES

12:00 PM LUNCH

Session II: Eggshell Histology

Moderators: Shukang Zhang, Koen Stein

1:30 PM **Konstantin Mikhailov**

KEYNOTE: STRUCTURE: AVIAN-LIKE VERSUS NON-ORNITHOID BIOMINERALIZATION AND EGGSHELL DINOSAURIAN EGGSHELLS

2:00 PM **Daniel Barta**

THE FIRST DINOSAUR EGGS FROM A NEW VERTEBRATE LOCALITY IN THE UPPER CRETACEOUS SEBEŞ FORMATION, ROMANIA

2:15 PM **Junchang Lü**

ASSOCIATION BETWEEN EGGSHELLS AND SKELETON OF AN ALVAREZASAURID THEROPOD FROM THE UPPER CRETACEOUS OF CHINA

2:30 PM **Shukang Zhang**

A NEW TYPE OF DINOSAUR EGGS FROM LOWER CRETACEOUS OF GANSU PROVINCE, CHINA

2:45 PM **Tzu-Ruei Yang**

REPRODUCTIVE BIOLOGY OF THE OVIRAPTORID DINOSAURS REVEALED BY THE INTERPRETED EGG INNER STRUCTURE

3:00 PM **Koen Stein**

SEMI-FLEXIBLE EGGSHELL IN LOWER JURASSIC PROSAUROPODS SUGGESTS PLESIOMORPHIC CONDITION IN DINOSAURS

3:15 PM COFFEE BREAK

Session III: Dental Tissues and their Paleobiological Implications

Moderators: Ian Corfe, Maitena Dumont

3:45 PM **Wendy Dirks**

KEYNOTE: HOW DENTAL HISTOLOGY TRACKS LIFE HISTORY FROM THE INDIVIDUAL TO THE SPECIES

4:15 PM **Santiago Gomez**

CEMENT, COLLAGEN FIBERS, OR MINERAL: WHAT IS THE PREDOMINANT INGREDIENT IN BONE BIREFRINGENCE?

4:30 PM **Tanja Wintrich**

TWO RECORDS OF OMPHALOSAURUS FROM THE MUSCHELKALK - THE RECONSTRUCTION OF TRIASSIC MARINE ECOSYSTEM BASED ON TEETH

4:45 PM **Maitena Dumont**

DENTAL HISTOLOGY OF *HESPERORNIS* AND *ICHTHYORNIS*: AN INSIGHT INTO THE BIOLOGY OF THE "LAST" TOOTHED BIRDS

5:00 PM **Ian Corfe**

TOOTH ULTRASTRUCTURE AND DEVELOPMENT OF A 200 MILLION YEAR OLD MAMMAL REVEALED WITH SYNCHROTRON NANOTOMOGRAPHY

5:15 PM **Elis Newham**

CEMENTUM HISTOLOGY REVEALS PHYSIOLOGY AT THE ROOT OF THE MAMMAL PHYLOGENY

SATURDAY, JULY 4

Session IV: Ontogeny and Development

Moderators: Torsten Scheyer, Anneke van Heteren

9:00 AM **Eva Maria Griebeler**

KEYNOTE: THE LIFE HISTORY OF FOSSILE TAXA: WHAT CAN GROWTH CURVES TELL US?

9:30 AM **Torsten Scheyer**

MICROSTRUCTURE IN THE MESOZOIC PREDATORY OPERCULAR MICROANATOMY AND FISH *SAURICHTHYS* (ACTINOPTERYGII)

9:45 AM **Peter Makovicky**

HISTOLOGICAL STUDY OF ANTARCTIC, EARLY JURASSIC SAURISCHIANS

10:00 AM **Holly Woodward**

AN ONTOGENETIC HISTOANALYSIS OF AUSTRALIAN POLAR DINOSAURS

10:15 AM **Kayleigh Wiersma**

HISTOLOGY OF THE SAUROPOD LONG BONES FROM THE HOWE-STEPHENS QUARRY (MORRISON FORMATION, WYOMING): TESTING HYPOTHESES OF SKELETAL UNITY

10:30 AM **John Horner**

FIBER COMPLEXES IN THE CRANIAL DOMES OF PACHYCEPHALOSAURID DINOSAURS

10:45 AM COFFEE BREAK

11:15 AM **Víctor Fondevilla**

IDENTIFYING SEXUAL SIZE DIMORPHISM IN THE MAASTRICHTIAN HADROSAUROIDS OF BASTURS POBLE (TREMP SYNCLINE, EASTERN IBERIA)

11:30 AM **Vivian de Buffrénil**

ONTOGENETIC DIFFERENTIATION AND GROWTH OF BONE ORNAMENTATION IN THE CROCODYLOMORPHA

11:45 AM **Meike Köhler**

FIRST RESULTS FROM BONE HISTOLOGY OF THE DWARF ELEPHANT *PALAEOLOXODON FALCONERI* FROM SICILY

12:00 PM **Anneke van Heteren**

PRE- AND POSTNATAL GROWTH RATES OF PLEISTOCENE DWARFED HIPPOPOTAMI FROM CYPRUS

12:15 PM **Carmen Nacarino-Meneses**

VALIDATING SKELETOCHRONOLOGY IN EQUIDS: INTRASKELETAL VARIABILITY IN *EQUUS HEMIONUS*

12:30 PM **Eli Amson**

NEW DATA ON CERVID HISTOLOGY - LIFE HISTORY AND ALLOMETRY

12:45 PM LUNCH

Session V: Physiology

Moderators: Adam Huttenlocker, Christen Shelton

2:15 PM **Adam Huttenlocker**

VASCULAR CORRELATES OF RED BLOOD CELL SIZE EVOLUTION IN TETRAPODS

2:30 PM **Lucas Legendre**

PALEOHISTOLOGICAL EVIDENCE FOR ANCESTRAL ENDOTHERMY IN ARCHOSAURS

2:45 PM **Christen Shelton**

OPHIACODONTIDAE (BASAL SYNAPSIDA) BONE HISTOLOGY AND THE ORIGIN OF MAMMALIAN ENDOTHERMY

3:00 PM **Anusuya Chinsamy-Turan**

UNUSUAL ENDOSTEAL BONE TISSUE IN *SALTASAURUS LORICATUS* (DINOSAURIA: SAUROPODA)

3:15 PM **Edina Prondvai**

EVALUATION OF THE REPRODUCTIVE ROLE OF MEDULLARY BONE-LIKE TISSUES IN FOSSILS

3:30 PM **POSTER SESSION**

SUNDAY, JULY 5

Session VI: Advanced Methodologies

Moderators: Vijay Sathe, Oliver Wings

9:00 AM **Sophie Sanchez**

KEYNOTE: X-RAY MICROTOMOGRAPHY: NEW PERSPECTIVES APPLIED TO PALAEOHISTOLOGY

9:30 AM **Dennis Voeten**

VIRTUAL VESSELS: THE MORPHOLOGY OF CORTICAL VASCULARIZATION VISUALIZED IN THREE DIMENSIONS USING SYNCHROTRON X-RAY MICROTOMOGRAPHY

9:45 AM **Jennifer Anné**

CHEMICAL HISTOLOGY VIA SYNCHROTRON ANALYSIS

10:00 AM **Jennifer Sensor**

USING STABLE ISOTOPES AND HISTOLOGY TO CORRELATE GROWTH OF THE TYMPANIC BONE WITH BALEEN PLATES IN ARCTIC WHALES

10:15 AM COFFEE BREAK

Session VII: Preservation over Deep Time

Moderators: Vijay Sathe, Oliver Wings

10:45 AM **Jakob Vinther**

KEYNOTE: MELANIN AND COLOUR PATTERNS IN THE FOSSIL RECORD

11:15 AM **Jasmina Wiemann**

CATCHING THE PIGMENTS OF LIFE: PRESERVATION POTENTIAL AND PALEOBIOLOGICAL IMPLICATIONS OF TETRAPYRROLIC COLOR PIGMENTS IN DINOSAUR EGGSHELL

11:30 AM **Marie Koschowitz**

A PRELIMINARY STUDY ON THE PRESERVATION OF ORIGINAL ORGANIC MATERIAL IN AMNIOTE BONES FROM THE LOWER PERMIAN TO SUB-RECENT

11:45 AM **Vijay Sathe**

MICROBIALITES AND VERTEBRATE FOSSIL RECORD: MICROSCOPIC VIEW

12:00 PM **Oliver Wings**

A NEW APPROACH TO BONE DIAGENESIS: MICROFACIES METHODS APPLIED TO CARBONATE CEMENTS IN FOSSIL BONE VOIDS

12:15 PM LUNCH

Session VIII: Phylogeny and Evolutionary Patterns
Moderators: Jennifer Botha-Brink, Alexandra Houssaye

1:45 PM **Jorge Cubo**

EVOLUTION OF THE WOVEN-PARALLEL COMPLEX IN TETRAPODS

2:00 PM **Michel Laurin**

MICROSTRUCTURAL FEATURES OF THE FEMUR IN EARLY OPHIACODONTS: A REAPPRAISAL OF ANCESTRAL HABITAT USE AND LIFESTYLE OF AMNIOTES

2:15 PM **Jennifer Botha-Brink**

BREEDING YOUNG AS A SURVIVAL STRATEGY IN THE AFTERMATH OF THE END-PERMIAN MASS EXTINCTION

2:30 PM **Martin Sander**

THE EVOLUTION OF PLESIOSAUR BONE HISTOLOGY: NEW EVIDENCE FROM NEW FINDS

2:45 PM **Catherine Sartin**

ONTOGENY IN IGUANODONTIA

3:00 PM **Alida Bailleul**

COMPARATIVE SUTURAL HISTOLOGY OF NON-AVIAN DINOSAURS AND THEIR EXTANT PHYLOGENETIC BRACKET

3:15 PM **Alexandra Houssaye**

BONE MICROSTRUCTURE EVIDENCE OF THE TRANSITION OF EOCENE WHALES FROM LAND TO SEA

3:30 PM COFFEE BREAK

Session IX: Biomechanics

Moderators: Mason Dean, Michael Buchwitz

4:00 PM **Mason Dean**

ONTOGENY, ULTRASTRUCTURE AND MECHANICS OF SHARK AND RAY TESSELLATED CARTILAGE

4:15 PM **Ron Shahar**

THE STRUCTURE AND MECHANICAL PROPERTIES OF THE ANOSTEOCYTIC BONE OF NEO-TELEOST FISH

4:30 PM **Michael Buchwitz**

HISTOLOGICAL INDICATIONS FOR A MECHANICAL SUPPORT FUNCTION OF DORSAL OSTEODERM SYSTEMS IN TRIASSIC ARCHOSAURIFORMS

4:45 PM **Tobin Hieronymus**

TESTING PHYLOGENETIC, FUNCTIONAL, AND SPATIAL SIGNAL IN THREE-DIMENSIONAL COLLAGEN FIBER ORIENTATIONS OF AVIAN LONG BONES

5:00 PM **Lisa Noelle Cooper**

COMPARTIVE ANISOTROPY IN THE CORTEX OF THE RADIUS OF BATS AND NON-VOLANT MAMMALS

5:15 PM **Justyna Miszkiewicz**

INVESTIGATING THE EXTENT TO WHICH ENTHESEAL CHANGES REFLECT BONE REMODELING AT THE FEMORAL MIDSHAFT IN ANCIENT HUMANS

POSTERS

1 Alexandra Gerasimova

STRUCTURE AND ORIGIN OF THE ALBID TISSUE OF CONODONTS

2 François Clarac

BONE AREA INCREASE DUE TO ORNAMENTATION IN THE CROCODYLIA: A QUANTITATIVE APPROACH

3 Sarah-Jane Strachan

EARLY CRETACEOUS ANKYLOSAUR SACRAL SHIELD FROM THE ISLE OF WIGHT DISPLAYS A REMARKABLE SEMI-LAMINATED STRUCTURE

4 Christian Heck

BONE GROWTH IN THE NINE-BANDED ARMADILLO (*DASYPUS NOVEMCINCTUS*): IMPLICATIONS FOR EXTINCT TAXA

5 Oscar Sanisidro

FIRST INSIGHTS ON THE LIFE HISTORY OF THE *HISPANOTHERIUM MATRITENSE* (RHINOCEROTIDAE, PERISSODACTYLA) FROM THE MIDDLE MIOCENE OF THE IBERIAN PENINSULA

6 Santiago Gomez

CEMENT, COLLAGEN FIBERS, OR MINERAL: WHAT IS THE PREDOMINANT INGREDIENT IN BONE BIREFRINGENCE?

7 Carsten Witzel

RECONSTRUCTING TIMING AND DURATION OF IMPAIRED SECRETORY AMELOBLAST FUNCTION IN INCISOR ENAMEL OF *SIVATHERIUM HENDEYI* FROM THE EARLY PLIOCENE OF LANGEBAANWEG, SOUTH AFRICA

8 Rodrigo Pellegrini

HISTOLOGY OF *MOSASAURUS MAXIMUS* PTERYGOID DENTITION AND ITS ATTACHMENT TISSUES

9 Xavier Jordana

DENTAL HISTOLOGY OF THE SICILIAN DWARF ELEPHANT *PALAEOLOXODON FALCONERI*

10 Guillem Orlandi-Oliveras

TUROLIAN DWARF *HIPPARION* FROM SPAIN: INFERRING LIFE HISTORY MECHANISMS UNDERLYING SIZE SHIFT FROM DENTAL MICROSTRUCTURE

11 Thomas Engler

MOLAR ENAMEL MICROSTRUCTURE AND HYPSODONTY IN THERIDOMYIDAE (RODENTIA) AT THE EOCENE-OLIGOCENE TRANSITION

12 Christen Shelton

EXCEPTIONAL SOFT TISSUE PRESERVATION WITHIN A TOOTH FROM THE WHITE SHARK *CARCHARODON* (LAMNIFORMES, LAMNIDAE) FROM SACACO, PERU (MIOCENE, PISCO FORMATION)

13 Jorge Mondéjar-Fernández

TEETH-ATTACHMENT AND PLICIDENTINE IN EXTANT PREDATORY OSTEICHTHYANS REVEALED BY 3D TOMOGRAPHY

14 Katja Waskow

RECONSTRUCTING JUVENILE MORPHOLOGY: A NON-DESTRUCTIVE METHOD TO DETECT HISTOLOGICAL STRUCTURES IN COMPUTED TOMOGRAPHY (CT) AND ITS POTENTIAL FOR FUTURE RESEARCH, USING THE EXAMPLE OF SAUROPOD RIBS

15 Elzbieta Teschner

HOW IMPORTANT ARE TEMNOSPONDYL HUMERI FOR SKELETOCHRONOLOGICAL ANALYSES? EVALUATING THE HISTOLOGICAL METHODOLOGY

16 Laura E. Wilson

PRELIMINARY ANALYSIS OF *PTERANODON* LONG BONE HISTOLOGY

17 Nicole Klein

MICROANATOMY, BONE HISTOLOGY, AND GROWTH OF NOTHOSAURIA EVALUATING THE HISTOLOGICAL METHODOLOGY

18 Vladimir Nikolov

OSTEOHISTOLOGY OF THE HADROSAUROID (DINOSAURIA: ORNITHOPODA) FROM LABIRINTA CAVE, BULGARIA: AN EXAMPLE OF INSULAR DWARFISM OR SIMPLY YOUNG GIANT?

19 Orosia García Gil

EXPLORING THE HISTOLOGY OF THE HUMAN PERINATAL VAULT BONES EVALUATING THE HISTOLOGICAL METHODOLOGY

20 Tom Hübner

FILLING A GAP – THE BONE HISTOLOGY OF *IGUANODON* AND *MANTELLISAURUS*

21 Vijay sathe

HIPPOPOTAMIDAE (GRAY 1821) IN INDIA: TAXONOMIC AND PALAEOENVIRONMENTAL INTERPRETATIONS EVALUATING THE HISTOLOGICAL METHODOLOGY

22 Marylène Danto

DEVELOPMENT OF THE VERTEBRAL CENTRA IN BASAL TETRAPODS EVALUATING THE HISTOLOGICAL METHODOLOGY

23 Philipp Knaus

UNRAVELING CRYPTIC SPECIES OF *DIMETRODON* FROM THE CLEAR FORK GROUP (LOWER PERMIAN) – PHYLOGENETIC IMPLICATIONS OF ONTOGENETIC HISTOLOGICAL FEATURES

24 Meike Köhler

BONE HISTOLOGY OF AN EXTANT REPRESENTATIVE OF INSULAR MAMMALS: THE AMAMI RABBIT (*PENTALAGUS FURNESSI*)

25 Vidushi Dabee

PERIOSTEAL BONE HISTOLOGY AND DEPOSITIONAL RATES IN *CROCODYLUS NILOTICUS*

26 Jessica Mitchell

QUANTITATIVE ASSESSMENT OF SECONDARY OSTEON SIZE AND SHAPE VARIABILITY IN AMNIOTES

27 Jingmai O'Connor

THE EVOLUTION OF RAPID GROWTH IN ORNITHOTHORACES

28 Xie Junfang

BIRTH OF THE DINOSAURS – EXHIBITION ON EGG AND EMBRYO FOSSILS FROM CHINA

BACK TO BASICS AND TESTING ASSUMPTIONS IN PALEOHISTOLOGY

HOLLY N. WOODWARD[1]

[1] *Oklahoma State University Center for Health Sciences, Tulsa, OK 74107, USA*
holly.n.woodward@gmail.com

Because bone tissue microstructure is the only conclusive way to determine minimum age and maturity status for extinct vertebrates, particularly non-mammalian vertebrates, paleohistology is increasing in use as its data potential for publications is realized. For instance, paleohistological growth curve and growth rate studies result in highly popular graphical interpretations of life history, especially in dinosaur paleontology. Studies on extant bone microstructure provide the foundation for such interpretations and have in recent years helped test and in many cases validate paleohistological assumptions. This is especially true for the increased understanding of cyclical growth marks. Unfortunately many paleohistological interpretations still rely on poorly tested, often qualitative, observations from extant vertebrate histology. For instance, more research is necessary to understand how latitude, migration, and photoperiod is recorded in bone, whether a vertebrate taxon has "indeterminate" or "determinate" growth, and even the interpreted meaning of bone fiber orientation and tissue type. The accuracy of dinosaur growth curve modeling methods has also recently been called into question. Thus, to sustain momentum and move paleohistology forward, researchers must step backward and continue efforts to "ground truth" by testing assumptions with replicable results. Increasing sample size is also of paramount importance, as individual variation affects growth curve interpretations. Assessing bone biology basics led in recent years to new discoveries in fossil bone microstructure, and will continue to advance paleohistology.

GLOBULI OSSEI IN TETRAPODS LONG BONES

ALEXANDRA QUILHAC[1,2], ARMAND DE RICQLÈS[1,2], HAYAT LAMROUS[1,2], AND LOUISE ZYLBERBERG[1,2]

[1] *Institut des Sciences de la Terre de Paris (UMR 7193), Sorbonne Universités, UPMC, Paris, 75005, France*
[2] *Institut des Sciences de la Terre de Paris (UMR 7193), CNRS, Paris, 75005, France*
alexandra.quilhac@upmc.fr

Globuli ossei (GO) are small bone-like burgeoning spheres developing into the hypertrophic cartilage matrix during endochondral ossification. They were briefly mentioned in the growth plates in some fossils as well as in extant tetrapods. The first question was to determine whether the cells contained in the GO are chondrocytes or come from the marrow. We report the results obtained from the appendicular long bones of metamorphosed juveniles and young adults newts (*Pleurodeles waltl*, Amphibia, Urodeles) by using histological and histochemical methods and transmission electron microscopy (TEM). The distal part of the cone-shaped cartilage contains a heterogeneous cell population composed of the typical light hypertrophic chondrocytes and scarce dark hypertrophic chondrocytes that probably undergo degeneration through chondroptosis. However, in the hypertrophic, calcified cartilage closest of the erosion front by the marrow, several non-invaded chondrocytic lacunae retain cells that do not show any morphological characteristics of degeneration and that cannot be identified as regular chondrocytes or osteocytes. These modified chondrocytes that have lost their regular morphology appear to be active in the terminal cartilage and synthesize collagen fibrils of a peculiar diameter intermediate between the type I collagen found in bone and the type II collagen characteristic of cartilage. It is suggested that the local occurrence of globuli ossei is linked with a low bone growth rate. Thus, to test this hypothesis, a survey to identify such globular structures is carried out in well-known species. The results could provide additional data in the determination of growth rates in extinct tetrapods.

MICROANATOMICAL DIVERSITY OF THE RIBS OF AMNIOTES AND CONSIDERATIONS FOR PALEOECOLOGICAL INFERENCES

AURORE CANOVILLE[1], MICHEL LAURIN[2] AND VIVIAN DE BUFFRÉNIL[2]

[1] *Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
canoville.aurore08@gmail.com
[2] *Centre de Recherches sur la Paléobiodiversité et les Paléoenvironnements (UMR 7207), Sorbonne Universités, MNHN/CNRS/UPMC, Paris, 75005, France*

Over the past decades, the bone microanatomical diversity of extant and extinct tetrapods has been extensively studied using increasingly sophisticated quantitative methods to assess its ecological, biomechanical and phylogenetic significances. Bone microanatomy has proven to be a reliable tool to infer the habitat and locomotion mode of extinct taxa.

However, the vast majority of previous works has been conducted on the appendicular skeleton (long limb bones). Few studies focused on the microanatomy of the axial skeleton (i.e., vertebrae and ribs) and its ecological signal. Taxonomically constrained studies have shown that rib microanatomy can be indicative of lifestyle (aquatic or terrestrial). Moreover, amniotes exhibit a great variability in rib morphology, often related to different habitat or locomotor adaptations. Considering the previous statements, differences at the microanatomical level can be expected in the ribs of tetrapods depending on their ecological adaptations.

