



SVPCA and SPPC 2016  
Liverpool

Abstract Book



## ACKNOWLEDGEMENTS

The organizers would like to thank our generous sponsors—The Palaeontological Association and The Company of Biologists, for their support of these meetings, as well as Frontiers in Earth Sciences for providing prizes.

We also wish to extend thanks to Richard Forrest for running the SVPCA website and handling abstract submissions, as well as for providing advice on running the conference. Similarly, thanks go to last years organizers for their advice.

## LOGO

This year's logo depicts two Liver Birds, mythical birds associated with the city of Liverpool. The story goes that one bird looks out to sea, and the other looks back over the city, keeping an eye on the sailors wives/pubs depending on which version of the story you read. And so they sit in the logo, facing outward either side of the word 'Liverpool.'

## HOST COMMITTEE

Peter L. Falkingham (Liverpool John Moores University)  
Karl T. Bates (University of Liverpool)  
Ariel L. Camp (Brown University)  
Ryan D. Marek (University of Liverpool)  
Sophie Macaulay (University of Liverpool)  
Pernille Troelsen (Liverpool John Moores University)

## ADDITIONAL HELPERS:

Lewis Finch (Liverpool John Moores University)  
Owen Fielding (Liverpool John Moores University)

## CONFERENCE APP

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# SCHEDULE OF EVENTS

## MONDAY 22<sup>ND</sup> AUGUST (SPPC)

- 09:00 - 09:30 SPPC registration open
- 09:30 - 09:40 Welcome and Opening Remarks
- 09:40 - 10:00 PSYCHO KNIVES AND WITHERS WEDGES—EXCAVATING A PLESIOSAUR  
*Richard Forrest*
- 10:00 - 10:20 MOULDING, CASTING AND LASER SCANNING OF DINOSAUR TRACKWAYS  
FROM THE LATE CRETACEOUS OF SOUTHERN ALBERTA, CANADA  
*Donald Henderson*
- 10:20 - 10:40 PART SEEN, PART REMEMBERED: THE PREPARATION, CONSERVATION  
AND CURATORIAL CHALLENGES OF VIRTUALLY RAISING LEVIATHAN  
*Jeff Liston and Glenys Wass*
- 10:40 - 11:20 **Coffee**
- 11:20 - 11:40 PREPARATION OF VERTEBRATE FOSSILS FROM THE MIOCENE CLAYPIT IN  
GRAM, DENMARK  
*Frank Osbæck*
- 11:40 - 12:00 A DOCUMENTATION MYSTIFICATION  
*Emma-Loiuse Nicholls and Joanne Hatton*
- 12:00 - 12:15 LIGHTNING TALKS  
*Poster presenters*
- 12:15 - 12:40 POSTER SESSION
- 12:40 - 14:00 **Lunch**
- 14:00 - 16:00 Tour of the Liverpool World Museum Collections (SPPC Fieldtrip)
- 19:00 - 22:00 Ice Breaker event at the Liverpool World Museum