Here we propose the first extensive study of the microanatomical diversity of amniote ribs. Our comparative sample comprises more than 145 species of extant amniotes and encompasses the diversity of this group from both taxonomic (mammals, lepidosaurs, crocodiles, birds) and ecological perspectives (aquatic, terrestrial, flying, arboreal, fossorial). We standardized our sampling location to the midshaft of the median rib in the rib series. Transverse sections were obtained from classical petrographic methods, as well as from X-ray microtomography. This preliminary and exploratory study aims to i) assess quantitatively the effects of habitat, locomotion, body size and phylogeny on the inner architecture of amniote ribs; ii) discuss the use of such information for paleoecological reconstructions.

HISTOLOGICALLY DETECTING POSTCRANIAL PNEUMATICITY IN SAUROPODOMORPHA: IMPLICATIONS FOR THE EVOLUTION OF THE DINOSAURIAN RESPIRATORY SYSTEM

FILIPPO BERTOZZO[1] AND P. MARTIN SANDER[1]

[1]*Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
filippo.bertozzo@gmail.com

Postcranial skeletal pneumaticity (PSP) is the modification of the postcranial skeleton by pneumatic diverticula of the respiratory system. The evolutionary history of PSP is still controversial, PSP being found also in non-avian theropods, sauropods, pterosaurs, and perhaps in basal Archosauriformes. Presence of PSP may be diagnostic for a highly heterogeneous avian-like respiratory system with air sacs based on osteological correlates such as pneumatic fossae for soft tissues that do not preserve. However, in some taxa such as basal sauropodomorphs, PSP may not be unequivocally present or show intraspecific variability, making inferences about respiratory soft tissue difficult. Since PSP originates from the invasion of respiratory tissue into the interior of bones, it leaves trace in the histology of bone caused by bone shape change. Analysis at the histological level of pneumatic bones thus may provide criteria for the recognition of air sacs adjacent to bone even in taxa where clear PSP is lacking. We analyzed thin sections of pneumatic postcranial bones of recent birds and sauropod dinosaurs and pneumatic skull bones of mammal taxa in order to detect such criteria. For comparison, we also analyzed non-pneumatic bones of crocodiles. As a first application, we analyzed thin sections taken from the lateral side of the centrum of cervicothoracal vertebra of basal sauropodomorphs and pelvic bones of sauropods to test for hypothesized PSP in these fossil taxa. As a further application, we sampled vertebrae of ornithischian dinosaurs. An avian-style lung may have been secondarily lost in this clade of herbivorous dinosaurs, but this hypothesis is supported only at the morphological level. Histological evidence for air sacs adjacent to bone would lend support to the hypothesis.

STUDY OF THE TEIID LIZARD *ASPIDOSCELIS TIGRIS* REVEALS ENVIRONMENTALLY CONTROLLED GROWTH IN SQUAMATES

HOLGER PETERMANN[1] AND JACQUES GAUTHIER[1]

[1]*Yale University, New Haven, CT-06511, USA*
holger.petermann@yale.edu

Squamates occupy a wide range of ecological niches and are very diverse especially in arid habitats. Paleohistological studies frequently focus on only two groups of extant and extinct squamates: snakes and mosasaurs. This, however, leaves many questions regarding the growth of the remaining squamate groups unaddressed. Their relatively slow growth rate makes them the perfect model organism for the study of the effects of the environment on the growth record (e.g. prolonged drought, yearly fluctuating amounts of resources).

Here we present the growth record of the teiid lizard *Aspidoscelis tigris* (the Tiger Whiptail lizard). The growth pattern observed in 29 adult *A. tigris* suggests a strong correlation of growth and environmental conditions (biotic and abiotic), rather than age. The oldest individual registered a minimum age of eight years, but at 73 mm snout vent length (SVL) it ranked as the second smallest individual. On the other hand, the minimum age of the largest ten specimens (ranging from 90 to 104 mm SVL) averaged between two and six years. We had prior knowledge of the gender of seven specimens; comparison of the growth record between the genders did not support the idea that male and female individuals show different growth patterns; a posteriori allocation of gender to specimen is impossible.

We therefore conclude that rather than correlating with age or gender, growth and growth rate in *A. tigris* are highly dependent on environmental factors such as food and temperature. Furthermore, we hypothesize this to be the standard condition for Squamata.

BONE MICROSTRUCTURE OF *BATHYERGUS SUILLUS* (RODENTIA: BATHYERGIDAE); CORTICAL BONE THICKENING AND SEXUAL DIMORPHISM

GERMAN MONTOYA[1] AND ANUSUYA CHINSAMY[1]

[1]*Department of Biological Sciences, University of Cape Town, Cape Town, 7701, South Africa*
getamoo@gmail.com

Given that patterns of bone development in mammals are mostly known for cursorial animals, there is a considerable gap in our understanding of how other lifestyles affect bone growth. Likewise, scarce research has been done on wild mammal populations, and these often include few individuals and incomplete ontogenetic series. This study examines the limb bone microstructure of a feral population of *Bathyergus suillus* (Bathyergidae; *n*=49), an endemic and solitary subterranean rodent from the Western Cape of South Africa. Undecalcified cross sections from the diaphysis of femur, humerus, tibia-fibula, ulna and radius through ontogeny were studied. Cortical bone thickening occurs mainly by periosteal apposition of zonal bone (fibrolamellar, parallel fibered and lamellar bone tissues) and limited endosteal resorption was observed. Thus, midcortical areas with woven and compact coarse cancellous bone tissues also contributed to the cortical thickening. Mid-diaphyses were well vascularized during ontogeny and secondary reconstruction was minor. Thickening of the compacta is evident in larger juveniles, although it is unclear if these changes are coupled with the attainment of sexual maturity and/or dispersion from nest. Histomorphometric analysis showed sexual dimorphism in femoral and humeral cortical porosity, with females having higher levels of intracortical resorption. The shape and size of resorption cavities also indicates sexual differences in mineral homeostasis. These findings contrasts with the generally high levels of resorption and remodeling documented in cursorial vertebrates. This study provides much insight into sexual differences of *B. suillus*, and provides fresh insight into how the subterranean lifestyle impacted on bone growth and development.

CALIBRATION OF BONE GROWTH WITH METABOLIC RATE AND LIFE HISTORY EVENTS IN *LEPUS EUROPAEUS*: A LABELING EXPERIMENT

MEIKE KÖHLER[1,2], XAVIER JORDANA[1], HANNO GERRITSMANN[3], THOMAS RUF[3], WALTER ARNOLD[3], GABRIELLE STALDER[3], NIKOLAUS HUBER[3] AND GUILLEM ORLANDI-OLIVERAS[1]

[1] *Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
[2] *ICREA at Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
meike.kohler@icp.cat
[3] *Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna 1160, Austria*

Paleobiology relies to a large extent on paleohistology as a tool to infer data on life history (LH), physiology, and phylogeny. While phylogenetic studies are based on well-established methodologies, studies on LH and physiology remain conjectural as they assume relationships between LH events or metabolic rate and bone microstructures that are not experimentally established hitherto. Thus, unlike lines of arrested growth (LAGs) which are known to form annually obeying photoperiod, and which are mediated by hormonal cycles, it is largely unknown whether the single, non-cyclical LH events leave marks in bone tissue, what these look like, and how they form. Similarly, a correlation between physiology and tissue types has been suggested on the basis of comparative studies between ecto- and endotherms; however, the effects of metabolic rate on tissue formation have never been tested so far.

Labeling hard tissues is the only way to reliably correlate changes in tissue types and growth marks with LH events and MR. We labeled 12 individuals of captive juvenile European hare (*Lepus europaeus*) from day -3 before birth to day 70 (about 1.5 months after weaning), and measured their daily weight gain and MR (the latter at the dates of labeling). We will report about the correspondence between tissue type and tissue growth rate, and their correlation with body mass and MR. We discovered a neonatal line and a weaning line, both moments of turnover in mineral and bone metabolism, and we will show how this affects the degree of tissue resorption and the formation of secondary bone.

BONE HISTOLOGY OF RED DEER (*CERVUS ELAPHUS*) AND IMPLICATIONS FOR LIFE-HISTORY INFERENCES

XAVIER JORDANA[1], CARMEN NACARINO-MENESES[1] AND MEIKE KÖHLER[2]

[1]*Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
xavier.jordana@icp.cat
[2] *ICREA at Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*

A deeper knowledge of ontogenetic changes in bone tissue in extant mammals is critical to a correct interpretation of growth patterns in extinct taxa. Here we present preliminary results of our study of bone thin sections of a red deer sample. We explored ontogenetic changes throughout zonal bone tissue. The sample is comprised of a growth series of around 25 red deer specimens coming from Spain (wild specimens), as well as from a herd confined in an enclosure in Vienna (Austria). Sex, age, date of death, and body mass are known for alpine deer. The Spanish deer sample has associated data on sex and date of death, while their age at death is determined from the state of dental eruption and cementum analysis. Thin sections of femora and tibia were prepared and examined under transmitted and polarized light. Histological features such as the number of LAGs, the perimeter of growth cycles, osteocyte lacunae density, vascular density, and vascular orientation were quantified. Our results indicate a good agreement between the number of LAGs and age at death, although additional (non-periodic) LAGs may be present. The study also shows great variability in body size in our red deer sample, which may hamper age retrocalculation based on the diameter or circumference of growth cycles. Bone tissue analysis highlights the significant ontogenetic variation in vascular and cellular features that reflect the slowdown in growth associated with the onset of maturity.

BIOMINERALIZATION AND EGGSHELL STRUCTURE: AVIAN-LIKE VERSUS NON-ORNITHOID DINOSAURIAN EGGSHELLS

KONSTANTIN E. MIKHAILOV[1]

[1] *Paleontological Institute of the Russian Academy of Sciences, Moscow 117647, Russia, mikhailov@paleo.ru*

The concept of *basic types* in structural classification of the eggshells of birds and reptiles, introduced by Prof. H.K.Erben at the end of 1970s, was an important step in our understanding of the regularities of eggshell morphogenesis in terms of biomineralization. Each basic type is a particular sequence of certain ultrastructural zones, the fine arrangement of which marks particular conditions of mineralization. Several basic types of hard eggshell appeared independently in the Jurassic. All of them are single-layered eggshells in terms of the ultrastructure. The ornithoid type is the only true two-layered eggshell, where the second layer reveals complex 3-D arrangement of fine biocrystaline material, known as the *squamatic ultrastructure*. This ultrastructure is under particular consideration as the mistakes in its identification bring to mistakes in the interpretation of the eggshell basic type, and to subsequent misidentifications in egg taxonomic associations and its further implications. For instance, only part of the elongated eggs from the Cretaceous sediments of Mongolia for certain belong to the theropods (oviraptorids) and most could be laid by some plant-eating dinosaurs, e.g. protoceratopsians. Of particular interest is that although basic types of eggshell are generally associated with larger groups of archosauromorphs (crocodiles, dinosaurs, birds), the theropods reveal enigmatic split in their eggshell structure: many of them share advanced ornithoid type of eggshell with birds and some of them (megalosaurids, segnosaurs) possess one-layered eggshell similar to that of sauropods.

THE FIRST DINOSAUR EGGS FROM A NEW VERTEBRATE LOCALITY IN THE UPPER CRETACEOUS SEBEŞ FORMATION, ROMANIA

DANIEL E. BARTA[1], AKINOBU WATANABE[1], MÁTYÁS VREMIR[2], RADU TOTOIANU[3] AND MARK A. NORELL[1]

[1]Richard Gilder Graduate School and Division of Paleontology, American Museum of Natural History, NY 10024, USA
dbarta@amnh.org
[2]Department of Natural Sciences, Transylvanian Museum Society (EME), Cluj-Napoca, 400009, Romania
[3] Sebeş Municipal Museum, Sebeş, 515800, Romania

Late Cretaceous island faunas of Europe have been the subjects of intense paleobiogeographical, paleoecological, and evolutionary interest for more than a century. Romania in particular has provided abundant insights, such as “island dwarf” dinosaurs and dinosaur eggs in the Haţeg basin. Until recently, however, eggs outside this basin were little-known. We report the first occurrence of non-avian dinosaur eggshell fragments from the Upper Cretaceous (Maastrichtian) Sebeş Formation in a new vertebrate locality in the Transylvanian basin. Subsequent fieldwork also uncovered several egg clutches. Use of an environmental scanning electron microscope reveals well-preserved eggshell structure in radial section. The eggshell measures 1.4-1.7 mm thick, with a single layer of fan-shaped shell units composed of radiating calcite wedges. Tube-shaped pores extend perpendicular to the eggshell surface, which exhibits compactituberculate ornamentation. An unusual network of cracks or channels within the calcite wedges near the base of the eggshell deserves further investigation, as it may either represent a diagenetic texture or possibly channels formerly occupied by fibers of the protein matrix. Eggshell characters allow assignment to *Megaloolithus* oosp. within the oofamily Megaloolithidae. This oofamily is attributed to sauropod dinosaurs on the basis of embryos in ovo (from Argentina) and an associated hatchling (from India), though some Haţeg megaloolithid eggs are associated with perinatal hadrosaur remains. This material provides a further similarity between the Transylvanian and Haţeg basin assemblages, highlights the widespread distribution of megaloolithid parent animals throughout Europe during the Late Cretaceous, and suggests faunal exchange with Gondwana during or before this time.

ASSOCIATION BETWEEN EGGSHELLS AND SKELETON OF AN ALVAREZASAURID THEROPOD FROM THE UPPER CRETACEOUS OF CHINA

JUNCHANG LÜ[1], MARTIN KUNDRÁT[2], LI XU[3], HANYONG PU[3], HUALI CHANG[3], CAIZHI SHEN[1] AND PER E. AHLBERG[2]

[1] *Institute of Geology, Chinese Academy of Geological Sciences, Beijing, 100037, China*
lujc2008@126.com
[2] *Department of Organismal Biology, Evolutionary Biology Centre, Uppsala University, Uppsala, 75236, Sweden*
[3] *Henan Geological Museum, Zhengzhou, 450016, China*

The first association between eggs and bone remains of an alvarezsaurid dinosaur has been reported for *Bonapartenykus ultimus* from the Allen Formation (Upper Cretaceous) in Patagonia, Argentina. The microstructure analysis revealed a unique combination of characters (e.g. three layers; eggshell thickness 1 mm; tubocanaliculate and obliquicanaliculate with inflated pneumatic chambers, prismatic/mammillary ratio 4.4-4.9:1) that distinguished the eggshell of *Bonapartenykus* from all known parataxa. It was therefore described as *Arriagadoolithus patagoniensis* oogen. et sp. nov, and was assigned to the new oofamily Arriagadoolithidae. Here we report on the first association between eggshells and skeletal remains of an alvarezasaurid dinosaur from Laurasia. The specimen came from the uppermost Cretaceous beds of the Qiupa Formation in Henan Province, China. EDAX spectra show that elemental composition is consistent with pure calcite. Laminar incremental microstructure of the matrix is visible on thin sections whereas vertically oriented prismatic columns are discernible on SEM images. The most striking are high amounts of phosphorus distributed continuously around apices of the mammillary cones as the layer with fibrous texture similar to the shell membrane of the *Bonapartenykus* eggshell. In contrast to *Bonapartenykus*, the Chinese alvarezsaurid laid eggs with strinkingly different microstructure. The eggshells consist of two structural layers: prismatic and mammillary. The maximum thickness is 1.46 mm. The thickness ratio of the prismatic and mammillary layers varies from 1.9:1 to 3.3:1. We hypothesize that alvarezsaurids in Laurasia and Gondwana evolved two different types of eggshells at the end of the Cretaceous.

A NEW TYPE OF DINOSAUR EGG FROM LOWER CRETACEOUS OF GANSU PROVINCE, CHINA

JUNFANG XIE[1], XINGSHENG JIN [1], SHUKANG ZHANG[2], DAQING LI[3] AND LINGQI ZHOU[3]

[1] Zhejiang Museum of Natural History, Hangzhou, Zhejiang, 310014, China
[2] Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, 100044, China
Zhangshukang@ivpp.ac.cn
[3] Gansu Geological Museum, Lanzhou, Gansu, 730050, China

The Early Cretaceous deposits cropping out in Gansu Province, northern China, have yielded numerous dinosaur skeletal materials and tracks, but fossil eggs have not been reported yet. Here we describe a new type of dinosaur egg from the Lower Cretaceous Hekou Group in the Lanzhou-Minhe Basin, representing a new oogenus and a new oospecies. The distinct morphology further leads us to erect a new oofamily. The new specimen can be distinguished from other known dinosaur eggs by the combination of the following eggshell micro-features: branched eggshell units without a compact layer near the outer surface, obvious horizontal accretion lines, interlocked or isolated eggshell units on tangential sections and irregular pore canals, differing from all known oofamilies. The known dinosaur eggs of China are largely unearthed from the Late Cretaceous deposits, with occasional reports from the Early Cretaceous in Liaoning, northeastern China. This study expands the geological and temporal distribution of dinosaur egg records in China, with implications for the morphological evolution of dinosaur eggs.

REPRODUCTIVE BIOLOGY OF THE OVIRAPTORID DINOSAURS REVEALED BY THE INTERPRETED EGG INNER STRUCTURES

TZU-RUEI YANG[1,2], MARTIN SANDER[1], JASMINA WIEMANN[1] AND YEN-NIEN CHENG[2]

[1] *Steinmann-Institut für Mineralogie, Geologie und Paläontologie, Universität Bonn, Bonn 53115 Bonn, Germany*
lereage@gmail.com
[2] *Division of Paleobiology, National Museum of Natural Sciences, Taichung 40453, Taiwan*

The hard-shelled egg with several membranes and complicated internal structures is an adaption in terrestrial animals to protect their offspring from predation and dehydration, and enhance the reproductive success. Extant eggs of reptiles and birds show great variation in porosity, which is related to nesting environments and incubation behavior. Calcified eggshell is mainly composed of the cuticle, calcareous shell, and *membrana testacea*, from outermost to innermost.

A fossilized *membrane testacea* has been reported in *Lufengosaurus*, titanosaurid dinosaur, and avian eggshells. However, no fossilized cuticle has been reported to date. Here we describe probable preservation of the cuticle in embryo-bearing oviraptorid dinosaur eggshells from the Cretaceous of China. Moreover, based on the thin sections of these oviraptorid eggshells, we infer internal egg features and incubation behavior of these dinosaurs.

In extant bird eggs, an air space, the so-called air cell, forms in the egg when the contents of the egg cool and contract after the egg is laid. The air cell is a common inner structure in avian eggs but not known in reptilian eggs. Eggshell thickness variation and erosion patterns resulting from calcium absorption by the developing embryo show that the air cell had not evolved in oviraptorid eggs. The clutch pattern of superimposed layers means that the eggs were unlikely to have been moved or manipulated, suggesting the lack of chalazae. Eggshell porosity evaluation suggests that the oviraptorid eggs were at least partially buried in the substrate. The reptilian-like oviraptorid egg structure and nest structure indicate that the brooding behavior did not appear in the oviraptorid dinosaurs, which might show guarding behavior as the extant crocodiles do.

SEMI-FLEXIBLE EGGSHELL IN LOWER JURASSIC PROSAUROPODS SUGGESTS PLESIOMORPHIC CONDITION IN DINOSAURS

KOEN STEIN[1], TIMOTHY HUANG[2], EDINA PRONDVAI[3], ROBERT REISZ[4] AND P. MARTIN SANDER[5]

[1] *Earth System Science - AMGC, Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium*
koen_stein@yahoo.co.uk
[2] *National Chung Hsing University, Taichung 402, Taiwan.*
[3] *MTA-ELTE Lendület Dinosaur Research Group, Eötvös Loránd University, Budapest, 1117, Hungary*
[4] *Department of Biology, University of Toronto at Mississauga, Mississauga, ON L5L 1C6, Canada.*
[5] *Steinmann Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn 53115, Germany*

Non-avian dinosaur eggshell microstructure is mostly known from Late Jurassic and Cretaceous dinosaurs. These dinosaurs generally have a thick mineralized eggshell and typical dinosauroid or ornithoid microstructure. The diversity and distinct structural morphologies of eggshells found in the extant phylogenetic bracket of dinosaurs, i.e. crocodiles, turtles and birds, combined with the discoveries of soft eggshells in pterosaurs, raise questions about of the nature of eggshell in the earliest dinosaurs. Recent discoveries of several Early Jurassic basal sauropodomorph embryos and associated eggshells allow for the first time a detailed analysis of the eggshell microstructure of the 'prosauropod' dinosaurs *Lufengosaurus* from the Lower Jurassic Lufeng Formation of YunNan (China), *Massospondylus* from the Lower Jurassic Elliot Formation of South Africa, and *Mussaurus* from the Upper Triassic to Lower Jurassic Laguna Colorada Formation of Argentina. These remains represent the oldest known terrestrial vertebrate eggshells. The very thin calcitic layer (50-100 µm) with units showing radiating crystals and an equally thick shell membrane, suggest semi-flexible eggshells in these early sauropodomorphs, which is in contrast to the >500 µm thick calcitic layer found in the eggshells of Late Jurassic and Cretaceous similar sized dinosaurs. This implies that early sauropodomorph eggs were incubated in buried nests similar to modern turtles, crocodiles, mound-building birds, and some squamates. Furthermore, the presence of a semi-flexible eggshell and other structural characteristics clearly show that eggshell-thickening evolved independently in sauropods, theropods, and ornithischian dinosaurs, making the thick mineralized eggshell a homoplastic character within Dinosauria

HOW DENTAL HISTOLOGY TRACKS LIFE HISTORY FROM THE INDIVIDUAL TO THE SPECIES

WENDY DIRKS[1]

[1]*Department of Anthropology, Durham University, Durham, DH1 3LE, United Kingdom*
wendy.dirks@durham.ac.uk

Because teeth are the most abundant element in the vertebrate fossil record, dental histology has been widely used to understand aspects of life history in extinct species and aid in our understanding of life history evolution within and between clades. Dental histology can also be used to understand the life history of an individual; events such as birth, illness and other types of physiological stress are recorded while teeth develop. I will review the techniques commonly used to infer life history and discuss their validity and applicability to the different levels of life history variation: individual, populational, specific, and between higher clades, including new methods for understanding individual variation using laser ablation and trace elements. Some of the measures we commonly make in histological sections of teeth tell us about how teeth develop their unique morphology and their only direct relationship to life history is the constraints brought about by the time frame within which the tooth must form. These include variables such as daily secretion rate, angle of the forming front of enamel and dentine, extension rate (a combination of the first two), periodicity of long period growth lines (Havers-Halberg Oscillation or HHO), and enamel thickness. While the development of the entire dentition is more closely related to the organism's life history and includes the ages at eruption of the teeth, some measures, such as HHO and extension rate, may also tell us something about life history, but only when applied to the right level of life history variation.

THE ARRANGEMENT OF COLLAGEN AND SHARPEY'S FIBERS IN MAMMOTH CEMENTUM. A HIGH SPATIAL-RESOLUTION IMAGING STUDY USING POLARIZATION CONFOCAL MICROSCOPY

SANTIAGO GOMEZ[1]

[1] *Department of Pathological Anatomy, University of Cadiz, Cadiz, 11003, Spain*
santiago.gomez@uca.es

Cementum in the mammoth tusk constitutes the thickest layer of cementum ever produced. The present investigation reports on the arrangement of collagen fibers and Sharpey's fibers in a well-preserved portion of a mammoth tusk (over 10,000 years old) from Yakutia Republic. Transverse ground semi-thin sections were prepared from poly-methylmethacrylate embedded blocks. Sections were examined after acid decalcification (in order to eliminate any mineral contribution in the polarization image) with polarization confocal microscopy. This type of polarization microscopy is a novel method that uses interference green polarization-colour to form in focus a monochromatic image allowing optical sectioning. Sharp, high spatial-resolution images of green-colour stained silhouette of collagen fibers (1.1 μm thick) and black-colour stained Sharpey's fibers (3.6 μm thick) were captured. In mammoth cementum, collagen fibers were disposed forming an intricate mesh with a circumferential component parallel to the outer surface, while Sharpey's fibers were found to run in wavy bundles, perpendicular to it.

TWO RECORDS OF *OMPHALOSAURUS* FROM THE MUSCHELKALK - THE RECONSTRUCTION OF TRIASSIC MARINE ECOSYSTEM BASED ON TEETH

TANJA WINTRICH[1] AND P. MARTIN SANDER[1]

[1] *Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
tanja.wintrich@uni-bonn.de

Omphalosaurus, an enigmatic ichthyosaur from the Middle Triassic of the Northern Hemisphere, previously has only been found in sediments deposited in pelagic habitats. Unexpectedly, highly informative specimens of *Omphalosaurus* were discovered in the Muschelkalk of the Germanic Basin. However, only one of the specimens is *Omphalosaurus*, the other being a placodont. Both specimens are important for the reconstruction of the mode of life of *Omphalosaurus* as well as for reconstructing Mesozoic marine ecosystems. "*Omphalosaurus" peyeri* was described from the Rüdersdorf Quarry by Maisch and Lehmann in 2002 as *Omphalosaurus* based on the typical dome-like teeth and enamel surface structure. A new *Omphalosaurus* specimen was discovered in the Polish Muschelkalk in 2004. Both finds show durophagous feeding adaptation and thick enamel. SEM of dental tissues and reconstruction of the dentition based on CT scans clarify the identity of the finds and have wider implications for marine reptile relationships. Enamel microstructure in the Polish *Omphalosaurus* is the same as in bonafide *Omphalosaurus* specimens from Spitsbergen whereas that of "*Omphalosaurus*" *peyeri* resembles that of placodonts. In addition, the Polish specimen and the Spitsbergen material show newly discovered unique canals in the dentin. We hypothesize that the differences in dental tissues and mineralization structure of the enamel in the two taxa are related to feeding on ammonites in the water column in *Omphalosaurus* versus feeding on bivalves on the sea floor in placodonts. The differentiation in feeding modes revealed by such microstructural investigations is necessary for the comprehensive reconstruction of Triassic marine ecosystems.

DENTAL HISTOLOGY OF *HESPERORNIS* AND *ICHTHYORNIS*: AN INSIGHT INTO THE BIOLOGY OF THE "LAST" TOOTHED BIRDS

MAITENA DUMONT[1], ANTOINE LOUCHART[1,2], PAUL TAFFOREAU[3], BHART-ANJAN BHULLAR[4], DANIEL FIELD[5] AND LAURENT VIRIOT[1]

[1]*IGFL (UMR 5242), Evo-Devo of Vertebrate Dentition Team, Lyon, 69634, France*
maitena.dumont@gmail.com
[2]*LECA ENS (UMR 5553), Paleo-Geomics Team, Lyon, 69364, France*
[3]*European Synchrotron Radiation Facility, Grenoble, 38043, France*
[4]*Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA 02138, USA*
[5]*Department of Geology and Geophysics, Yale University, New Haven, CT 06520, USA*

Even though modern birds are toothless, their Mesozoic relatives comprise a majority of toothed species. We investigated teeth and jaw fragments of *Hesperornis* and *Ichthyornis*, the closest toothed relatives of modern birds, from the late Cretaceous. Their histological study has been carried out using synchrotron x-ray microtomography, and also confocal and electron microscopy, and comparing them with other bird or theropod teeth. The bird teeth microstructure observations reveal that the enamel is very thin, simple, formed by parallel crystals. Teeth implantation is different between the two species. The *Ichthyornis* teeth are inserted in alveolar bone, whereas teeth in *Hesperornis* dentary are present in a groove, wedged by bulge constriction. The *Hesperornis* teeth are also attached directly to the jaw bone by a thick cementum; numerous Sharpey's fibers confirm that a periodontal ligament could be present. Resorption pit in *Ichthyornis* tooth root confirms a vertical replacement, previously observed in *Parahesperornis*, *Archaeopteryx* and in Crocodylia. Finally tooth development analysis via dentine incremental lines indicates that these toothed birds present a high rate of tooth formation (crown extension) and high rate of root extension as well. These new structural and histological characteristics of toothed Ornithurae allow proposing new interpretations regarding their paleobiology.

TOOTH ULTRASTRUCTURE AND DEVELOPMENT OF A 200 MILLION YEAR OLD MAMMAL REVEALED WITH SYNCHROTRON NANOTOMOGRAPHY

IAN CORFE[1], AKI KALLONEN[2], ELIS NEWHAM[3], PAMELA GILL[4], KEIJO HAMALAINEN[2] AND JUKKA JERNVALL[1]

[1] *Institute of Biotechnology, University of Helsinki, Helsinki, 00014, Finland*
ian.corfe@helsinki.fi
[2] *Department of Physics, University of Helsinki, Helsinki, 00014, Finland*
[3] *Engineering and the Environment, and National Oceanographic Centre, University of Southampton, Southampton, SO17 1BJ, UK*
[4] *School of Earth Sciences, University of Bristol, Bristol, BS8 1RJ, UK*

Three-dimensional relationships between tooth dentine tubules, enamel tubules and enamel prisms are not fully understood. Previous visualisation methods have been in two dimensions or concern only limited tooth regions. We utilzsed non-destructive synchrotron nanotomography, producing 3D models of dental ultrastructure with voxel resolutions down to 25 nanometers, and quantified the number, shape and 3D spatial relationships of tubules and prisms of lower molars of mouse *Mus musculus*, shrew *Sorex minutissimus*, vole *Myodes glareolus* and the Early Jurassic mammaliaform *Morganucodon watsoni*. Dentine tubule densities follow similar patterns, increasing with distance from cusp tips in all taxa, but were twice as dense in the shrew. In all species, dentine tubules split to form more but smaller diameter tubules traversing the enamel-dentine junction (EDJ), and continuous with equal sized enamel tubules. *Mus* enamel tubules merge and terminate close to the EDJ, whereas in *Sorex* enamel tubules run throughout the enamel; *Myodes* and *Morganucodon* are intermediate in enamel tubule length and density. Enamel tubules of *Sorex* are often but not always associated with an enamel prism sheath. In extant species, there is a sharp angle change of enamel and dentine tubules close to the EDJ, with tubules crossing the EDJ perpendicularly before bending towards the pulp cavity. In *Morganucodon* however, this angle change is considerably less pronounced, with tubules following a near straight line from EDJ to pulp cavity. These results suggest the overall developmental and mineralization ontogeny of *Morganucodon* molars was similar to those of extant mammals, but differed in the finer details.

CEMENTUM HISTOLOGY REVEALS PHYSIOLOGY AT THE ROOT OF THE MAMMAL PHYLOGENY

ELIS NEWHAM[1,2], PAMELA GILL[3] AND IAN CORFE[3]

[1]*Faculty of Engineering and the Environment, Southampton, SO17 1BJ, United Kingdom*
[2]*Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton Waterfront Campus, Southampton, SO14 3ZH, United Kingdom*
ecdn1g14@soton.ac.uk
[3] *School of Earth Sciences, University of Bristol, Bristol, BS8 1RJ, United Kingdom*
[4] *Institute of Biotechnology, Helsingin Yliopisto, 00014, Finland*

All three mineralized dental tissues, cementum, dentine and enamel, record periodic annuli which, if unmodified by diagenesis, form a permanent record of growth. Such annuli have been extensively studied in many extant mammalian taxa, and their relation to chronological age is well understood. However, ours is the first study to analyse such features in Mesozoic mammals. We have chosen to study cementum annuli, as cementum is the only dental hard tissue not to be resorbed through ontogeny, and so provides the most complete record of life history available. Cementum is a collagenous tissue that anchors teeth within the alveoli against masticative forcing, and has been consistently shown to record seasonal changes in dietary quality through alternating dark/light bands of differing mineral density and structure. Our chosen taxon, *Morganucodon watsoni*, is one of the most basal and best known mammaliaforms, reprented by thousands of isolated teeth found within the *Hirmeriella* fissure suite of Glamorgan, South Wales (UK). We have used high resolution synchrotron tomography for the first time to study cementum incrementation. The improved resolution and three dimensional perspective of tomographic data overcame several caveats of previous studies of cementum increments based on thin section-histology. Tomography also allowed a population-level sample of teeth to be studied entirely non-evasively, in order to determine a minimum estimate of maximum lifespan of seven years for *M. watsoni.* This estimate is considerably longer than extant mammals of comparable body size, a finding that suggests an equal disparity in metabolic potential between basal mammaliaforms and extant taxa.

THE LIFE HISTORY OF FOSSILE TAXA: WHAT CAN GROWTH CURVES TELL US?

EVA MARIA GRIEBELER[1], NICOLE KLEIN[2] AND P. MARTIN SANDER[3]

[1] *Department of Ecology, University of Mainz, Mainz, D-55099, Germany*
em.griebeler@uni-mainz.de
[2] *State Museum of Natural History, Stuttgart, D-70191, Germany*
[3] *Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*

Information on aging, maturation, and growth is important for understanding life histories of organisms. In extinct taxa, such information can be derived from the histological growth record preserved in the mid-shaft cortex of long bones. Unfortunately, many humeri and femora of fossil taxa show no quantifiable growth mark record throughout the complete ontogeny of the individual. In the inner part of the bone growth cycles are lost due to remodeling/resorption processes or non-deposition. Only in adult individuals, all three phases of sigmoidal growth (exponential, quasi-linear, asymptotic phase) can be covered. The absence of growth marks in the inner cortex of the long bone (e.g. in the majority of sauropods), and/or a bad coverage of the asymptotic growth phase in the growth record (e.g. in non-fully grown individuals) is challenging, when establishing growth curves for individuals. So far, studies that conducted growth curve modelling often *a priori* chose one of the standard growth models from biology. This is problematic, when applying the concept of the inflection point of the growth curve to estimate the individual's age at sexual maturity. In my talk, I will present a new mathematical approach to identify the best growth curve for a given growth record in terms of statistics, but also in terms of its biological reliability. I will further present some promising examples on how a multi-element approach can be used to derive better growth curves for long bones of fossils. Fossil taxa studied until now are Sauropodomorpha and Sauropterygia.

OPERCULAR MICROANATOMY AND MICROSTRUCTURE IN THE MESOZOIC PREDATORY FISH *SAURICHTHYS* (ACTINOPTERYGII)

TORSTEN M. SCHEYER[1], LEONHARD SCHMID[1], HEINZ FURRER[1] AND MARCELO R. SÁNCHEZ-VILLAGRA[1]

[1]*Paläontologisches Institut und Museum, Universität Zürich, Zurich, CH-8006, Switzerland*
tscheyer@pim.uzh.ch

Life history data (e.g., aging, age at sexual maturity, reproductive lifespan, etc.) are fundamental in many palaeontological studies to better understand the biology of extinct animals and their role in and impact on their respective ecosystems. We utilised opercular bones of *Saurichthys*, an easily recognisable, predatory, long-snouted fish that was nearly globally distributed during the Triassic, to assess potential life history traits in this animal genus. The opercula were chosen, sectioned, and studied in a phylogenetic framework of extant non-teleost actinopterygians (sturgeon, bichir and gar), to see whether these prominent skull bones provide reliable age estimates, data that are yet largely unknown in these fossil fishes. Whereas opercular bones in the extant outgroups provided good age data, and despite the fact that growth marks were visible in all studied *Saurichthys* opercula, reliable individual age data could not be collected from the latter, based on difficulties of identifying all age-related structures and because of morphogenetic differences in histogenesis between *Saurichthys* and the outgroup taxa. On the other hand, surface relief in the form of low ridges or rows of tubercles was found to be unrelated to growth marks and purely ornamental in nature, thus refuting previous propositions that the external features reflect growth stages. In comparison, internal growth cycles were well visible and more easily countable in a sectioned *Saurichthys* ceratohyal, a bone with an ovoid shaft cross-section, making it a suitable candidate for future skeletochronological studies.

HISTOLOGICAL STUDY OF ANTARCTIC, EARLY JURASSIC SAURISCHIANS

PETER J. MAKOVICKY[1], DIANA BOUDREAU[2] AND STEPHANIE PEDERSEN[2]

[1] *Field Museum of Natural History, Chicago, 60605, USA*
pmakovicky@fieldmuseum.org
[2] *Department of Geology, Augustana College, Rock Island, 61201, USA*

We conducted multi-element histological studies on two Early Jurassic Antarctic dinosaurs, including the holotype of the crested theropod *Cryolophosaurus*, and a nearly complete, small basal sauropodomorph specimen. We sampled limb bones and axial elements in both specimens to gauge variation in growth markers and other histological features of the skeleton of saurischians. Axial elements (rib, gastralia) as well as the fibula of *Cryolophosaurus* exhibit attenuating growth with diminishing spacing between Lines of Arrested Growth (LAGs) toward the outer surface. One rib section preserves 11-13 LAGs, with the last few closely packed and indicating a near cessation of growth. By contrast, the femur exhibits only two faint annuli and continuing rapid growth. In the sauropodomorph, hindlimb elements exhibit highly vascularized, fibrolamellar bone with no growth markers and a large medullary cavity. Secondary osteons are absent, consistent with Type C bone tissue as classified by Klein and Sander. Axial element sections appear more mature (Type D bone tissue) with lamellae evident in primary osteons, longitudinally arranged vascular canals, and incipient development of secondary osteons in the medullary region. One or two truncated, asymmetric LAGs are evident in all axial elements. Our study demonstrates that axial elements of saurischians can preserve more growth markers than limb bones, and may be more useful for age determination. However, axial bones also exhibit an earlier slowdown in growth than limb bones. These marked differences in growth between elements in the same skeleton indicate that multiple lines of evidence should be used to infer maturity.

AN ONTOGENETIC HISTOANALYSIS OF AUSTRALIAN POLAR DINOSAURS

HOLLY N. WOODWARD[1], THOMAS H. RICH[2] AND PATRICIA VICKERS-RICH[3]

[1] *Oklahoma State University Center for Health Sciences, Tulsa, OK 74107, USA*
holly.n.woodward@gmail.com
[2] *Museum Victoria, Melbourne, Victoria 3001, Australia*
[3] *School of Geosciences, Monash University, Clayton, Victoria 3800, Australia*

High-latitude paleofaunas are of particular interest to dinosaur paleontologists because of the unique conditions under which dinosaurs survived and flourished, including months of twilight or polar darkness. Basal ornithopods ("hypsilophodontids") and small theropods are common in the Early Cretaceous (Aptian-Albian) high latitude fossil record of Victoria, Australia. A previous histologic analysis suggested Victorian polar dinosaurs had physiologies similar to their lower-latitude relatives. For the present study, hypsilophodontid and theropod tibiae and femora were histologically examined to better understand polar dinosaur ontogenetic life histories, which have previously remained largely unexplored. The Aptian sample consists of eleven hypsilophodontids with cyclical growth mark (CGM) counts between zero and seven. A plot of CGM versus tibia length reveals a weak asymptotic curve with considerable individual variation in body size versus age. The outer cortex of two hypsilophodontids (with 6 and 7 CGMs) consists of an EFS, signaling skeletal maturity. No asymptotic curve emerges for the Albian sample, possibly due to the smaller sample size of six, individual variation in body size, and/or unrecognized different species. However, three of the six Albian hypsilophodontids contain an EFS, and these three individuals have CGM counts between 3 and 4. The two Aptian theropod samples included a tibia of 17.8 cm and a femur of 19.3 cm, with zero and 8 CGMs, respectively. This initial ontogenetic study suggests high individual variation in body size, and confirms a small asymptotic adult size for Victorian hypsilophodontids. With additional sampling, separation between ontogenetic, individual, and species variation will become more evident.

HISTOLOGY OF THE SAUROPOD LONG BONES FROM THE HOWE-STEPHENS QUARRY (MORRISON FORMATION, WYOMING): TESTING HYPOTHESES OF SKELETAL UNITY

KAYLEIGH WIERSMA[1], AND P. MARTIN SANDER[1]

[1] *Steinmann-Institut für Geologie, Mineralogie, and Paläontology, Universität Bonn, Bonn, 53115, Germany*
kw1990@planet.nl

Sauropod bone histology has emerged as the major source of information on life history of these giant extinct animals. It provides an insight into the growth record and ontogenetic age of an individual. Sauropod specimens from the Morrison Formation are mostly found as partially articulated skeletons or as isolated bones, as seen in, e.g., the Dinosaur National Monument quarry, which makes an assignment of specific bones to individuals difficult. In this study, a detailed assessment of skeletal unity is provided by means of paleohistology for several Morrison Formation sauropod partial skeletons and isolated long bones from the Howe-Stephens Quarry, Wyoming, USA. Using histological characters such as Histological Ontogenetic Stages, growth marks, annual cyclicity, remodeling rate, and the number of generations of secondary osteons, an assignment of bones to individuals was made and compared with assignments that were made based on field observations. It is possible to histologically assign isolated bones to an existing individual, match isolated bones to comprise a new individual, and to test whether a specific bone belongs to the assigned individual. The hypothesis of skeletal unity was also tested for select other Morrison Formation and Tendaguru specimens, and the method can also be applied here. The findings of this study thus establish a method for testing skeletal unity in fossil tetrapod skeletons.

FIBER COMPLEXES IN THE CRANIAL DOMES OF PACHYCEPHALOSAURID DINOSAURS

JOHN R. HORNER[1,2], MARK B. GOODWIN[3] AND ALIDA M. BAILLEUL[1,2]

[1] *Museum of the Rockies, Bozeman, MT, 59717, USA*
[2] *Department of Earth Sciences, Montana State University, Bozeman, MT, 59715, USA*
jhorner@montana.edu
[3] *University of California Museum of Paleontology, Berkeley, CA, 94720, USA*

The frontoparietal domes of mature pachycephalosaurid dinosaurs contain vast networks of fibers, some of which are clearly Sharpey's fibers, and others that are more enigmatic. We employ paleohistology, micro-CT and synchrotron tomography to determine the morphology and roles that each of these fibrous complexes may have played during dome growth. Sharpey's fibers originate and terminate either completely encapsulated within the mineralized fibrolamellar matrix, or reach the ectocranial surface to join tendinous or ligamentous tissues. Dense fibril complexes of Sharpey's fibers border the frontoparietal sutures in the dome. The fibers in this "Sharpey's fiber-rich bone" differ in morphology and size from typical Sharpey's fibers. A third fibril complex is associated with the overall growth of the domes. Initial frontoparietal dome growth, which commenced late in ontogeny, was accomplished by directional radial fibrolamellar expansion similar to the growth of osteosarcomas. Unlike osteosarcomas, however, the bony struts between the vascular canals are laced with long 'fibers' of up to 1 mm in length and 5mm in width. Later in ontogeny when the vascular canals were filled with osteonal tissues, these 'fibers' persist and in mature specimens originate or terminate at the walls of vascular canals. The dimensions of these 'fibers' and their direct connection with vascular canals suggest that they may be axons belonging to neuronal cells. The microstructure of pachycephalosaurid domes has no modern analog. The presence of a complex vascular network intimately associated with microscopic 'fibers' indicates the preservation of innervated dermal bone previously undetected in dinosaur skulls.

IDENTIFYING SEXUAL SIZE DIMORPHISM IN THE MAASTRICHTIAN HADROSAUROIDS OF BASTURS POBLE (TREMP SYNCLINE, EASTERN IBERIA)

VÍCTOR FONDEVILLA[1], BLANCA MONCUNILL-SOLÉ[2] AND MEIKE KÖHLER[2,3]

[1] *Departament de Geologia, Universitat Autònoma de Barcelona, 08193, Bellaterra, Catalonia, Spain*
victor.fondevilla@uab.cat
[2] *Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
[3] *ICREA at Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*

The Tremp Syncline of the Iberian Peninsula yields a rich fossil record of hadrosauroids exhibiting a broad size spectrum. However, classical taxonomic studies are difficult and problematic due to the fragmentary conditions of the material. Nevertheless, their abundance, especially in the Basturs Poble bone bed (BP), allows to focus studies on bone histology. Fourteen representative tibiae and femora of different size classes were selected and sectioned in order to establish the ontogenetic status of the hadrosauroid remains of BP. Our microstructural and histological analysis reveals that the smaller and more abundant bones belong to juvenile individuals with an age of approximately two years, while the larger individuals represent two adult size morphs with divergent growth trajectories. The smaller and more abundant adult morph reached maturity at two years, whereas the larger one attained maturity at three years. The presence of more than one species in the BP bone assemblage is unlikely because there is no evidence for this from the external morphology of the bones. Rather, the finding of undifferentiated juveniles together with two adult size morphs with divergent trajectories of growth and maturation suggests that the individuals belonged to a population of a single species with pronounced sexual size dimorphism (SSD). This pattern matches that of large herbivores where females decelerate growth earlier and remain smaller than males, conforming to Rensch's Rule for artiodactyls. Male-biased SSD is in accordance with the notion of hadrosaurs as ecological equivalents of ungulates.

ONTOGENETIC DIFFERENTIATION AND GROWTH OF BONE ORNAMENTATION IN THE CROCODYLOMORPHA

VIVIAN DE BUFFRENIL[1], FRANCOIS CLARAC[1,2], JORGE CUBO[2,3] AND MICHEL LAURIN[1]

[1] *Centre de Recherches sur la Paléobiodiversité et les Paléoenvironnements (UMR 7207), Sorbonne Universités, MNHN/CNRS/UPMC, Paris, 75005, France*
vdebuff@mnhn.fr
[2] *Institut des Sciences de la Terre de Paris (UMR 7193), Sorbonne Universités, UPMC, Paris, 75005, France*
[3] *Institut des Sciences de la Terre de Paris (UMR 7193), CNRS, Paris, 75005, France*

The occurrence of “ornamental” reliefs, consisting of pits and ridges, over dermal bones is frequent in vertebrates, but it remains incompletely understood at both developmental and functional levels. The Crocodylomorpha (crocodilians and their closest allies) display one of the most typical examples of this characteristic; however, the basic osteogenetic processes involved in the differentiation and growth of this character remain controversial. This study aims at further documenting this question through observational and experimental approaches in extant and extinct crocodylomorph taxa. Bone ornamentation in extant Crocodylia is initially created by local resorption of cortical surfaces, and later maintained during somatic growth by a complex remodeling process combining local resorption, followed by partial reconstruction. All crocodyliform taxa that we observed, as also the phytosaurs, share the same basic process, at least in subadults and adults (juveniles were available only for extant taxa). Pits on crocodylomorph dermal bones are thus permanently transformed through enlargement in width or depth, drift, stretching, shrinking, or complete filling. Ridges are also remodeled in corresponding ways. These processes allow accommodation of unitary ornamental motifs to the increasing size of the bones during growth. The results of this study should end controversies about the formation of bone ornamentation in crocodilians. A parsimony optimization based on both the present results, and similar data previously published on non-crocodyliform crurotarsans and more distant taxa, suggests that the morphogenetic mechanism described above is a general feature of the Crurotarsi. This issue is discussed with reference to available comparative data about other vertebrates.

FIRST RESULTS FROM BONE HISTOLOGY OF THE DWARF ELEPHANT *PALAEOLOXODON FALCONERI* FROM SICILY

MEIKE KÖHLER[1,2], XAVIER JORDANA[1], BLANCA MONCUNILL-SOLÉ[1], CARMEN NACARINO-MENESES[1], MARIA RITA PALOMBO[3], ANTONIETTA ROSSO[4], ROSSANA SANFILIPPO[4] AND FRANCESCO SCIUTO[4].

[1]*Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
[2]*ICREA at Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
meike.kohler@icp.cat
[3]*Department of Earth Sciences, University of Rome "La Sapienza", Rome, I-00185, Italy*
[4] *Dipartimento di Scienze Biologiche, Geologiche e Ambientali Sezione di Scienze della Terra, Catania, 95129, Italy.*

With a shoulder height of only 0.9 m to 1.20 m, *Palaeoloxodon falconeri* from the Middle Pleistocene deposits of Spinagallo cave (Eastern Sicily, Mediterranean) is the smallest of all insular elephants ever found. The accompanying endemic fauna was composed of amphibians, reptiles, birds, bats, and a few small mammals. *Palaeoloxodon falconeri* is considered to descend from the continental 10 tons and 4.3 meter high *Palaeoloxodon antiquus*. Such spectacular size changes have intrigued many researchers. Thus, based on an estimated body mass of 100 kg and using the allometric relationship between physiological time and body mass ($t = M^{0.25}$), it has been proposed that *P. falconeri* attained sexual maturity at 3-4 years, much earlier than extant elephants (Addo 7.0; average South African *Loxodonta africana* 9.1; elsewhere 11.9).

We performed new body mass estimations for adult *P. falconeri*, which provided a range between 300 and 500 kg; the hitherto used body mass of 100 kg, hence, is an underestimation. Long bone histology of an ontogenetic series shows that the bone tissue pattern of *P. falconeri* differs fundamentally from those of its ancestor *P. antiquus*, and the extant species *Loxodonta africana* and *Elephas maximus*, suggesting a much slower growth rate than in "normal-sized" extant and fossil elephants. Age at sexual maturity was around 7-8 years, which is well within the range of extant elephants and much later than expected from our body mass estimations. Dental histology and isotope analyses are currently in progress.

PRE- AND POSTNATAL GROWTH RATES OF PLEISTOCENE DWARFED HIPPOPOTAMI FROM CYPRUS

ANNEKE H. VAN HETEREN[1] AND P. MARTIN SANDER[1]

[1]*Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
Anneke.vanHeteren@uni-bonn.de

Fossil insular mammalian dwarfs have variably been reported to show rapid ontogenetic development, slow development, as well as truncation of growth. These three modes of dwarfing have different implications for the life history of the animals under consideration and their morphological plasticity. The three modes of dwarfing have been recognised in different species, on different islands, using different methodologies. It may, thus, be hypothesised that different taxa show different responses to island environments, or that environmental differences are the cause for the different dwarfing modes. Alternatively, the difference may even be a methodological artefact.

The main objective of this study was to determine the mode of dwarfing in insular hippopotami using bone histology. Bones of Pleistocene dwarfed hippopotami from Cyprus (*Phanourios minor*), and their normal sized relatives (*Hippopotamus amphibius*), were thin-sectioned and studied under an optical microscope. Type of bone matrix, bone lacunae densities and counts of lines of arrested growth (LAGs) served as proxies for development rate and time.

Preliminary histological analyses on the radius suggest that both prenatal and postnatal bone growth in Cypriot dwarfed hippos is different from the normal mammalian pattern. Cypriot dwarfed hippos appear to have had slower growth rates than their normal-sized relatives both pre- and postnatally. Normal prenatal mammalian bone histology is typical for fast growth. The observed prenatal growth pattern in the Cypriot dwarf has never been reported in any other mammal and could represent a previously unrecognized strategy to cope with changing environments, particularly when dealing with food stress during pregnancy.

VALIDATING SKELETOCHRONOLOGY IN EQUIDS: INTRASKELETAL VARIABILITY IN *EQUUS HEMIONUS*

CARMEN NACARINO-MENESES[1], XAVIER JORDANA[1] AND MEIKE KÖHLER[2]

[1]*Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
carmen.nacarino@icp.cat
[2]*Dep. Evolutionary Biology, Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*

Over the last years, many studies have pointed out the relevance of skeletochronology in reconstructing life histories of extant and extinct mammals. The study of growth marks recorded in the bone tissue allows inferences about longevity, age at maturity or growth rate, key life history traits that are essential for reconstructions of past environments. Equids are a classical group of study in paleontology, but they have not yet been widely analyzed under this perspective. Thus, the information obtained from the study of their hard tissues could greatly contribute to our knowledge of the evolution of their life histories in an ecological context.

Because the histological study of extant species provides the basis for reconstructing life histories of fossil mammals, we have analyzed bone histology, including growth marks, of several limb bones (femur, tibia, metacarpal and metatarsal) in an ontogenetic series of extant *Equus hemionus*, the most appropriate representative of fossil horses. The results show that the number of growth marks generally fits the age provided by dental eruption, indicating that skeletochronology is a reliable method to study longevity in these mammals. Also, it has been noted that the number of growth marks varies between long bones of the same individual. We could indentify an additional growth mark in several limb bones that apparently records a specific key event in the life of this equid.

NEW DATA ON CERVID HISTOLOGY - LIFE HISTORY AND ALLOMETRY

ELI AMSON[1], TORSTEN M. SCHEYER[1], CHRISTIAN KOLB[1] AND MARCELO R. SÁNCHEZ-VILLAGRA[1]

[1] *Paläontologisches Institut und Museum der Universität Zürich, Zürich, CH-8006, Switzerland*
eli.amson@pim.uzh.ch

Our knowledge of the histology of the Cervidae (deers) was recently expanded with a work describing long bone and tooth histology of various taxa. Included in this study was the Miocene *Procervulus*, an early cervid characterized by low growth rate. The present study adds to our knowledge of cervid bone histology by describing that of another Miocene taxon, *Dicrocerus*. Along with the nature of the bone tissues, the skeletochronology of *Dicrocerus* is consistent with an intermediate growth rate, differing from the condition of *Procervulus*, and hence documenting diversity in early cervid life history.

Bone histology is now documented in various cervid taxa. Moreover, cervids are adequate (large range of body sizes, uniform lifestyles, and well-resolved phylogenetic relationships) for investigating in an evolutionary (phylogenetically informed) framework the relationships of traits with body size. In order to characterize the inner organization of long bones, parameters related to the bidimensional repartition of bone tissue along the cross-sectional area can be measured. While these parameters were shown to be correlated with specific lifestyles, little attention has been given to the influence of body size on these parameters. In effect, the gross morphology of limb bones is known to be subject to allometry, as scaling relationships between their components and body size differ from isometry. Moreover, our dataset also comprises different ontogenetic stages for some taxa, allowing us to study ontogenetic allometry. Compactness parameters appear to have isometrical relationships with body size proxies, suggesting that bone inner organization is not significantly affected by body size.

VASCULAR CORRELATES OF RED BLOOD CELL SIZE EVOLUTION IN TETRAPODS

ADAM K. HUTTENLOCKER[1] AND C. G. FARMER[1]

[1] *University of Utah, Salt Lake City, Utah, 84112, U.S.A.*
ahuttenlocker@gmail.com

Vascular canal networks in recent and fossil limb bone cortices display a variety of motifs, sizes, and densities whose architecture has been considered in light of growth and biomechanics. However, distributions of canal sizes within a single bone and physiological constraints on their minima have rarely been considered. In tetrapod muscle, capillary caliber attends red blood cell (RBC) diameter, the smallest found in mammals and the largest in amphibians due to their enlarged RBCs. It has been suggested that increased vascular resistance in some amniotes was mitigated by higher blood pressure and smaller RBCs (and enucleated RBCs in the case of mammals). Here, we evaluate the relationship between RBC size and vascular canal histometrics in several tetrapod species. Blood smears were taken when available and femora were dissected, sectioned at the midshaft, and digitally imaged for analysis. Non-phylogenetic and PGLS regressions indicate that minimum and harmonic mean canal caliber covary with RBC size (i.e., with those species having smaller canals accommodating smaller RBCs). Vascular and osteocyte densities are strongly negatively correlated with RBC size independent of body size. Despite having a more richly vascularized cortex, the smallest canals and highest vascular densities were found in sampled mammals and birds, which have the smallest RBCs. We hypothesize that smaller channel sizes permit greater vascular densities and shorter diffusion distances to the lacunocanalicular network. We are beginning to use the relationship determined from extant vertebrates to estimate RBC maximum sizes in fossil tetrapods and present preliminary results from fossil non-mammalian synapsids.

PALEOHISTOLOGICAL EVIDENCE FOR ANCESTRAL ENDOTHERMY IN ARCHOSAURS

LUCAS J. LEGENDRE[1,2], GUILLAUME GUÉNARD[3], JENNIFER BOTHA-BRINK[4] AND JORGE CUBO[1,2]

[1] *Institut des Sciences de la Terre de Paris (UMR 7193), Sorbonne Universités, UPMC, Paris, 75005, France*
lucasjlegendre@gmail.com
[2] *Institut des Sciences de la Terre de Paris (UMR 7193), CNRS, Paris, 75005, France*
[3] *Département de sciences biologiques, Université de Montréal, Montréal, H3C 3J7, Canada*
[4] *Karoo Palaeontology, National Museum and Department of Zoology and Entomology, University of the Free State, Bloemfontein, 9300, South Africa*

Archosaurs are a clade of vertebrates that includes birds, crocodiles, and numerous fossil groups. This clade has been a matter of debate among paleontologists for decades concerning the evolution of its thermometabolism. The classical hypothesis considers that only modern birds are truly endotherms (i.e. able to produce their own body heat), whereas all other archosaurs are ectotherms (i.e. relying on the external environment to maintain their body at a high temperature). Bone histology allows the study of several traits linked to thermometabolism, otherwise impossible to estimate on fossil specimens. However, no quantitative estimation of metabolic rate has ever been performed on fossils using bone histological features.

Here we performed statistical predictive modeling in a phylogenetic context using a sample of vertebrates and a set of bone histological features to estimate metabolic rates of fossil archosauromorphs. We used the recently published method called Phylogenetic Eigenvector Maps (PEM) to express phylogenetic relationships between species as independent variables in our models.

Our results show that Mesozoic theropod dinosaurs exhibit metabolic rates very close to those of modern birds, that archosaurs share an ancestral metabolic rate significantly higher than that of extant ectotherms, and that this derived metabolic rate was acquired at a more inclusive level of the phylogenetic tree, among non-archosaurian archosauromorphs. This implies that the last common ancestor of archosaurs was likely an endotherm, and that modern crocodiles became secondarily ectothermic. These preliminary results may be the first step to a better comprehension of the evolution of metabolic strategies in fossil vertebrates.

OPHIACODONTIDAE (BASAL SYNAPSIDA) BONE HISTOLOGY AND THE ORIGIN OF MAMMALIAN ENDOTHERMY

CHRISTEN SHELTON[1] AND P. MARTIN SANDER[1]

[1] *Steinmann-Institut für Geologie, Mineralogie und Paläontolgie, Universität Bonn, Bonn, 53115, Germany*
CShelton@uni-bonn.de

The origin of mammalian endothermy has long been held to reside within the early therapsid groups. However, shared histological characteristics have been observed in the bone matrix and vascularity between the pelycosaur (non-therapsid synapsid) *Ophiacodon* and the later Therapsida. Historically, this coincidence has been explained as simply a reflection of the presumed aquatic lifestyle of *Ophiacodon* or even a sign of immaturity. Here we show, by histologically sampling an ontogenetic series of *Ophiacodon* humeri, as well as additional material, the existence of fibrolamellar bone (FLB) in the postcrania of this pelycosaur. Our findings have reaffirmed what previous studies first described as fast growing tissue, and have disproven that the highly vascularized cortex is simply a reflection of young age. This tissue demonstrates the classic histological characteristics of FLB. The cortex consists of dense radially arranged primary osteons in a woven bone matrix and remains highly vascularized throughout ontogeny, providing evidence of fast skeletal growth. Overall, the FLB tissue we describe in *Ophiacodon* is more derived or "mammal-like" in terms of the osteonal development, bone matrix, and skeletal growth than what has been described thus far for any other pelycosaur taxa. With regard to the histological record, our results remain inconclusive as to the preferred ecology of *Ophiacodon*. Our findings suggest that the evolutionary beginnings of mammalian endothermy and high skeletal growth rates date back to the Late Carboniferous, approximately 35 million years earlier than previously believed.

UNUSUAL ENDOSTEAL BONE TISSUE IN *SALTASAURUS LORICATUS* (DINOSAURIA: SAUROPODA)

ANUSUYA CHINSAMY[1], IGNACIO CERDA[2] AND JAIME POWELL[3]

[1] Department of Biological Sciences, University of Cape Town, Rhodes Gift, 7700, South Africa
Anusuya.chinsamy-turan@uct.ac.za
[2] CONICET, Instituto de Investigación en Paleobiología y Geología, Universidad Nacional de Río Negro, Museo Carlos Ameghino, Cipolletti, Argentina
[3] CONICET, Facultad de Ciencias Naturales Universidad Nacional de Tucumán, San Miguel de Tucumán, Argentina

The presence of highly vascularized endosteal bone in the medullary region of nonavian dinosaurs has been invoked as evidence of medullary bone (specialized endosteal bone formed during ovulation). However, a pathological origin has been verified in some of these reports. Here we report on the occurrence of unusual endosteally formed tissue in several bones of *Saltasaurus loricatus* (an armoured titanosaur sauropod from the Upper Cretaceous of Argentina): i) within the medullary cavity of a metatarsal, ii) inside a pneumatic cavity of a posterior caudal vertebra, iii) lining large vascular canals and iv) in intra-trabecular spaces in an osteoderm. The endosteal bone is composed mainly of woven and, to a lesser extent, parallel fibred bone. In these tissues vascularisation is high, bone cell lacunae are abundant and irregularly arranged. In the metatarsal and caudal vertebra vascular spaces are lined by lamellar bone. The presence of two shallow, irregular depressions overlain by a highly fibrous tissue in the metatarsal suggest a pathological origin for the endosteal bone in this element. There is no evidence of reactive periosteal bone in the vertebra and the osteoderm. Our results provide new evidence for the possibly pathological origin of the highly vascularized endosteal tissue in *Saltasaurus* and demonstrate that this tissue can be formed not only in the diaphysis of long bones, but also in the axial and dermal skeleton.

EVALUATION OF THE REPRODUCTIVE ROLE OF MEDULLARY BONE-LIKE TISSUES IN FOSSILS

EDINA PRONDVAI[1]

[1]*MTA-ELTE Lendület Dinosaur Research Group, Eötvös Loránd University, Budapest, 1117, Hungary*
edina.prondvai@gmail.com

Gender identification in non-avian dinosaurs had been a highly debated issue until medullary bone (MB) was reported in the long bones of some saurischian and ornithischian dinosaur specimens. MB is a special endosteal tissue known to form in the bones of female birds during egg-laying to serve as a calcium reservoir for building the hard eggshell. Its presence in non-avian dinosaurs is therefore treated as the incontestable evidence that those specimens were sexually mature females in their reproductive period. This interpretation has led to further inferences on some life history aspects of these non-avian dinosaurs. Recently, a study describing MB-like tissues in the mandibular symphyses of the azhdarchid pterosaur *Bakonydraco* concluded that these tissues most probably had non-reproductive functions in these pterosaurs and suggested that more caution should be exerted when inferring an exclusively reproductive role of MB-like tissues in other fossils, as well. However, the histological observations, the correct identification of the tissue, and hence the conclusions in the latter study have received criticism and informal rejection from a few experts. By addressing all points of criticism and integrating additional arguments based on published data I intend to account for the validity of this tissue-assignment as well as for the hypothesis that alternative functions of MB-like tissues may not only apply to pterosaurs but also to non-avian dinosaurs. Finally, I aim to discuss the importance of acknowledging this uncertainty in fossil taxa and the perspectives of a potential functional alteration of MB-like tissues in an evolutionary context.

X-RAY MICROTOMOGRAPHY: NEW PERSPECTIVES APPLIED TO PALAEOHISTOLOGY

SOPHIE SANCHEZ[1,2]

1 SciLife Lab and Department of Organismal Biology, Uppsala University, Uppsala, 752 36, Sweden
2 European Synchrotron Radiation Facility, Grenoble, 38043, France
sophie.sanchez@ebc.uu.se

The first sectioned preparations of extant animal material for observation with an optical microscope were made by Van Leeuwenhoek in 1673. Despite fossils being known and studied, it was not until the 19th century that the first sectioned mineralised fossil tissues were analysed using a light microscope (Owen, 1840). Since then, many technical advances have occurred in the field of microscopy. New techniques such as serial grinding, confocal and electron microscopy created new possibilities for understanding mineralised microstructures in three dimensions. However, some of these techniques were destructive while others could not penetrate entirely the fossil samples.

Recently, various kinds of X-ray microtomography have been used as palaeontological tools to access the internal structures of irreplaceable fossils non-destructively. Since 2006 has it been possible, thanks to the use of propagation phase-contrast synchrotron microtomography, to visualize the micron-scale architecture of fossil hard tissues in three dimensions (3D) with no damage to the samples. This technique brings a new dimension to the field of palaeohistology: it allows the quantification of volumes (e.g. bone cell lacunae, vascularisation), it distinguishes structures based on their different degrees of mineralisation (e.g. primary bone versus secondary bone, calcified cartilage), and it provides orientation and density information. Because the microstructural organization can be observed in 3D over the entire sample, this technique also helps determining the sequences of deposition during the development of the organism (e.g. odontodes, lines of arrested growth). Based on case studies, I propose to show the potential of this technique applied to vertebrate palaeohistology.

VIRTUAL VESSELS: THE MORPHOLOGY OF CORTICAL VASCULARIZATION VISUALIZED IN THREE DIMENSIONS USING SYNCHROTRON X-RAY MICROTOMOGRAPHY

DENNIS F.A.E. VOETEN[1 2], SOPHIE SANCHEZ[2 3], PAUL TAFFOREAU[2] AND STANISLAV BUREŠ[1]

[1] *Department of Zoology and Laboratory of Ornithology, Palacký University, Olomouc, 771 46, Czech Republic*
dennis.voeten01@upol.cz
[2] *European Synchrotron Radiation Facility, Grenoble, 38000, France*
[3] *SciLife Lab, Uppsala University, Evolutionary Biology Centre, Department of Organismal Biology, Uppsala, SE-752 36, Sweden*

Cortical vascularization represents one of the main structures of interest in osteohistology. The nature, orientation and volume of vascular canals in cortical bone are influenced by numerous factors, including whole-bone stress distribution, growth rate and metabolic rate. To gain insight in such parameters in fossil taxa, understanding vascular patterns in extant taxa is of substantial importance.

One of the difficulties in classical (osteo-) histological sampling is the inherent two-dimensional nature of the thin sections under study. Our approach relies on data acquired through high-resolution synchrotron X-ray microtomography and allows three-dimensional visualization of cortical bone vasculature. This method is insensitive to features that may be over- or underrepresented in pure transverse samples. The virtual models obtained through this technique also permit quantification of crucial parameters.

We visualized the humeral and ulnar cortical vascularization at circa mid-diaphysis of a sample set of over ten species of modern birds that display a great variety in phylogenetic positions and flight modes, and included an unidentified non-avian dromaeosaur ulna for reference. These vascular patterns were mutually compared and the dependence of the vascularization along the bone long axis was quantified with fiber analysis software.

Vascular orientation analysis revealed a wide range in vascular longitudinality values within birds that is suggested to partially result from flight style. Furthermore, the cortical vascular pattern of the non-avian dromaeosaur displays a circumferential zonation of vascular density that is not recognized in the avian sample set. This is interpreted to result from differences in growth strategy.

CHEMICAL HISTOLOGY VIA SYNCHROTRON ANALYSIS

JENNIFER ANNÉ[1], ROY A. WOGELIUS[1], UWE BERGMANN[2], FRED MOSSELMANS[3], NICHOLAS P. EDWARDS[1] AND PHILLIP L. MANNING[2]

[1] School of Earth and Environmental Sciences, University of Manchester, Manchester, M13 9PL, UK
jennifer.anne@postgrad.manchester.ac.uk
[2] SLAC National Accelerator Laboratory, Linac Coherent Light Source, Menlo Park, 94025, USA
3 Diamond Light Source, Didcot, OX11 0DE, UK

Bone physiology is traditionally interpreted through the optical observations of 2D (thin section) or 3D (computed tomography) fine histological structures. Although optical based image techniques have improved drastically over the last century, there are still some limitations to both the resolution and depth of field that can be observed. In addition, these techniques are only suitable for specimens that exhibit exceptional preservation of the histological morphology. Recent application of chemical imaging has revealed differential distributions of trace elements between different biological and geological fine structures. The different chemical inventories highlight specific features within a specimen and can be used to better visualize and interpret fine structures within biological tissues. Here we present a *de novo* approach to histological interpretation, chemical histology through a combination of Synchrotron Rapid Scanning-X-Ray Fluorescence (SRS-XRF) and microfocus elemental mapping.

Elemental maps revealed both 2D and 3D histological features previously not seen in thin section in both extant and fossil material. These included: 1] details of the pathologic-normal bone interface of a fracture callus (*Allosaurus fragilis*; 145mya), 2] cutting cones and connecting canals of secondary osteons in haversian systems (extant and fossil Sirenians, 19mya; extant hyena), 3] differential tissue patterning of growth annuali (cave hyena; 40kya). In addition, some of the trace elements associated with discrete histological feature could be identified as biologically important (ex. zinc, calcium, etc.). Thus we are able to correlate specific tissue types with trace elements crucial to bone physiology, matching chemical physiological processes *in vivo* of bone tissue types.

USING STABLE ISOTOPES AND HISTOLOGY TO CORRELATE GROWTH OF THE TYMPANIC BONE WITH BALEEN PLATES IN ARCTIC WHALES

JENNIFER SENSOR[1], CRAIG GEORGE[2], MARK CLEMENTZ[3], RAPHAELA STIMMELMAYR[2], ROBERT SUYDAM[2] AND J.G.M.THEWISSEN[1]

1 Northeast Ohio Medical University, Rootstown, 44272, USA
jsensor@neomed.edu
2 Department of Wildlife Management, North Slope Borough, Barrow, 99723, USA
3 Department of Geology and Geophysics, Laramie, 82071, USA

Bowheads are arctic baleen whales that migrate annually between isotopically different oceans. Baleen develops just before birth and continues to grow throughout life. The keratin in baleen plates captures the annual isotopic oscillations between summer and wintering grounds, and can register up to about 10 years of the whale's life but wears at its distal end.

The tympanic bulla of the bowhead whale consists of three zones that differ in gross and histological appearance. The bulla is unique in that all zones show little to no signs of remodeling, and therefore holds a persistent ontogenetic and developmental record. The innermost layer (zone 1) is vascular fibrolamellar bone with mostly reticular vessels. Under polarized light the collagen fibers are directionally organized. The central layer (zone 2) also consists of fibrolamellar bone but its vessels and collagen fibers are oriented more radially. The periosteal layer (zone 3) is organized lamellar bone with reduced vasculature and clear growth layer groups.

In this study we correlate stable isotope patterns in baleen to histological and isotopic patterns in the tympanic bulla. Zone 1 is formed during the prenatal period and zone 2 during nursing in the first year of life. Zone 3 growth layer groups match the number of annual isotopic oscillations found in the baleen. We are planning to use our findings regarding bone histology to investigate other modern (beluga) and fossil (*Pakicetus*) cetaceans.

MELANIN AND COLOUR PATTERNS IN THE FOSSIL RECORD

JAKOB VINTHER[1]

[1]*Schools of Biological Sciences and Earth Sciences, University of Bristol, Bristol, BS8 1TQ, UK*
Jakob.vinther@bristol.ac.uk

Melanin is a ubiquitous pigment in vertebrates and other metazoans, which serve for photoprotection, against microbial infection, signaling and camouflage among others. Recent discoveries have shown that melanin preserves in exceptional fossil Lagerstätten, and can be characterized as small granules in cephalopod ink sacs, or as the melanin bearing organelles (melanosomes) incorporated into animal dermal layers and keratinous integuments.

Since melanin serve so many key functions, characterizing it in fossils will be of interest to identify melanin bearing organs (i.e. liver, peritoneum, eyes), but even original colours and colour patterns. There are two main types of melanins: Black coloured eumelanin and reddish brown coloured phaeomelanin. These melanins are seen to occupy different melanosomes of distinct morphology across mammals and birds, which suggest an ancient correlation and thus that simply studying melanosome morphology can be used to identify melanin based colour from fossils. Melanosomes also can be arranged to form structural colours, iridescence.

We have demonstrated that fossil feathers, including dinosaurs preserve melanosomes and that by comparisons to modern feather melanosomes we can statistically differentiate black, brown, grey and iridescence in fossils. This has now been employed in a couple of fossil feathered dinosaurs and birds.

Advanced in chemical characterization of fossil melanin has now also been well under way, and we can demonstrate that the melanosomes contain a diagenetically altered signature for melanin, and in some cases still some molecularly intact melanin.

Some criticism has been advanced that these structures resemble bacteria, which was the original interpretation of melanosomes in soft tissue fossils. However, the growing body of evidence shows that maintaining this interpretation is far fetched.

Other pigments are also involved in metazoan colouration. Some of these have been discovered in fossils, but are generally less common than melanins and have distinct phylogenetic distributions. Caution should be exercised in particular when studying chromatophore-bearing integuments as is seen in non-endothermic vertebrates however.

Understanding ancient colour patterns and reliably reconstructing these from fossils provide a hitherto unprecendented avenue for unraveling important aspecsts of how animals camouflage and communicate, which can provide key evidence for understanding shifts in visual communication and predation.

CATCHING THE PIGMENTS OF LIFE: PRESERVATION POTENTIAL AND PALEOBIOLOGICAL IMPLICATIONS OF TETRAPYRROLIC COLOR PIGMENTS IN DINOSAUR EGGSHELL

JASMINA WIEMANN[1], TZU-RUEI YANG[1] AND P. MARTIN SANDER[1]

[1]*Steinmann-Institut für Geologie, Mineralogie and Paläontologie, Universität Bonn, Bonn, 53115, Germany*
jasmina.wiemann@hotmail.com

Dinosaur nesting behavior is a popular but controversial research topic. In extant birds, eggshell coloration based on protoporphyrin IX (reddish pigment) and biliverdin (bluish-greenish pigment) reflects the nesting environment and brooding behavior. Hitherto, the biochemical and physiological pathways for producing colored eggshell were generally seen as bird synapomorphies. However, maniraptoran dinosaur eggs have never been tested for the presence of eggshell pigments. Here we present the phylogenetically most basal evidence, based on ESI (+) mass spectrometry, of endogenous biliverdin and protoporphyrin which are preserved unaltered in 66 million year-old oviraptorid *Heyuannia huangi* eggshells from Henan, Jiangxi and Guandong province, China. The eggs of *Heyuannia huangi* were likely to be colored olive-greenish resulting in efficient crypsis in vegetation covered open nests. Unlike biliverdin being incorporated over almost the entire thickness of the eggshell, protoporphyrin is stored mainly in the outer eggshell cuticle; thus the discovery of PP suggests cuticle preservation. Eggshell coloration, serving mainly for egg crypsis, became positively selected for when parental animals started building open nests. Thus the pigment preservation in the oviraptorid eggshells indicates open or partially open nesting, for which there is also evidence through porosity measurements. In extant birds, greenish egg pigmentation indicates complex social adaptions, for instance, intensive parental care and increased paternal investment, suggesting similar behavior in oviraptorid dinosaurs. Furthermore especially the biliverdin physiologically hints at a bird-like oviduct which enzymatically provides a membrane transfer and eggshell-pigment incorporation mechanism. This discovery offers a new biochemical perspective on eggshell paleobiology and a new geochemical perspective on the preservation of organic matter endogenous to eggshell.

A PRELIMINARY STUDY ON THE PRESERVATION OF ORIGINAL ORGANIC MATERIAL IN AMNIOTE BONES FROM THE LOWER PERMIAN TO SUB-RECENT

MARIE-CLAIRE KOSCHOWITZ[1] AND P. MARTIN SANDER[1]

[1]*Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*

Recently, the known fossil record of original organic materials in vertebrate bones, e.g. collagen, osteocytes, etc. has expanded rapidly, with such materials now being reported from a number of temporally and geographically ranging sites. The taphonomic factors responsible for such preservation (commonly referred to as "still-soft-tissue" preservation) are poorly understood however, and lack a comparative framework including data from different sites, which vary in their age and taphonomic background. To better understand potential causal mechanisms responsible for this mode of preservation, material from the Steinmann-Institute of Geology, Mineralogy and Palaeontology of the University of Bonn was dissolved using Ethylenediaminetetraacetic acid (EDTA) to liberate putative original organic materials. In total 38 tetrapods covering a wide taxonomic diversity were examined, from sites demonstrating a range of preservational styles, spanning from the Lower Permian (295 MA) to the Sub-Recent (c. 1000 years old). Of these taxa, four yielded evidence of original organic materials after treatment with EDTA, including samples of *Eryops* from the Lower Permian making this the oldest record of this preservational type. However, no correlation was recovered between the preservation of organic structures, as revealed by *in-situ* or thin section examination, and their presence after EDTA treatment. Further study using a gas chromatograph revealed the presence of high levels of organic compounds in a plesiosaur vertebra preserved with osteocytes. This study illuminates the pervasiveness of fossilized original organic materials, however, further study is required using a broad range of biochemical approaches to effectively quantify this mode of preservation.

MICROBIALITES AND VERTEBRATE FOSSIL RECORD: MICROSCOPIC VIEW

VIJAY SATHE[1] AND VARSHA KELKAR-MANE[2]

[1]*Department of Archaeology, Deccan College Postgraduate and Research Institute, Pune, 411006, India*
vijay19sathe@gmail.com
[2]*Department of Biotechnology, University of Mumbai, Mumbai, 400098, India*

Scholars have long recognised the effects of microbial activity on fossil record. Microbial biofilms have been identified as part of the process of degradation of archaeological/fossil bone. Numbers of such studies have helped us in understanding the complex process of bone biodeterioration in archaeological and fossil bone collections. In this context, the recent study on the bones of vertebrates from Indian Pleistocene fossil record examined in juxtaposition with the data from experimental work with modern bones, has demonstrated that micro-organisms play an important role in mineral deposition. Microorganisms and their components dictate mineralisation and yet physico-chemical conditions like temperature, pH, humidity, redox potentials dictate the type of organism dominance, which are found in symbiotic association or counter affecting each others survival. The biofilm formation is an essential phenomenon for the survival of organisms and may itself serve as a site of mineralization, dictating the pattern of deposition as well on the fossilising surfaces. Using optical and scanning electron microscopy, the present paper describes for the first time the evidence of microcolonisation of fungi and/or bacteria on the fossilised bones from Late Pleistocene deposits from Peninsular India. The ‘dynamics of interaction’ between the bones and microorganisms brings us closer to better understanding of taphonomic history of a fossil record.

A NEW APPROACH TO BONE DIAGENESIS: MICROFACIES METHODS APPLIED TO CARBONATE CEMENTS IN FOSSIL BONE VOIDS

OLIVER WINGS[1]

[1]*Landesmuseum Hannover, Hannover, 30169, Germany*
dr.wings@gmail.com

Carbonate cements are a well-established source in microfacies to reveal diagenetic histories of carbonate rocks. Similar cements in trabecular bone and other bone voids were given relatively little attention despite the fact that porous and permeable bones are ideal for the precipitation of calcite cements. Analysis of carbonate cements in the pore space can provide information about taphonomy and diagenesis (e.g. reworking, depositional setting), which may not be accessible otherwise.

Fossil bone samples were studied via thin-sections and cover a broad range of environmental settings and diagenetic histories. Calcite cements occur in most fossil bones and certain cement types can be attributed to specific diagenetic environments. For example, bones from the Wealden of the Isle of Wight shows a great variety in cementation types (including botryoidal cements likely paramorphic after marine aragonite), revealing a complex diagenetic history. Isopachous rims (e.g., Isle of Wight, Swanage, Tendaguru) indicate phreatic conditions, but cannot help to distinguish between marine and meteoric environments. Bones are commonly deposited in flood plains or intertidal deposits, but surprisingly, vadose cements like gravitational or meniscus cements (marine vadose cements) or vadose silts (freshwater vadose cements) are very rare. By far the most common calcite cementation in bone cavities is sparite. Such granular and drusy cements occur in many submarine and several subaerial environments during a late diagenetic stage and usually fill the last porosity available in the voids.

EVOLUTION OF THE WOVEN-PARALLEL COMPLEX IN TETRAPODS

JORGE CUBO[1]

[1] *Institut des Sciences de la Terre de Paris (UMR 7193), Sorbonne Universités, UPMC, Paris, 75005, France*
jorge.cubo_garcia@upmc.fr

Tetrapod periosteal ossification starts with a phase of static osteogenesis producing woven bone: mesenchymal cells differentiate into functionally polarized, randomly oriented, osteoblasts, which differentiate into osteocytes *in situ*. Either throughout, or by the end of, the growth period, tetrapods form an outer layer of parallel-fibred bone tissue through a process of dynamic osteogenesis in which osteoblasts are uniformly oriented and form a movable sheet of cells. In some taxa, a combination of both static and dynamic osteogenesis occurs in between these two phases, producing what is known as woven-parallel complex: the vascular cavities of a woven scaffold are filled by centripetal (lamellar or non-lamellar) parallel-fibred bone tissue, forming primary osteons. Some taxa show a particular type of woven-parallel complex: the fibrolamellar complex, characterized by the presence of a high vascularity and a high proportion of woven bone. The first ("pure" static osteogenesis) and the last ("pure" dynamic osteogenesis) phases may occur always in tetrapod periosteal ossification. Here we show that the phase in between them (the formation of woven-parallel complex by a combination of static and dynamic osteogenesis) can be present or absent and, when present, it can be fibrolamellar or not. For instance, within Lepidosauromorpha, *Podarcis muralis* only undergoes the first and the last phases, whereas *Varanus niloticus* shows, in addition, a layer of non-fibrolamellar woven-parallel complex. Optimization of the presence of fibrolamellar complex onto a phylogeny of tetrapods using parsimony shows a homoplastic pattern suggesting that the fibrolamellar complex of synapsids is not homologous to that of diapsids.

MICROSTRUCTURAL FEATURES OF THE FEMUR IN EARLY OPHIACODONTS: A REAPPRAISAL OF ANCESTRAL HABITAT USE AND LIFESTYLE OF AMNIOTES

MICHEL LAURIN[1] AND VIVIAN DE BUFFRENIL[1]

[1] *Centre de Recherches sur la Paléobiodiversité et les Paléoenvironnements (UMR 7207), Sorbonne Universités, MNHN/CNRS/UPMC, Paris, 75005, France*
laurin@mnhn.fr

Ophiacodontids have long been considered the basalmost synapsids, and to have retained a fairly aquatic, piscivorous lifestyle typical of stem-amniotes. A restudy of their bone histology and microanatomy shows that *Clepsydrops collettii*, a Late Carboniferous ophiacodontid, has a fairly thin, compact cortex and lacks a medullary spongiosa, two features that suggest a truly terrestrial lifestyle. The Early Permian *Ophiacodon uniformis* has a thicker cortex with a few resorption cavities and bone trabeculae surrounding the free medullary cavity. The use of a previously published inference model, based on Bone Profiler and linear discriminant analyses, yields a terrestrial lifestyle for both taxa, though *O. uniformis* may have been slightly more aquatic (possibly amphibious) than *C. collettii*. However, an optimization of inferred lifestyle of other early stegocephalians (based on bone microanatomy) suggests that the first amniotes were terrestrial. Therefore, the possible amphibious lifestyle of *O. uniformis*, though not supported by our inference model (but fairly widespread in the literature), would have thus been secondary. Histological features of femoral cortices in these two taxa closely resemble those previously described in extant species of large varanids and teids, but the occurrence of ramified, anastomosed vascular canals in *Ophiacodon* suggests that it grew somewhat faster than extant large squamates.

BREEDING YOUNG AS A SURVIVAL STRATEGY IN THE AFTERMATH OF THE END-PERMIAN MASS EXTINCTION

JENNIFER BOTHA-BRINK[1,2], DARYL CODRON[3,4], ADAM HUTTENLOCKER[5,6] AND KENNETH D. ANGIELCZYK[7]

[1]*Karoo Palaeontology, National Museum, Bloemfontein, 9300, South Africa*
[2]*Department of Zoology and Entomology, University of the Free State, Bloemfontein, 9300, South Africa*
jbotha@nasmus.co.za
[3]*Florisbad Quaternary Research, National Museum, Box 266, Bloemfontein, 9300, South Africa*
[4]*Centre for Environmental Management, University of the Free State, Bloemfontein, 9300, South Africa*
[5] *Department of Biology, University of Utah, Salt Lake City, UT 84112, USA*
[6] *Natural History Museum of Utah, Salt Lake City, UT 84108, USA*
[7] *Integrative Research Center Field Museum, Chicago, IL 60605-2496, USA*

Understanding the response of species to mass extinctions is fundamental to understanding patterns of vulnerability and post-extinction recovery. Studies on the effects of mass extinctions on past ecosystems have tended to focus on factors such as diversity/disparity, abundance, behavior and resource availability as key determinants of survival. Although life history also plays a critical role in the survival of populations and communities, differences in postnatal growth rates have rarely been considered as drivers of differential survival during mass extinctions and in their aftermath. Our analysis of histological growth patterns and body size distributions in Permo-Triassic therapsids, reveals a marked shift in life history tactics before and after the greatest mass extinction in Earth's history, namely the end-Permian mass extinction (EPME). Post-extinction species are characterized by shortened developmental times, which we suggest would have promoted early onset of reproductive activity and shortened generation times based on ecological models. These life history traits equipped post-extinction species with a strategy to mitigate against the higher risks of extinction associated with highly unpredictable Early Triassic environments and reduced resource availability. This is the first study to use osteohistological data in a paleoecological context to investigate the evolutionary links between animal growth rates, life histories, and ecology, and their importance for explaining differential extinction and survival amongst therapsids during the EPME.

THE EVOLUTION OF PLESIOSAUR BONE HISTOLOGY: NEW EVIDENCE FROM NEW FINDS

P. MARTIN SANDER[1], SHOJI HAYASHI[2], ALEXANDRA HOUSSAYE[3], YASUHISA NAKAJIMA[1], TAMAKI SATO[4] AND TANJA WINTRICH[1]

[1]*Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
martin.sander@uni-bonn.de
[2]*Osaka Museum of Natural History, Osaka, 546-0034, Japan*
[3] *FUNEVOL (UMR 7179), CNRS/MNHN, Paris, 75005, France*
[4] *Tokyo Gakugei University, Tokyo, 184-8501, Japan*

Considering that Plesiosauria are the most diverse clade of Mesozoic marine reptiles, their bone histology and bone microanatomy has received remarkably little study. Like for other marine tetrapods inhabiting open waters, a cancellous structure has been reported for plesiosaurs. This microanatomy represents a decrease in skeletal mass as an adaptation to fast swimming. A new extensive sample now reveals a more complex pattern and evolutionary trends. The sample includes the newly discovered first Triassic plesiosaur, which is also the most basal plesiosaur, as well as a diversity of European Jurassic taxa and Japanese Cretaceous taxa. Plesiosaurs show distinctive histological difference between long bones (humerus and femur) and vertebrae, which exhibit cancellous bone in most taxa, representing the expected bone mass decrease. Long bones, however, more commonly show an osteosclerotic or even pachyosteosclerotic condition, representing bone mass increase. One Jurassic plesiosaur in our sample also has a cancellous midshaft region. The new Triassic plesiosaur shows the radial vascular pattern, lack of perimedullary resorption activity, and lack of remodeling seen in stem Pistosauria such as *Pistosaurus*. It differs from these in the lack of growth marks and better development of primary osteons, suggesting higher growth rates in the plesiosaur but also bone mass increase. Jurassic plesiosaur long bones generally show some secondary cortical bone remodelling, contributing to the maintainance or increase of high cortical density. Growth marks in plesiosaur long bones always start at a relatively large size and give low counts (< 5), consistent with large, K-selected offspring and fast growth.

ONTOGENY IN IGUANODONTIA

CATHERINE SARTIN[1]

[1]*Johns Hopkins School of Medicine, Baltimore, 21205, USA*
csartin2@jhmi.edu

In iguanodontian dinosaurs, histologic ontogenetic series of two basal taxa (*Dysalotosaurus lettowvorbecki* and *Tenontosaurus tilletti*) and one derived taxon (*Maiasaura peeblesorum*) are well known. The two ontogenetic series of taxa sectioned for this study (*Eolambia caroljonensa* and an unnamed styracosternan Iguanodontian) are phylogenetically situated between these basal and derived taxa. These taxa are intermediate in adult body size between basal and derived taxa, providing a good opportunity to begin to understand how small, basal members of the iguanodontian clade evolved into the enormous derived members. By comparing the histology of humeri with that of femora and tibiae in each series, we can begin to understand how bipedality in basal members of the clade evolved into the facultative bipedality in derived members.

Throughout both series, bone growth shows signs of being relatively slow (i.e. well organized tissue, small vascular canals), although the youngest specimens do preserve areas of knitted texture which is indicative of rapid growth. Secondary osteons begin appearing in mid-sized individuals and increase in number with increasing age. This is similar to what is seen in both *Dysalotosaurus* and *Tenontosaurus* but not the more derived taxon, *Maiasaura*. From this comparison, we can determine that changes in gross morphology precede changes in growth rate within the clade.

In addition, growth is similar between forelimb and hindlimb elements throughout both series, indicating that changes in locomotion occurred between the basal taxa and *Eolambia* and the yet unnamed styracosternan, the intermediate taxa in this study.

COMPARATIVE SUTURAL HISTOLOGY OF NON-AVIAN DINOSAURS AND THEIR EXTANT PHYLOGENETIC BRACKET

ALIDA M. BAILLEUL[1,2] AND JOHN R. HORNER[1,2]

[1] *Museum of the Rockies, Bozeman, MT, 59717, USA*
[2] *Department of Earth Sciences, Montana State University, Bozeman, MT, 59715, USA*
alida.bailleul@msu.montana.edu

Sutures are fibrous tissues that unite the skull bones of vertebrates. The degree of sutural closure has been used for decades in paleontology to assess maturity in mammals and non-avian dinosaurs. Surprisingly, little is known about the biology of sutures in extant archosaurs, birds and crocodilians. We use paleohistology to retrace the ontogenetic history of craniofacial sutures in the emu, the American alligator, hadrosaurs, pachycephalosaurs and ceratopsids. Comparisons with mammalian sutural histology from the literature were made. Emus and mammals possess a sutural periosteum, but it disappears rapidly during ontogeny in American alligators. We identify seven types of sutural mineralized tissues in extant and extinct archosaurs and group them into four categories: periosteal tissues, acellular tissues, fibrous tissues and intratendinous tissues. Due to the presence of a periosteum in their sutures, emus and mammals possess periosteal tissues at their sutural borders. The mineralized sutural tissues of crocodilians and non-avian dinosaurs are more variable and can also develop via a form of bionecrosis for acellular tissues and metaplasia for fibrous and intratendinous tissues. We hypothesize that non-avian dinosaurs, like the American alligator, lacked a sutural periosteum and their primary mode of ossification involved the direct mineralization of craniofacial sutures. The microstructural differences between sutures in archosaurs and mammals are undeniable. This suggests that mammals should not be used as the extant analogues for non-avian dinosaurs in many paleontological matters, including maturity assessment using sutural closure as a proxy.

BONE MICROSTRUCTURE EVIDENCE OF THE TRANSITION OF EOCENE WHALES FROM LAND TO SEA

ALEXANDRA HOUSSAYE [1,2], PAUL TAFFOREAU [3], CHRISTIAN DE MUIZON[4] AND PHILIP D. GINGERICH[5]

[1] *FUNEVOL (UMR 7179), CNRS/MNHN, Paris, 75005, France*
houssaye@mnhn.fr
[2] *Steinmann-Institut für Geologie, Paläontologie und Mineralogie, Universität Bonn, Bonn 53115, Germany*
[3] *European Synchrotron Radiation Facility, Grenoble, 38043, France*
[4] *Centre de Recherches sur la Paléobiodiversité et les Paléoenvironnements (UMR 7207), Sorbonne Universités, MNHN/CNRS/UPMC, Paris, 75005, France*
[5] *Department of Earth and Environmental Sciences and Museum of Paleontology, University of Michigan, Ann Arbor, U.S.A*

Cetacea underwent their land-to-sea transition during the Eocene. The lifestyles of the primitive forms, called archaeocetes, remain strongly debated. This study proposes to investigate this question with a microanatomical approach. We document the internal structure of long bones, ribs and vertebrae in fifteen specimens belonging to the three more derived archaeocete families — Remingtonocetidae, Protocetidae, and Basilosauridae — using conventional and synchrotron microtomography for virtual thin-sectioning. The osseous specialization bone mass increase is observed in the ribs and femora of all taxa, whereas the vertebrae are essentially spongious. Humeri change from very compact to spongious in the progressive independence of cetaceans from a terrestrial environment, which is in accordance with the progressive loss of propulsive role for the forelimbs that were used instead for steering and stabilizing. The opposite trend is observed in femora, with basilosaurid hind-limbs being strongly reduced with no involvement in locomotion. Our results confirm that Remingtonocetidae and Protocetidae were almost exclusively aquatic in locomotion for the taxa sampled, which probably were shallow water suspended swimmers. Conversely, basilosaurids display osseous specializations similar to those of modern cetaceans and are considered more active open-sea swimmers.

ONTOGENY, ULTRASTRUCTURE AND MECHANICS OF SHARK AND RAY TESSELLATED CARTILAGE

RONALD SEIDEL[1], DAVID KNOETEL[2], MERLIND SCHOTTE[2], DANIEL BAUM[2], DANIEL HUBER[3], MICHAEL BLUMER[4], LING LI[5], JAMES C. WEAVER[5] AND MASON N. DEAN.[1]

[1] *Department Biomaterials, Max Planck Institute, Potsdam, Germany*
mason.dean@mpikg.mpg.de
[2] *Department Visual Data Analysis, Zuse Institute Berlin, Germany*
[3] *Department of Biology, University of Tampa, FL, USA*
[4] *Division für klinisch-funktionelle Anatomie, Medizinische Universität, Innsbruck, Austria*
[5] *Wyss Institute for Biologically Inspired Engineering, Harvard University, Cambridge, MA, USA*

Extant fish skeletal tissues are far more diverse than those of mammals, providing unique windows into skeletal biology, development and form-function relationships, but also the evolutionary and environmental pressures that shape anatomy. We investigate the materials, structure and mechanics of shark and ray endoskeletons, comprised of unmineralized cartilage covered in a layer of geometric, sub-millimeter, mineralized tiles (tesserae). Our interdisciplinary collaboration investigates the growth, morphology and material properties of this tissue, tying together histological, high-resolution materials science, and skeletal morphometric techniques to understand the genesis and regulation of the tiled pattern and its effect on skeletal mechanics. We show that tesserae begin from isolated, cell-associated mineralization centers, under a similar mineralization pathway to bone, but being patterned on a wider diversity of collagens. As tesserae grow into contact, striking patterns of structural reinforcement appear, developing mineral density and tissue stiffness comparable to (and sometimes higher than) mammalian mineralized cartilage or bone. Using quantitative shape analyses of high-resolution CT scans, we map the massive network of tesserae on skeletal elements, then use these data as inputs into physical (e.g. 3D-printed) and theoretical models of tessellated cartilage. Combining our materials and ultrastructure analyses with quantitative shape and mechanics studies of whole jaws from shark species with different diets, we are building a holistic understanding of form and function for this tissue, integrating multiple size scales. Our investigations shed light on fundamental structure-growth-function relationships for tesserae, but also tiled and/or accretive growth skeletal tissues in general, both extant and extinct.

THE STRUCTURE AND MECHANICAL PROPERTIES OF THE ANOSTEOCYTIC BONE OF NEO-TELEOST FISH

AYELET ATKINS[1], LIOR OFFER[1], MARIA LAURA HABEGGER[2], PHILIP MOTTA[2], MASON N. DEAN[3], JOHN D. CURRREY[4], STEVE WEINER[5] AND RON SHAHAR[1]

[1] *Hebrew University of Jerusalem, Rehovot, 7600, Israel*
Ron.shahar1@mail.huji.ac.il
[2] *University of South Florida, Tampa, Florida 33613, USA*
[3] *Max Planck Institute, Potsdam 14476, Germany*
[4] *University of York, Y010 5DD, York, UK*
[5] *Weizmann Institute of Science, Rehovot, 76100, Israel*

Palaeohistology is concerned with the different levels of organization of mineralized tissues, such as bone, calcified cartilage, teeth (dentine, enamel and enameloid) and scales, in fossil organisms, based on studies of extant taxa. Such studies allow the examination of structure-function relationships, which are obviously impossible to perform on fossils. In this regard, the study of the skeleton of osteichthyes (bony fish) has contributed significantly to our understanding of the origin of the vertebrate skeleton.

It was noted already in the mid- 19th century that many fish species totally lack osteocytes in their skeleton (anosteocytic). Furthermore, it was demonstrated that the primitive condition was osteocytic, and anosteocytic bone was a derived characteristic. Considering the fundamental importance associated with osteocytes in terms of regulation of modeling and remodeling of bones, and the mechanical consequences of these two processes, it is surprising that very little is known about the structure and mechanics of anosteocytic bone.

In this presentation, we describe the results of several investigations of the structure of anosteocytic bone (from the micro- to the nano-scale), its composition and mechanical properties, showing also preliminary results which suggest that it can respond to load by adapting its external morphology, and (at least in some fish species) undergo intense remodeling despite the lack of osteocytes. In this regard, comparisons of the biomechanics and structure-function relationships in anosteocytic and osteocytic fish bone are of interest and can provide clues to the selective pressures that drove the evolution of different vertebrate skeletal tissue types.

HISTOLOGICAL INDICATIONS FOR A MECHANICAL SUPPORT FUNCTION OF DORSAL OSTEODERM SYSTEMS IN TRIASSIC ARCHOSAURIFORMS

MICHAEL BUCHWITZ[1] AND SUSANNE EBERSPÄCHER[2]

[1]*Museum für Naturkunde Magdeburg, Magdeburg, 39108, Germany*
michael.buchwitz@museen.magdeburg.de
[2]*Geowissenschaftliche Sammlungen, TU Bergakademie Freiberg, Freiberg, 09599, Germany*

Crocodiles and many of their relatives among Triassic archosauriforms feature dorsal osteoderm systems that include a double row of paramedian osteoderms in proximity to vertebral spines. In extant crocodiles these osteoderms form insertion sites for tendons of epaxial muscles and are connected to each other and the vertebral spines through ligaments or cartilage, constituting a trunk-carrying system which has also been proposed for certain fossil crocodile relatives. We describe the osteohistological features of eleven osteoderms referred to four aetosaur and three phytosaur taxa as well as the "rauisuchian" *Batrachotomus* on the basis of 25 individual sections, focussing on small-scale variation within and between osteoderms. Paramedian aetosaur osteoderms feature distinct sets of Sharpey's fibers that display narrowly varying orientations oblique to the osteoderm surface and are confined to certain cortex parts. The fiber patterns differ from those in lateral and ventral aetosaur osteoderms and are concordant with an anteroventral field of muscle insertion in addition to ligament connections between neighboring osteoderms. Furthermore paramedian aetosaur osteoderms share a marked ventral-dorsal allometry: Considerable bone resorption from the dorsal surface and slow episodic dorsal bone accretion contrast with somewhat faster and constant ventral bone accretion. Such a growth mode keeps the ventral osteoderm surface intact - as expected if it functioned as insertion site for muscle systems. Histological indications for a mechanical support function are equivocal in the other sampled archosauriforms and further data, preferably from non-destructive analysis of articulated specimens, might be needed to tackle the question of trunk-carrying system origins.

TESTING PHYLOGENETIC, FUNCTIONAL, AND SPATIAL SIGNAL IN THREE-DIMENSIONAL COLLAGEN FIBER ORIENTATIONS OF AVIAN LONG BONES

TOBIN HIERONYMUS[1] AND DAVID WAUGH[1]

[1] *Department of Anatomy and Neurobiology, Northeast Ohio Medical University, Rootstown, 44272,USA*
thieronymus@neomed.edu

A broad sample of data from extant taxa suggests that collagen fiber orientation in bone may develop in response to principal bone strains during some forms of modeling and remodeling. This relationship holds out a tantalizing proxy for mechanical function that could be interpreted from paleohistological sections, but any application must take into account (a) conflicting results from studies of mechanical correlation, (b) confounding relationships with primary osteon orientation and growth rate, and (c) whether collagen fiber orientations evolve quickly enough to reliably track changing bone mechanics (phylogenetic signal). We are testing the relative importance of these factors in mid-diaphyseal sections of extant avian long bones. We have constructed a low-cost quantitative polarized light microscopy system that allows simultaneous pixel-resolution estimates of collagen fiber azimuth and elevation. Our preliminary data focus on the ulnae from fourteen neognath avian taxa. We analyzed the distribution of orientations against both (i) a 'best-fit' model of combined torsion + bending, and (ii) a multi-scale spatial model of the cortex. The fits for each explanatory model were then compared by variation partitioning. Preliminary results suggest collagen fiber orientations do display variation consistent with torsional and bending stresses in the cortex, but this variation is vastly outweighed by mechanically neutral patterns of spatial variation. A preliminary comparison across taxa points to significant phylogenetic signal in orientation distributions. Ongoing work will address potential overlap in phylogenetic and mechanical signal, as well as variation among skeletal elements within taxa.

COMPARTIVE ANISOTROPY IN THE CORTEX OF THE RADIUS OF BATS AND NON-VOLANT MAMMALS

LISA NOELLE COOPER[1], DAVID A. WAUGH[1], NANCY B. SIMMONS[2] AND TOBIN L. HIERONYMUS[1]

[1] *Department of Anatomy and Neurobiology, Northeast Ohio Medical University, Rootstown, Ohio, 44236, USA*
l.noelle.cooper@gmail.com
[2] *Department of Mammalogy, American Museum of Natural History, New York, 10024, USA*

Bats are the only mammals to achieve powered flight. Bones of the bat wing are unusually resilient and capable of undergoing large deformations during flight. The phalanges of bats are known to bend to ~50% of their resting length during a flight stroke. A possible contribution to this performance is organization of the bone matrix. This study tested whether the cortex of the radius of bats (n=7) was unique in its organization relative to non-volant mammals (n=5; mice, squirrels, moles). Midshaft histological sections were imaged with a camera and computer-controlled polarizing filter. The software package RotoPol assigned a quantitative value to each pixel based on collagen orientation and intensity of birefringence. Subsequent eigenvector analysis in R-software showed that both groups display at least 70% of their collagen fibers oriented near the longitudinal axis of the radius (bats 71-85%, rodents 87-91%, mole 86%, and flying squirrel 88%). However, the median value of longitudinally-oriented fibers was ~10% lower in bats. This departure in orientations is seen along the endosteal and, to a lesser extent, periosteal regions. Bone near these surfaces was oriented circumferentially in bats, but near longitudinally in non-volant taxa. The radius of the middle Eocene fossil bat, *Hassianycteris*, showed apatites in the mid-cortex that were oriented circumferentially, unlike extant bats that show longitudinally oriented fibers in this region. Ongoing analyses will compare quantitative measure of collagen anisotropy in a larger sample of fore- and hindlimb bones of bats and non-volant mammals.

INVESTIGATING THE EXTENT TO WHICH ENTHESEAL CHANGES REFLECT BONE REMODELING AT THE FEMORAL MIDSHAFT IN ANCIENT HUMANS

JUSTYNA J. MISZKIEWICZ[1], TRACY L. KIVELL[2,3], STEPHEN H. SCHLECHT[4], PATRICK MAHONEY[1]

[1] *Human Osteology Research Laboratory, School of Anthropology and Conservation, University of Kent, Canterbury, CT2 7NZ, UK.*
jm553@kent.ac.uk
[2] *Animal Postcranial Evolution Laboratory, School of Anthropology and Conservation, University of Kent, Canterbury, CT2 7NZ, UK.*
[3] *Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Leipzig 04103, Germany.*
[4] *Orthopaedic Research Laboratory, Department of Orthopaedic Surgery, University of Michigan, Ann Arbor, 48109 USA.*

The principles underlying bone functional adaptation are well established, although recent experimental studies suggest that the bone-tendon-muscle relationship may be more complex than originally thought. Anthropologists examine the morphology of "muscle markers" or entheses to infer past behavior, but the extent to which entheseal change reflects the underlying bone remodeling remains largely unexplored. Here, a classic muscle marker scoring method is evaluated using histomorphometry on a large ancient human archaeological sample from Canterbury, UK. Adult femora (n = 441) were grouped into different (absent, hypertrophy, stress lesion) *adductor longus* (AL) and *adductor magnus* (AM) entheseal categories. Intact, fragmentary, and osteon population densities, as well as osteon area, Haversian canal area and diameter, and osteocyte lacunae density were recorded in sections removed from the midshaft *linea aspera* region and compared across the entheseal categories using univariate inferential statistics. The histology variables did not consistently correspond with outer entheseal morphology (AL: p = .000 - .012, AM: p = .000 - .131), particularly when age (AL: young p = .007 - .883, middle-aged p = .000 - .101, AM: young p = .022 - .591, middle-aged p = .007 - .271) and sex (AL: females p = .004 - .655, males p = .000 - .093, AM: females p = .049 - .934, males p = .011 - .617) were accounted for in the analysis. Results indicate that biomechanical inferences gained from the underlying bone growth mechanism may not support conclusions drawn from macroscopic observations, suggesting the need for multi-methodological approaches in future studies.

STRUCTURE AND ORIGIN OF THE ALBID TISSUE OF CONODONTS

ALEXANDRA I. GERASIMOVA[1], ANDREY V. ZHURAVLEV[2] AND ELENA V. ROSSEEVA[3]

[1]NMRU "Gornyi",St.Petersburg, 199106, Russia
jiiin-94@mail.ru
[2]Polargeo Inc., St.Petersburg, 199106, Russia
[3]State University, St.Petersburg, 199106, Russia

Conodont elements are composed with lamellar, paralamellar, interlamellar, and albid hard tissues. The albid tissue is suggested as unique to conodonts, and seems to be most advanced hard tissue in this extinct group of animals. The tissue composes cores of denticles of conodont elements. This study is focused on comparative investigation of the inner structure and boundaries of the albid tissue of the Early and Middle Palaeozoic conodonts, based on SEM, TEM, XMT, and optical methods. Crystallites of the albid tissue are highly ordered and compose porous mesocrystal. Organic matter has the uniform structure (1.5-2 mkm reticulation) in all the tissue types, however the albid tissue contains least amount of organic matter. Albid tissue of the Late Devonian coniform elements (Jablonnodus) have a set of regular pores composing cone-like structures, similar to ramiform and platform elements of Ozarkodinida. The Ordovician coniform elements (Oistodus) demonstrate simpler structure of the albid tissue: pores are isometric and irregular, crystallites are slightly disordered. The albid tissue forms gradual boundaries with lamellar and paralamellar tissues. Transient zones bear rare pores and demonstrate clear lamellar structure. Supposed that conodonts had the biologically controlled extracellular mineralization. Elaborated model of the albid tissue forming comprises five stages: resorption of the outer lamellar tissue and part of the albid tissue lamellae; restoring of the resorpted part of the albid tissue lamellae; forming of the organic matrix of the new albid tissue lamellae; initial crystallization of the disordered crystallites of the lamellae; recrystallyzation of the crystallites around the organic matrix into the mesocrystal.

BONE AREA INCREASE DUE TO ORNAMENTATION IN THE CROCODYLIA: A QUANTITATIVE APPROACH

FRANÇOIS CLARAC[1,2], THIBAUD SOUTER[3], RAPHAËL CORNETTE[3], JORGE CUBO[1] AND VIVIAN DE BUFFRENIL[2]

[1] *Institut des Sciences de la Terre de Paris (UMR 7193), Sorbonne Universités, UPMC, CNRS, Paris, 75005, France*
fclarac@mnhn.fr
[2] *Centre de Recherches sur la Paléobiodiversité et les Paléoenvironnements (UMR 7207), Sorbonne Universités, CNRS/MNHN/UPMC, Paris, 75005, France*
[3] *MNHN PPF plateformes (CNRS IFR 101, UMR 5202), Paris, 75005, France*

Bone ornamentation involves highly repetitive motives created by pits and ridges. It is a frequent feature on vertebrate skull roofs and osteoderms. However, the functional significance of this character remains unknown. The many diverging proposed hypotheses assume that bone ornamentation should increase significantly the surface area of the bones that bear it. In order to test this assumption in the Crocodylia, we developed a method for quantifying the gain in area due to ornamentation using a 3D surface scanner. On crocodilian osteoderms, the gain in area can be up to 40%, and on the cranial table, it ranges from 10 to 32% in adult specimens (in both cases, it shows substantial differences between the adults of the various species included in the sample). Area gain on the snout is lesser (0 to 20% in adults), and highly more variable between species. In general, juvenile specimens show less pronounced bone ornamentation resulting in fewer area gains.

EARLY CRETACEOUS ANKYLOSAUR SACRAL SHIELD FROM THE ISLE OF WIGHT DISPLAYS A REMARKABLE SEMI-LAMINATED STRUCTURE

SARAH-JANE STRACHAN[1], GARETH DYKE[1], STUART POND[1] AND COLIN PALMER[1]

[1] *National Oceanography Centre, Southampton University, Southampton, Hampshire SO14 3ZH, UK*
sjs2g14@soton.ac.uk / mail@sarahstrachan.co.uk

The rarity of fossil specimens has meant that there have been few histological analyses of ankylosaur sacral shields. Here we report an unusual 'schichttorte' (layer cake) feature present across the sacral shield of a well-preserved ankylosaur from the Isle of Wight, southern England, and discuss its functional implications and usefulness in determining phylogeny. Originally thought to be *Polacanthus foxii*, this new ankylosaur specimen has yet to be described and is considered nodosauroid (indet.). The sacral shield exhibits alternating light and dark layers parallel to the dorsal surface and visible at the macro-level in the hand specimen. The lighter layers are revealed under the microscope as bone matrix rich in highly organised structural collagen fibre bundles. The addition of elastic, collagen fibre rich layers to the bone matrix creates a light, semi-laminated fibrous composite material. The biomechanical properties inferred are an increase in compliance, toughness and resistance to the propagation of cracks. We propose that the sacral shield was effective as light, but tough protective armour and had evolved to be able to maintain integrity whilst sustaining damage. The histology of this Isle of Wight ankylosaur is dissimilar to current *Polacanthus* descriptions and may be unique to this taxon.

BONE GROWTH IN THE NINE-BANDED ARMADILLO (*DASYPUS NOVEMCINCTUS*): IMPLICATIONS FOR EXTINCT TAXA

CHRISTIAN HECK[1], DAVID VARRICCHIO[2], TIMOTHY GAUDIN[3], HOLLY BALLARD[1] AND JOHN R. HORNER[2]

[1] *Department of Biomedical Sciences, Oklahoma State University Center for Health Sciences, Tulsa, Oklahoma, 74107, USA*
ctheck@okstate.edu
[2] *Department of Earth Sciences, Montana State University, Bozeman, Montana, 59717, USA*
[3] *Department of Biological and Environmental Sciences, University of Tennessee-Chattanooga, Chattanooga, Tennessee, 37403, USA*

Increasing importance has been placed on bone microstructure studies of extant organisms to better interpret the fossil record. For instance, studies examining extant crocodylians, aves, and mammals help describe and interpret extinct tetrapod growth. Nine-banded armadillos (*Dasypus novemcinctus*) are common taxa throughout the southern United States. Although armadillo biology has been studied extensively, work on growth rates is limited. Here we describe long bone microstructure in an ontogenetic series of nine-banded armadillos to elucidate patterns of bone growth. Primary woven bone of fibrolamellar organization is present in the smallest specimen. The smallest individual displays signs of erosion on both the periosteal and endosteal surfaces. The primary tissue becomes remodeled extensively into compacted coarse cancellous bone throughout the cortex of the larger specimens. Primary tissue near the trochanteric side of the femora is the last area of the cortex to undergo remodeling. In the larger specimens multiple layers of avascular lamellar bone are deposited along the eroded endosteal surface, leaving behind faint tide lines. Avascular lamellar bone is also deposited along the periosteal surface, but this deposition is completed later in femoral bone growth. Circumferential growth lines are evident in the large specimen on the trochanteric side, but merge onto the periosteal surface away from the trochanter. Bone development and growth in nine-banded armadillos appears to be a unique process that requires further investigation. Understanding the full developmental process can provide a framework for use on extinct cingulates and other extinct taxa.

FIRST INSIGHTS ON THE LIFE HISTORY OF THE *HISPANOTHERIUM MATRITENSE* (RHINOCEROTIDAE, PERISSODACTYLA) FROM THE MIDDLE MIOCENE OF THE IBERIAN PENINSULA

OSCAR SANISIDRO[1] AND CAYETANA MARTINEZ-MAZA[1]

[1] *Museo Nacional de Ciencias Naturales – CSIC, Madrid, 28006, Spain*
oscarsanisidro@gmail.com

The rhinoceros *Hispanotherium matritense* is a typical elasmotheriine rhinoceros of the Aragonian (Middle Miocene) deposits of the Iberian Peninsula. The Middle Miocene site of Príncipe Pío-2 (Madrid, Spain) has yielded one of the most valuable collections for the species with more than 1,000 fossil remains. We have selected a sample of *H. matritense* postcranial remains to carry out the first histological study in this species in order to provide data about its life history. Most of the specimens showed taphonomically-altered cortical bone throughout the endosteal and medial regions. However, the well-preserved bone structure of the periosteum and some intracortical regions allowed us to identify particular histological features. These areas have a high degree of bone remodeling. The preserved primary cortical bone shows differences in the vascular pattern. Humeri and femora show a laminar bone tissue with circumferentially-arranged vascular canals. Tibiae show a laminar vascular pattern with longitudinal primary osteons randomly distributed. Metapodials display a combination of longitudinal primary osteons with a random distribution. Radii were highly remodeled and no evident pattern could be identified. Regarding growth marks, we have identified lines of arrested growth (LAGs) and external fundamental system (EFS). Skeletochronological data allow us to identify specimens from one to more than nine-years-old, suggesting that *H. matritense* reach the skeletal maturity at ten years old. Results obtained in this work provide new insights in the life history of *H. matritense* and show differences comparing to the only previous species analyzed *Coelodonta antiquitatis*.

CEMENT, COLLAGEN FIBERS, OR MINERAL: WHAT IS THE PREDOMINANT INGREDIENT IN BONE BIREFRINGENCE?

SANTIAGO GOMEZ[1]

[1] *Department of Pathological Anatomy, University of Cadiz, Cadiz, 11003, Spain*
Correspondence. santiago.gomez@uca.es

In paleohistology, light microscopy characterization of the bone tissues composing a fossil bone is referred to the microstructure of recent bones. Osteocyte lacuna distribution and collagen fibers organization are usually studied. While the size, shape, and density of osteocyte lacuna are readily noticeable in bone thin sections, the assessment of the arrangement of collagen fibers in the same sections is not so easy because polarization microscopy resulted in bright and dark areas which sometimes have a different significance. The present investigation systematically analyzed the use of interference polarization-colors and birefringence sign (positive or negative) in order to characterize what bone matrix component (cement, collagen fibers, or mineral) predominates in the polarization images. To this goal, samples of recent bone (undecalcified or decalcified), burnt bone (at 200° C for 24 h), and fossil bone (with some collagen decay) were processed. Ground thin-sections were studied with circularly polarization microscopy, with polarization microscopy using ¼-, 1-λ plate compensators, and with polarization by absorption using dichroic filters. Total birefringence of bone was the sum of positive birefringence of collagen and cement, and negative of mineral. In a given bone thin-section, the displayed interference colors were dependent on the proportional content of these components.

RECONSTRUCTING TIMING AND DURATION OF IMPAIRED SECRETORY AMELOBLAST FUNCTION IN INCISOR ENAMEL OF *SIVATHERIUM HENDEYI* FROM THE EARLY PLIOCENE OF LANGEBAANWEG, SOUTH AFRICA

CARSTEN WITZEL[1], TAMARA FRANZ-ODENDAAL[2], UWE KIERDORF[1] AND HORST KIERDORF[1]

[1] *Department of Biology, University of Hildesheim, Universitätsplatz 1, 31141 Hildesheim, Germany*
kierdorf@uni-hildesheim.de
[2] *Department of Biology, Mount St. Vincent University, Halifax, Nova Scotia, B3M 2J6, Canada*

High prevalence of enamel hypoplasia has previously been reported in *Sivatherium hendeyi* from the Early Pliocene of Langebaanweg and attributed to seasonally occurring nutritional stress. This study histologically analyzed two permanent *Sivatherium* incisors, one showing severe enamel defects, the other exhibiting normal enamel. On external inspection, about 75% of the labial crown surface of the former tooth showed pitting of the enamel, indicative of enamel hypoplasia. Analysis of a labio-lingual ground section of this tooth revealed the presence of a zone of altered enamel structure that was sandwiched between a cuspally located, earlier-formed (inner) and a cervically located, later-formed (outer) zone of normal enamel structure. This finding indicates that the period of secretory ameloblast disturbance was both preceded and followed by a period of normal secretory activity. In areas where the entire enamel layer exhibited structural alterations and a reduced thickness, the ameloblast had apparently been affected during the complete secretory stage of amelogenesis. Based on the recording of daily incremental enamel markings (laminations) in the pathological incisor, and of a reduction in enamel extension rate in cervical direction, we conclude that about 40% of crown formation time of the *Sivatherium* incisor exhibiting enamel hypoplasia had been affected by a stress event. This is compatible with the hypothesis that the enamel defect was caused by seasonal nutritional stress. Our results further indicate that it is not possible to reliably reconstruct the duration of stress periods affecting enamel formation based only on external inspection of tooth crowns.

HISTOLOGY OF *MOSASAURUS MAXIMUS* PTERYGOID DENTITION AND ITS ATTACHMENT TISSUES

RODRIGO PELLEGRINI[1] AND BRIAN BEATTY[2]

[1] *New Jersey State Museum, Trenton, NJ 08625-0530, USA*
Rodrigo.Pellegrini@sos.nj.gov
[2] *Department of Anatomy, NYIT College of Osteopathic Medicine, Old Westbury, NY 11568, USA*

Although the pterygoid of *Mosasaurus hoffmani* has been examined in regards to tooth replacement and attachment, no published images of histological sections of the element with teeth *in situ* are known. Here, we present histological sections of the right pterygoid of the very closely related *M. maximus* from New Jersey (USA), and test the assumptions and expected results from previous non-histological examinations of the pterygoid element of *M. hoffmani*. We conclude our work confirms previous published results.

DENTAL HISTOLOGY OF THE SICILIAN DWARF ELEPHANT *PALAEOLOXODON FALCONERI*

XAVIER JORDANA[1], MEIKE KÖHLER[1,2], JOAN MADURELL-MALAPEIRA[1], ANTONIETTA ROSSO[3], ROSSANA SANFILIPPO[3] AND FRANCESCO SCIUTO[3]

[1] *Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
xavier.jordana@icp.cat
[2] *ICREA at Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
[3] *Museo di Scienze della Terra, Università degli Studi di Catania, Catania, 95129, Italy*

The Pleistocene *Palaeoloxodon falconeri* from the island of Sicily is the smallest elephant (shoulder height of 1 m) that ever lived. It descends from *Palaeoloxodon antiquus* (4 m tall) of Middle Pleistocene deposits of mainland Europe. The spectacular change in the size of this insular elephant is considered the most outstanding example of island dwarfing. Here, as part of a more general project aimed to study the life-history evolution of *P. falconeri*, we present the preliminary results on the analysis of dental histology. Three types of incremental marks (first, second and third-order) have been described in proboscidean teeth, which correspond to annual, circa-weekly and daily growth marks, respectively. We analysed thin sections of a tooth sample of *P. falconeri* from Spinagallo cave (Eastern Sicily) under polarized light microscopy. The sample includes plates of almost all types of the elephant lower teeth (dP/3, dP/4, M/1, M/2 and M/3). For comparisons, we additionally analysed a molar plate of *P. antiquus* from the Middle Pleistocene site of Torralba (Soria, Spain). Second and third-order incremental markings in enamel and dentine are visible in both fossil elephant species, allowing the reconstruction of timing and rates of tooth formation. Our results add to our understanding of the developmental mechanisms leading to insular dwarfing.

TUROLIAN DWARF *HIPPARION* FROM SPAIN: INFERRING LIFE HISTORY MECHANISMS UNDERLYING SIZE SHIFT FROM DENTAL MICROSTRUCTURE

GUILLEM ORLANDI-OLIVERAS[1], XAVIER JORDANA[1] AND MEIKE KÖHLER[1,2]

[1 1]*Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
guillem.orlandi.92@gmail.com
[2] *ICREA at Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*

The classic continental fossil sites from Valdecebro Rambla (Teruel Basin, Spain) have provided a rich mammal record from the Late Turolian (MN13), the Hipparioni tribe being one of the most represented groups, which reached its maximum diversity on the Iberian Peninsula during the Turolian. In addition to this taxonomical diversity, there was a size shift resulting in species significantly smaller than their ancestors. Particularly, some fossil sites, such as Valdecebro II, yielded three species of *Hipparion* of different body sizes that most likely evolved through sympatric speciation. The largest species is Hipparion primigenium which was a medium sized hipparion with an estimated body mass of 138 kg, the other two species *Hipparion gromovae* and *Hipparion periafricanum* were considerably smaller reaching 59 and 23 kg respectively. The main purpose of this study is to reveal the changes in life history mechanisms that underlie these size shifts and to understand how this sympatric speciation occurred. We use parameters from dental histology such as enamel daily secretion rate, enamel extension rate or the dentin and enamel incremental markings to reconstruct the growth patterns of the small-sized hipparions and compare them with the larger hipparions. The studied sample consists of a large set of isolated M3 from the lower series of the sympatric species. Dental microstructure parameters are widely used as proxies of the species' pace of life; however, the results must be set in the context of hypsodonty and the allometric scaling related to the body size changes.

MOLAR ENAMEL MICROSTRUCTURE AND HYPSODONTY IN THERIDOMYIDAE (RODENTIA) AT THE EOCENE-OLIGOCENE TRANSITION

THOMAS ENGLER[1] AND THOMAS MARTIN[1]

[1]*Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
Thomas.Engler@Uni-Bonn.de

The Eocene-Oligocene transition (Grande Coupure) is marked by fundamental faunal turnovers when forests were replaced by open drier grasslands due to climatic changes. The biostratigraphically important theridomyids, a rodent group endemic to Europe (MP13 - MP30), evolved independently in several lineages hypsodont cheek teeth, apparently to compensate increasing wear by more abrasive food. The changes in form and function of the dentition are also reflected in modifications of their enamel microstructure. To detect these modifications that occurred along with increasing hypsodonty, the enamel microstructure in the cheek teeth of five theridomyid subfamilies was studied under the SEM. The low-crowned and weakly hypsodont theridomyid species exhibit all the "*Sciurus*"-type schmelzmuster. At least in two lineages, Issidoromyinae and Theridomyinae, hypsodonty evolved independently. Issiodoromyinae with partially hypsodont cheek teeth have a single-layered schmelzmuster with straight and weakly inclined Hunter-Schreger bands (HSB), whereas in Theridomyinae, a thick inner layer of radial enamel (RE) and an outer layer of HSB can be found. In the outer layer, HSB appear initially irregular in transverse section (*Protechimys*) and are later turned into irregular enamel (*Archaeomys*). Therefore, Archaeomyini possess a unique leading–trailing edge pattern. The leading edge with primitive RE is almost completely reduced. However, the trailing edge is differentiated in a push side formed by thick RE (65%) and a pull side with irregular enamel pattern. This schmelzmuster is unique for rodents and completely different from that of the morphologically similar cheek teeth of chinchillids (Caviamorpha).

EXCEPTIONAL SOFT TISSUE PRESERVATION WITHIN A TOOTH FROM THE WHITE SHARK *CARCHARODON* (LAMNIFORMES, LAMNIDAE) FROM SACACO, PERU (MIOCENE, PISCO FORMATION)

CHRISTEN SHELTON[1], DANA EHRET[2], MARIE-CLAIRE KOSCHOWITZ[1] AND GORDON HUBBELL[3]

[1] *Steinmann-Institut für Geologie, Mineralogie und Paläontogie, Universität Bonn, Bonn, 53115, Germany*
Cshelton@uni-bonn.de and m.koschowitz@uni-bonn.de
[2] *The University of Alabama Museums, Box 870340, Tuscaloosa, AL 35487 USA*
djehret@ua.edu
[3] *Jaws International, 1703 SW 82nd Drive,Gainesville, FL 32607 USA*
Jawsint@aol.com

The Pisco Formation of Sacaco, Peru has yielded exceptionally well preserved marine vertebrates including whales and sharks due to rapid sedimentation rates which occurred during the Late Miocene to Early Pliocene. Here we describe the dental histology of the white shark *Carcharodon hubbelli* (Lamniformes, Lamnidae) from teeth collected by one of the authors, and sectioned both transversely and longitudinally. The standard method for producing thin sections was followed as outlined in any recent paleohistological study. Our findings reveal unique structures, possibly preserved due to a quick burial. These structures are reminiscent of blood vessels, capillaries, and erythrocytes, and they can be observed throughout the osteodentine. Blood vessels branching out connecting the individual dentinal osteons (denteones) as they would have in life are also visible in thin section. The presumed erythrocytes, which range in size from 10 to 25 micrometers, are comparable in size to erythrocytes in extant fish and are restricted to blood vessels and capillary structures. An EDTA extraction revealed three-dimensionally preserved tubules, and the presumed erythrocytes seem to have been permineralized. These structures may ultimately be revealed as iron globules resulting from a biogenic origin. A comparison to the modern white shark *C. carcharias* needs to be made in order to fully understand these findings. Subsequently, additional vertebrate material from the Sacaco, Peru lagerstätten needs to be histologically examined in order to confirm the preservation of microscopic soft tissue structures by the unique taphonomic processes that occurred here.

TEETH-ATTACHMENT AND PLICIDENTINE IN EXTANT PREDATORY OSTEICHTHYANS REVEALED BY 3D TOMOGRAPHY

JORGE MONDEJAR-FERNANDEZ[1], DAMIEN GERMAIN[1] AND FRANÇOIS J. MEUNIER[2]

[1] *Centre de Recherches sur la Paléobiodiversité et les Paléoenvironnements (UMR 7207), Sorbonne Universités, MNHN/CNRS/UPMC, Paris, 75005, France*
mondejar@mnhn.fr
[2] *BOREA (UMR 7208), CNRS/IRD/MNHN/UPMC, Département des Milieux et Peuplements Aquatiques, Paris, 75231, France*

Plicidentine constitutes a particular spatial arrangement of the dental dentine, characterized by the occurrence of more or less branched folds that invade the pulp cavity of the teeth. Plicidentine has been interpreted as a specialization to strengthen the attachment of the tooth to the supporting bone in predatory osteichthyans (bony fishes). Long considered an exclusive feature of extinct sarcopterygians (lobe-finned fishes), plicidentine was thought to be absent from extant osteichthyans, with the only exception of the large predatory garpike *Lepisosteus* among actinopterygians (ray-finned fishes). However, recent studies have shown the presence of plicidentine in the oral teeth of several extant osteichthyans, such as the coelacanth *Latimeria*, and various predatory teleosteans like the osteoglossiform *Arapaima*, the characiform *Hoplias* and the lophiiform *Lophius*. In these taxa, the plicidentine is much less developed than in fossil sarcopterygians. Dentine folds consist of simple, primary plies located at the base of the teeth. However, the identification of the plicidentine based on histological preparations is not always easy, especially if it is weakly developed. Three-dimensional visualization is therefore essential to properly characterize plicidentine's structure, function and evolutionary implications. Here we present new data on the occurrence and characteristics of the plicidentine in the aforementioned osteichthyan taxa through 3D tomography, thus confirming the presence of folded dentine in these predatory fishes. We propose to extend this technical approach to the survey of the teeth of other extant teleostean fishes but also to fossil sarcopterygian material, too rare and precious to section.

RECONSTRUCTING JUVENILE MORPHOLOGY: A NON-DESTRUCTIVE METHOD TO DETECT HISTOLOGICAL STRUCTURES IN COMPUTED TOMOGRAPHY (CT) AND ITS POTENTIAL FOR FUTURE RESEARCH, USING THE EXAMPLE OF SAUROPOD RIBS

KATJA WASKOW[1]

[1] *Steinmann Institut für Geologie, Mineralogie und Paläontologie, Bonn, 50321, Germany*
waskow@uni-bonn.de

The knowledge about ontogenetic changes during growth of an individual is indispensable to understand the life of extinct animals with no recent equivalence. However, in most cases there is only little known about the ontogenetic change in morphology from a juvenile to an adult. In sauropods, the largest terrestrial animals ever, especially fossils of hatchlings and young juveniles are not preserved. Traditionally their bones were studied with the destructive method of histology to find out more about their life history traits. Due to the lack of growth marks in long bones, growth is difficult to quantify. Hence earlier studies used ribs for skeletochronology, even if local morphological change during ontogeny has precluded the calculation of a rib-based growth curve for an individual. Here we present a new method based on computed tomography (CT) that prevents unnecessary damage to the bone and additionally has the potential of reconstructing the morphology of the bone at different ontogenetic stages. By scanning a complete sauropod rib, lines of arrested growth (LAGs) become visible. These structures are one of the most important elements of traditional bone histology. By making them visible in the CT, histological sectioning can be avoided or the best sampling location can be detected. By tracing single LAGs through the bone, surfaces at earlier ontogenetic stages can be reconstructed. For sauropod research, this opens new perspectives for developing a correction formula for morphometric changes during ontogeny that allows the construction of a growth curve. This method could also be used for the understanding the ontogenetic history of other tetrapods showing LAGs in some of their skeletal elements.

HOW IMPORTANT ARE TEMNOSPONDYL HUMERI FOR SKELETOCHRONOLOGICAL ANALYSES? EVALUATING THE HISTOLOGICAL METHODOLOGY

ELZBIETA M. TESCHNER[1] AND DOROTA KONIETZKO-MEIER[1]

[1] *Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
teschner@uni-bonn.de

Until recently, not many histological studies have been done on temnospondyl amphibian bones. Analyses of the postcranial skeleton are usually based on the femora, and not the humeri. The morphological characters of these two bones differ greatly. The metoposaurid humerus is a tetrahedral bone with a twist between the distal and proximal end and a rather short midshaft region. In a former study, three humeri have been analyzed and they showed a wide histological variety. This might be a result of different ontogenetic stages, sectional plane was not exactly along the midshaft, or the skeletochronological information just were not preserved in these bones. Since histology is a destructive method and the postcranial fossil material of Temnospondyli is rare, the aim of this study was to test the importance of the metoposaurid humeri for skeletochronological purposes. The sixteen analyzed humeri of *Metoposaurus diagnosticus krasiejowensis* originated from the Middle-Late Carnian beds in Krasiejow, SE Poland. The bones were first scanned with a high-resolution micro-computed tomography, after which the position of the midshaft was determined using the software VG Studio MAX. Finally, thin sections were made. This study showed that, metoposaurid humeri can be used for histological analyses, provided that, to avoid the loss of information, the sectional plane cuts exactly through the midshaft region.

PRELIMINARY ANALYSIS OF *PTERANODON* LONG BONE HISTOLOGY

LAURA E. WILSON[1]

[1] *Sternberg Museum of Natural History and Department of Geosciences, Fort Hays State University, Hays, 67601, USA*
lewilson6@fhsu.edu

The number of *Pteranodon* specimens collected from the Smoky Hill Member of the Niobrara Chalk in western Kansas allows for analysis of bone microstructure across multiple size classes. Here, descriptions of femoral microstructure patterns provide the beginning of an ontogenetic framework for studying *Pteranodon* bone histology. The largest femur sampled (length = 23.49 cm) has a cortex dominated by parallel-fibered to lamellar bone with rounded osteocyte lacunae and a moderate number of simple vascular canals. Vasculature is predominately longitudinal, with some reticular canals present. Regions of compacted coarse cancellous bone of inconsistent thickness are present in the outer cortex and are bordered by resorption lines. Periosteal to the coarse cancellous bone, a thin layer of avascular lamellar bone with flattened osteocyte lacunae lines the periosteal surface. This is interpreted as an outer circumferential layer and suggests skeletal maturity. In contrast, a mid-sized femur (length = 18.72 cm) reveals a cortex of woven bone perforated by a moderate number of simple, longitudinal vascular canals and abundant Sharpey's fibers. No compacted coarse cancellous bone is present and no outer circumferential layer of lamellar bone is observed along the periosteal surface. Rather, vascular canals open to the periosteal surface, suggesting a sub-adult ontogenetic stage.

These preliminary results show distinct changes in *Pteranodon* microstructure that correspond to femur length and suggest significant changes in femur shape through ontogeny. Continued analysis will increase the number of specimens and size classes sampled, improving the resolution of ontogenetic changes in bone microstructure within the genus.

MICROANATOMY, BONE HISTOLOGY, AND GROWTH OF NOTHOSAURIA

NICOLE KLEIN[1], ALEXANDRA HOUSSAYE[2] AND EVA MARIA GRIEBELER[3]

[1] *State Museum of Natural History Stuttgart, Stuttgart, 70191, Germany*
nicole.klein@smns-bw.de
[2] *FUNEVOL (UMR 7179), CNRS/MNHN, 75000, France*
[3] *Zoological Institute, Department of Ecology, University of Mainz, Mainz, 55128, Germany*

Nothosaurs are a successful group of Middle Triassic marine reptiles (Sauropterygia) that invaded the shallow epicontinental seas of the Tethys Ocean. Hundreds of isolated nothosaur bones can be found in the Muschelkalk sediments of the Germanic Basin (Central Europe), providing a decent database for bone histological studies. These nothosaurs grew with parallel-fibred bone tissue that is dominated by longitudinal and radial vascular canals and sometimes primary osteons. The cortex is regularly stratified by growth marks. The growth pattern follows standard growth models used for extant reptiles. Nothosaur bone tissue is similar to that described for *Simosaurus* although--based on bone tissue organization and vascularization--growth rate is lower in nothosaurs. Contrary to the uniform bone tissue and growth pattern, microanatomy changes from Lower Muschelkalk to Upper Muschelkalk nothosaurs. The small *Nothosaurus marchicus* from the Lower Muschelkalk has a triangular humeral cross section with a small to moderate medullary cavity. The triangular form of the cross section resembling an airfoil as well as the dorsoventrally flattened overall morphology of the humerus indicate an active use of the forelimbs during swimming and is kept and intensified throughout nothosaur evolution. However, some large forms from the Upper Muschelkalk reduced their cortex to few millimetres as was already described, whereas others kept a more “normal” ratio between cortex and medullary cavity. These differences in microanatomy point to different swimming styles in nothosaurs (function signal) and may indicate the use of different habitats (developmental plasticity) or be a phylogenetic signal.

OSTEOHISTOLOGY OF THE HADROSAUROID (DINOSAURIA: ORNITHOPODA) FROM LABIRINTA CAVE, BULGARIA: AN EXAMPLE OF INSULAR DWARFISM OR SIMPLY YOUNG GIANT?

VLADIMIR NIKOLOV[1]

[1] *Department of Geology, Paleontology and Fossil Fuels, Sofia University, Sofia, 1504, Bulgaria*
vlado_raptor@mail.bg

The hadrosauroid remains from Kajlâka Formation (Upper Maastrichtian) limestones of the Labirinta Cave, NW Bulgaria, are most interesting for their small size but without paleohistological data it was not possible to affirm whether they belong to young individuals or to small-sized mature animals. To elucidate their histology and ontogenetic state, six associated cortical fragments and one partial diaphysis were sectioned and studied. Thin-sections reveal cortex build of highly vascularized tissues of the woven-parallel complex. Vascularization patterns are somewhat intermediate between those of derived hadrosauroids and non-hadrosauroid ornithopods, yet characterized by thick sequences of laminar bone. Bone tissue matrix consists largely of parallel-fibered or lamellar bone tissue. Cortical tissues are affected by processes of secondary remodeling that locally results in dense Haversian tissue reaching the subperiosteal cortex. No growth marks or external fundamental system are observed in any of the specimens. The transition from bone tissues with predominantly longitudinally oriented osteons to true laminar bone, the thickness of the latter, the extensive secondary bone remodeling and Haversian tissue with at least 3 generations of secondary osteons, as well as the presence of endosteal bone in one of studied specimens all suggest that the material pertains to animals at a late sub-adult ontogenetic stage. The high presence of parallel-fibered and lamellar tissues in the cortex indicates significantly slower growth rates in comparison with similarly sized but ontogenetically younger derived hadrosauroids. The osteohistology of the Bulgarian hadrosauroid reveals yet another example of dinosaurian insular dwarfism in latest Cretaceous European archipelago.

EXPLORING THE HISTOLOGY OF THE HUMAN PERINATAL VAULT BONES

OROSIA GARCÍA GIL[1], OSCAR CAMBRA-MOO[1,2], JULIA AUDIJE GIL[1], MIGUEL ANGEL RODRÍGUEZ BARBERO[3], JOSEFINA RASCÓN PÉREZ[1] AND ARMANDO GONZÁLEZ MARTÍN[1,2]

[1]Laboratorio de Poblaciones del Pasado (LAPP). Departamento de Biología, Facultad de Ciencias, Universidad Autónoma de Madrid, Madrid, 28049, Spain
oscar.cambra@uam.es
[2]Grupo de Investigación en Arqueología Antigua y Medieval, Universidad de Oviedo, Oviedo, 33011, Spain
[3]Instituto de Cerámica y Vidrio, Consejo Superior de Investigaciones Científicas (CSIC), Madrid, 28049, Spain

Previous analysis of human vault bones from individuals with different ages, has shown that during childhood, when cranium size is nearly complete, an almost avascular lamellar bone could be identified in both ectocranial and endocranial tables. After that, during youth, vault bones present a largely reduced diploe and, a convoluted-like fibrolamellar bone that accompanies the bones thickness increase, occupies the major part of the bone section. Finally, during adulthood, the diploe's cavities become extremely extended and the mineralized tissue acquires its typical cancellous structuration. Despite these preliminary results have encouraged an interesting discussion, they are insufficient and further studies are needed in the histological characterization of vault bones' ontogeny.

Herein we present the results of an exploratory analysis carried out in human perinatal vault bones. The osteoarchaeological material was recovered from the ossuary of the *Santa María de la Soledad* mediaeval church (Castilla-La Mancha, Spain). Left frontal, right parietal and squamous occipital were entirely embedded in transparent resin and three thin sections (of the complete bones) were prepared. After photographing the bones under polarized light microscopy, we mapped their histomorphology. All sections presented a mineralized matrix constituted by woven bone with a trabecular or embrionic-like appearance. Non-mineralized cavities varied from little and rounded to very large and irregular in shape, and these variations seem to be related with the distance from ossifications centres. In several areas of the three bones a finely paralleled fibered bone delimiting the cavities of the diploe, was identified under polarized light microscope.

FILLING A GAP – THE BONE HISTOLOGY OF *IGUANODON* AND *MANTELLISAURUS*

TOM HÜBNER[1]

[1] *LWL-Museum für Naturkunde, Münster, 48161, Deutschland*
Tom-Ray@gmx.net

In comparison with other dinosaur groups, ornithopods are well-studied in terms of their bone histology. However, there is a significant yet unstudied phylogenetic gap, which comprises the non-hadrosaurid ankylopollexian taxa. The evolutionary pathway from the variable bone microstructure of basal ornithopods and basal iguanodontians towards the derived pattern seen in hadrosaurids is still unresolved.

The locality Brilon-Nehden in western Germany, stratigraphically of similar age as the famous finds from Bernissart, yielded a wide size range of numerous disarticulated bones of the derived iguanodontians *Iguanodon bernissartensis* and *Mantellisaurus atherfieldensis*. Unfortunately, most bones are heavily impregnated by pyrite and marcasite making them vulnerable to decomposition. The bone tissue in the thin sections of femora is therefore often altered and stained and birefringence under crossed plane polarizers is difficult to observe. On the other hand, pyrite can occasionally cover the external bone surface, so that the fine trabeculae of newly forming periosteal bone were preserved.

The cortices mainly consist of fibrolamellar bone tissue with dense longitudinal to circumferential primary osteons organized in a laminar to plexiform vascularization pattern. Noteworthy are erosion cavities and mature secondary osteons already present in the smallest sampled femur, which is comparable to the late juvenile stage of the hadrosaur *Maiasaura*. Apart from vascularization shifts, no other growth marks could yet be found. The vascular organization in the femora of *Iguanodon* and *Mantellisaurus* is similar to the pattern seen in dryosaurs and hadrosaurids, whereas the onset and extent of secondary remodeling is more similar to *Rhabdodon* and hadrosaurids.

HIPPOPOTAMIDAE (GRAY 1821) IN INDIA: TAXONOMIC AND PALAEOENVIRONMENTAL INTERPRETATIONS

VIJAY SATHE[1]

[1]*Department of Archaeology, Deccan College Postgraduate and Research Institute, Pune, 411006, India*
vijay19sathe@gmail.com

Hippopotamus is a mega mammal component of the Plio-Pleistocene vertebrate fauna of India, emerging as an important candidate for palaeoenvironmental reconstruction. The family is represented by a single genus *Hexaprotodon sivalensis*. The four subspecies of *H. sivalensis* have been identified viz. *H. s. dhokwazirensis*, *H. s. namadicus*, *H. s. palaeindicus*, *H. s. deccanensis*; confined to the Indian subcontinent. They are believed to have become extinct from India at the end of Pleistocene and thus it is truly an extinct genus in India. *H. namadicus* and *H. palaeindicus* have a wide distribution throughout the late-Mid to Late Pleistocene in Peninsular India. A recent discovery of a calvarium from southern India is assigned to a separate subspecies viz. *H. s. deccanensis* on the basis of morphology. It is generally assumed that *Hexaprotodon sivalensis* has given rise to *Hexaprotodon namadicus*, which in turn has evolved into *H. palaeindicus*, occupying much of Peninsular India. However, the multi species status of the genus needs to be verified. The pan Indian spread and their successful survival and extinction towards the end of Pleistocene suggest the crucial role of the aquatic bodies. The tooth enamel microstructure and chemical composition of fossil teeth were examined using the principles of hierarchical complexity in enamel microstructure as well as the composition of major, minor and trace elements for palaeoenvironmental reconstruction. The paper highlights the histological attributes of tooth enamel and offers significant observations on taxonomy, and palaeoenvironmental interpretations for the extinct hippopotami of India.

DEVELOPMENT OF THE VERTEBRAL CENTRA IN BASAL TETRAPODS

MARYLÈNE DANTO[1], FLORIAN WITZMANN[2] AND NADIA B. FRÖBISCH[1]

[1]*Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Berlin, 10115, Germany*
marylene.danto@mfn-berlin.de
[2]*Department of Ecology and Evolutionary Biology, Brown University, Providence, RI 02912, USA*

Basal tetrapods display a great diversity in their vertebral body construction. The vertebral types range from multipartite centra in stem-tetrapods, temnospondyls, and seymouriamorphs up to monospondylous centra in lepospondyls. Moreover, a contrasting pattern of vertebral ossification was described: the multipartite centra became preformed in cartilage and are subsequently ossified. In contrast, the monospondylous centrum was formed by direct ossification. However, the precise details of the developmental origin of the vertebrae remain poorly understood. In this study, we sought to investigate the bone histology of the multipartite and monospondylous centra to detect similarities and differences between the two types and their mode of ossification. The intercentrum of the stem-tetrapod *Whatcheeria* is characterized by a thin stripe of compact periosteal bone and a large area of endochondral bone. In plagiosaurid temnospondyls, the periosteal region is thickened and highly vascularized. High amounts of calcified cartilage are preserved in the endochondral region. In the juvenile seymouriamorph *Discosauriscus*, the trabeculae are strongly remodelled. Among lepospondyls, the thickened periosteal region is composed of compact, lamellar bone in microsaurs, whereas the nectridean centrum is characterized by a spongiose periosteal region with large intertrabecular spaces. The endochondral region is loose with remnants of calcified cartilage. These results indicate that regardless of whether multipartite or monospondylous, the vertebrae display a similar developmental origin: they are formed as cartilaginous element and subsequently ossified endochondrally. Periosteal bone is deposited radially and ventro-laterally. However, the centra show an interspecific variability in growth rate, organization, and extent of the endochondral and periosteal region.

UNRAVELING CRYPTIC SPECIES OF *DIMETRODON* FROM THE CLEAR FORK GROUP (LOWER PERMIAN) – PHYLOGENETIC IMPLICATIONS OF ONTOGENETIC HISTOLOGICAL FEATURES

PHILIPP L. KNAUS[1], CHRISTEN D. SHELTON[1,2], AND P. MARTIN SANDER[1]

[1] *Steinmann-Institut für Geologie, Mineralogie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
philipp_knaus@hotmail.com
[2] *University of Cape Town, Cape Town, 7701, South Africa*

Dimetrodon is one of the most common genera of the Lower Permian Redbeds of Texas and Oklahoma and presents one of the best studied. Yet, its internal diversity is subject to debate as historically, species have been mostly distinguished based on stratigraphic occurrence and body size. This has led to interpretations of previously described sympatric species as parts of common ontogenetic series, but new studies on bone histology have verified sympatric species in the Wichita Group (Lower Permian) of Texas. *Dimetrodon* of the Vale formation in Texas and its equivalents in Oklahoma has been determined to be monospecific despite a bimodal distribution of body size frequency at the Sid McAdams locality.

Employing distinct ossification stage classification and bone histological analysis of five *Dimetrodon* femora of Clear Fork Group age, here we find sympatric *D.* species to be present in the Vale Formation. The previously undocumented small species either extends the stratigraphic range of *D. natalis* by an interval of four formations or presents a new taxon. Reconstructed growth trajectories for the sympatric species suggest that body size increased in larger *Dimetrodon* species through acceleration of growth rate. The finding supports the previously doubted notion that morphologically similar species of *Dimetrodon* were a common occurrence in the Lower Permian ecosystems of Texas and Oklahoma.

BONE HISTOLOGY OF AN EXTANT REPRESENTATIVE OF INSULAR MAMMALS: THE AMAMI RABBIT (*PENTALAGUS FURNESSI*)

MEIKE KÖHLER[1,2], DAISUKE KOYABU[3], BLANCA MONCUNILL[2], GUILLEM ORLANDI OLIVERAS[1], AND XAVIER JORDANA[1]

[1]*Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
[2]*ICREA at Institut Català de Paleontologia Miquel Crusafont (ICP), Bellaterra, 08193, Spain*
meike.kohler@icp.cat
[3]*The University Museum, The University of Tokyo, Tokyo, 113-0033, Japan*

The peculiar and highly endangered Amami rabbit is endemic to Amami-Ohshima Island (712 km2) and Tokuno-Shima Island (248 km2) in the Nansei Archipelago (southern Japan), 500 km isolated from the mainland of Japan. It exhibits a series of postcranial traits typical for endemic insular mammals, such as short legs, stout feet and hands, and a strongly curved vertebral column. Cranial adaptations are the small eyes, short ears, low and flat skull, and the frequent lack of M/3. Nevertheless, life history and demographic traits, key to successful conservation, are surprisingly poorly known. One to two altricial neonates of approximately 100g are born per year and weaned around 3-4 months, indicating a shift towards a slow life history.

We performed bone histology on an ontogenetic series of *Pentalagus* femora. The overall growth pattern is comparable with that of continental *Lepus* and *Oryctolagus* in showing predominantly longitudinal vascularization, and radial growth along muscle insertions. Nevertheless, *Pentalagus'* bone tissue is outstanding in that osteocytes are very sparsely distributed over the cortex in comparison with the pattern found in *Lepus* and, especially, in *Oryctolagus* where osteocytes are extremely closely packed, indicating a markedly slower growth rate in *Pentalagus*. We will interpret this slow growth rate in the context of life history evolution under conditions of insularity, with special emphasis on the correlation between life history traits and brain size, which exhibit a positive scaling pattern in mammals from mainland ecosystems.

PERIOSTEAL BONE HISTOLOGY AND DEPOSITIONAL RATES IN *CROCODYLUS NILOTICUS*

VIDUSHI PREMA DABEE[1] AND ANUSUYA CHINSAMY[1]

[1]*University of Cape Town, Department of Biological Sciences, Cape Town, 7701, South Africa*
vidushette@gmail.com

According to Amprino, there is a direct relationship between the type of bone microstructure and the rate at which bone is deposited. Here, our preliminary findings on the long bone microanatomy, histology and depositional rates of the Nile crocodile (*Crocodylus niloticus*) are presented.

The study material comprised of four juvenile crocodiles (two males and two females) that were injected intraperitoneally with three fluorochrome stains (two Engemycin and one Alizarin Red solutions) at specific intervals. The aim of the research was to examine the bone depositional rates within different bones of each individual, as well as among the different individuals. A total of 80 bones (including both sagittal planes of skeletal elements) were analyzed in this study. Using the fluorescent labelling, we examined the nature of the bone histology and the bone depositional rate in the fore-limb bones (humerus, radius, ulna, 1st metacarpal), the hind limb bones (femur, tibia, fibula, 1st metatarsal) and thoracic ribs (4th and 10th thoracic ribs). Bone depositional rates will be quantified using confocal microscopy, *NIS Elements* and multivariate analysis.

Preliminary histological findings show that the bone histology of *Crocodylus niloticus* comprises of a lamellar-zonal type of bone. During the favourable growing season, the bone tissue comprises of a more woven bone to parallel-fibered bone with many simple vascular channels, whereas during the unfavourable season, a lamellar type of bone tissue without any vascular channels occurs. Variation in bone depositional rates in different skeletal elements and among the individuals will be presented.

QUANTITATIVE ASSESSMENT OF SECONDARY OSTEON SIZE AND SHAPE VARIABILITY IN AMNIOTES

JESSICA MITCHELL[1]

[1]*Steinmann-Institut für Mineralogie, Geologie und Paläontologie, Universität Bonn, Bonn, 53115, Germany*
jessica.mitchell@uni-bonn.de

Haversian bone is a common secondary tissue type in many vertebrates. Because humans heavily remodel their bones, it is well studied for our species. But relatively very little has been done understanding the variability in Haversian tissue among other amniotes, particularly with extinct and extant amniotes. The overall research aim is to explore the morphometric nature of Haversian bone in several taxa by assessing the inter- and intraspecific variability of secondary osteons and then determining whether there is an ecological (aquatic versus terrestrial adaptation), phylogenetic, physiological or biomechanical signal. Here I examine the morphology of secondary osteons in long bones and ribs of approximately 50 species with different lifestyle adaptations from Mammalia, Aves, Dinosauria and Sauropterygia. The size and shape of secondary osteons are measured and analyzed to see whether there are significant differences between species. Initial observations show that certain species have higher variability or larger secondary osteons than others, as shown by the extinct xenarthrans, *Thalassocnus*, the semiaquatic giant sloth, and *Megatherium*, the giant ground sloth, which have significantly larger secondary osteons than modern arboreal sloths (*Bradypus* and *Choloepus*), as well as secondary osteons that are more irregularly shaped. These differences may be related to lifestyle adaptations or phylogenetics. Further analysis will provide insights into the formation of Haversian tissue across these and other taxa, and a more comprehensive understanding of this pervasive bone tissue will be gained.

THE EVOLUTION OF RAPID GROWTH IN ORNITHOTHORACES

JINGMAI O'CONNOR[1] AND JESSIE ATTERHOLT[2]

[1] *Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China*
jingmai.oconnor@gmail.com
[2] *Department of Integrative Biology, Museum of Vertebrate Zoology, Museum of Paleontology, University of California, Berkeley, USA*

Neornithes, the clade that includes all living birds, is nested within Ornithuromorpha, sister-taxon to Enantiornithes (Aves: Ornithothoraces), the dominant clade of Cretaceous birds. Both lineages first appear in the Early Cretaceous fossil record. Members of Ornithurae, the derived ornithuromorph clade that includes the common ancestor of *Ichthyornis* and living birds and all their descendants, have essentially modern bone microstructure. However, all other sampled non-ornithurine ornithuromorphs retain lines of arrested growth (LAG) (the Late Cretaceous *Patagopteryx* and *Hollanda*). We report on the first histological samples from an ornithuromorph from the prolific Jehol Biota; the holotype of *Iteravis huchzermeyeri* from the 128 Ma Yixian Formation is one of the oldest known taxa. Surprisingly, the specimens revealed rapidly formed bone with no LAGs similar to Ichthyornis. This indicates that the modern avian style of rapid growth appeared early in ornithuromorph evolution but that some basal lineages retained slow growth. Until now all histologically sampled adult enantiornithines preserve LAGs including recently sampled Jehol enantiornithines. However, samples from a Late Cretaceous enantiornithine from North America reveal rapidly formed bone with tightly packed rest lines forming an outer circumferential layer (OCL), similar to the Early Cretaceous basal pygostylian, *Confuciusornis*. These new data reveal that growth strategies were diverse between and within clades of Cretaceous birds and that rapid growth evolved at least three times during avian evolution.

BIRTH OF THE DINOSAURS – EXHIBITION ON EGG AND EMBRYO FOSSILS FROM CHINA

XIE JUNFANG[1], LI YUNLONG[2] AND JIN XINGSHENG[1]

[1] *Zhejiang Museum of Natural History, Hangzhou, 310014, China*
xjuner81@163.com
[2] *National Museum of Natural Science, Taichung, 40453, Taiwan*

"Birth of the Dinosaur" exhibitions feature amazing collections of dinosaur eggs, nests, embryos and young discovered from China. This is the first time that dinosaur egg fossils have been systematically assembled into an exhibition. Topics include rocks and fossils, taxonomic research, dinosaur egg fossil fakes, ongoing research into unique dinosaur egg fossil finds, dinosaur growth and development, and new information from past finds. 138 fossil specimens are on view, and many rare and unusual fossil specimens will stimulate the imagination. For example, egg fossils from different dinosaur species have found in the same clutch, two clutches of different species have been discovered together, dinosaur bone fossils have been found in close proximity to dinosaur egg fossils, Oviraptorosaur fossil with one egg inside and one egg outside the pelvic cavity. These discoveries are providing the clues that allow scientists to unlock the mysteries of dinosaur reproductive and social behavior.