# TUESDAY 23<sup>RD</sup> AUGUST (SVPCA)

- 08:45 - Registration open
- 09:15 - 09:20 Welcome and Opening Remarks
- 09:20 - 09:40 A NEW LOOK AT RADOTINA - A UNIQUE DIVERSITY OF BASAL GNATHOSTOMES IN THE EARLY DEVONIAN OF THE PRAGUE BASIN  
*Valeria Vaskaninova and Per E. Ahlberg*
- 09:40 - 10:00 BAYESIAN MORPHOLOGICAL CLOCKS AND THE PHYLOGENY OF EARLY GNATHOSTOMES (JAWED VERTEBRATES)  
*Benedict King et al.*
- 10:00 - 10:20 THE DIVERSE DENTITION OF EARLY CARBONIFEROUS LUNGFISH: AN ADAPTIVE RESPONSE TO THE END-DEVONIAN EXTINCTION?  
*Tim Smithson et al.*
- 10:20 - 10:40 PHYLOGENETIC RELATIONSHIPS OF THE 'HIGHER HETEROSTRACANS'  
*Emma Randle and Robert Sansom*
- 10:40 - 11:20 **Coffee**
- 11:20 - 11:40 ARCHES AND ACTINOPTS: HYOID BAR COMPOSITION NEAR THE BASE OF THE RAY-FIN TREE  
*Michael Coates et al.*
- 11:40 - 12:00 PHYLOGENETIC ANALYSIS IMPLIES EARLY DIVERSIFICATION OF TETRAPODS IN THE TOURNAISIAN  
*Jennifer Clack et al.*
- 12:00 - 12:20 SELECTION TOWARDS LARGER BODY SIZE IN BOTH HERBIVOROUS AND CARNIVOROUS SYNAPSIDS DURING THE CARBONIFEROUS  
*Neil Brocklehurst and Kirstin Brink*
- 12:20 - 12:40 RE-EVALUATION OF *PHOLIDOSA URUS PURBECKENSIS* (CROCODYLIFORMES: TETHYSUCHIA) FROM THE EARLY CRETACEOUS OF ENGLAND, WITH IMPLICATIONS FOR THE EVOLUTION OF PHOLIDOSAURIDAE AND DYROSAURIDAE  
*Thomas Smith et al.*
- 12:40 - 14:00 **Lunch**
- 14:00 - 14:20 HISTORICAL CLASSIFICATIONS AS A TEST OF BIOLOGICAL EVOLUTION  
*Robert Asher*
- 14:20 - 14:40 CONTROLLING FOR THE SPECIES-AREA EFFECT REMOVES LONG-TERM DIVERSITY TRENDS IN MESOZOIC TERRESTRIAL VERTEBRATES  
*Richard Butler et al.*
- 14:40 - 15:00 SEA LEVEL REGULATED TETRAPOD DIVERSITY THROUGH THE JURASSIC/CRETACEOUS TRANSITION  
*Jonathon Tennant et al.*
- 15:00 - 15:40 **Coffee**
- 15:40 - 16:00 DIVERSITY OF CHONDRICHTHYAN SKIN DENTICLES AND THE ORIGINS OF VERTEBRATE DENTITIONS  
*Zerina Johanson et al.*

- 16:00 - 16:20 PATTERNS IN THE PALAEOECOLOGY OF MODERN AND CRETACEOUS CHONDRICHTHYAN FAUNAS  
*Emma-Louise Nicholls*
- 16:20 - 16:40 LEVIATHAN RISING: THE SHARK OF PUBLIC SECTOR DEADLINES BITING THE BLEEDING EDGE OF RESEARCH  
*Jeff Liston*
- 16:40 - 17:00 BIOGEOGRAPHIC AND PHYLOGENETIC IMPLICATIONS OF THE GIANT MADTSOIID SNAKE *GIGANTOPHIS GARSTINI* FROM THE EOCENE OF NORTH AFRICA  
*Jonathan Rio et al.*
- 17:00 - 18:00 PALAEOONTOLOGY & THE REF  
*An open forum, chaired by Dave Unwin*

## WEDNESDAY 24<sup>TH</sup> AUGUST (SVPCA)

- 09:00 - 09:20 THERIAN MAMMALS EXPERIENCE AN ECOMORPHOLOGICAL RADIATION DURING THE LATE CRETACEOUS AND SELECTIVE EXTINCTION AT THE K-PG BOUNDARY  
*David Grossnickle and Elis Newham*
- 09:20 - 09:40 SIZE ISN'T EVERYTHING: RE-EXAMINING STEREOGNATHUS HEBRIDICUS (TRITYLODONTIDAE, SYNAPSIDA) FROM THE MIDDLE JURASSIC OF SKYE, SCOTLAND  
*Elsa Pancirioli et al.*
- 09:40 - 10:00 WHAT, IF ANYTHING, IS A POLYDOLOPIMORPHIAN? RESOLVING THE AFFINITIES OF A MAMMALIAN MOUTHFUL  
*Robin Beck*
- 10:00 - 10:20 AN ASSOCIATED NOTOUNGULATE SKELETON FROM PATAGONIA: POSTCRANIAL OSTEOLOGY AND BODY SIZE OF *THOMASHUXLEYA EXTERNA* (MAMMALIA, NOTOUNGULATA)  
*Juan David Carrillo et al.*
- 10:20 - 10:40 FIRST *IN SITU* EVIDENCE OF REPLACEMENT OF THE MULTITUBERCULATE I2, AND NEW DATA ON MULTITUBERCULATE DENTAL DEVELOPMENT  
*Ian Corfe et al.*
- 10:40 - 11:20 **Coffee**
- 11:20 - 11:40 RESOLVING THE DIETS OF PTEROSAURS: SHIFTING FROM QUALITATIVE INFERENCES TO QUANTITATIVE METHODOLOGIES VIA 3D TEXTURAL ANALYSIS OF TOOTH MICROWEAR  
*Jordan Bestwick et al.*
- 11:40 - 12:00 LATE MAASTRICHTIAN PTEROSAURS FROM THE TETHYS SEAWAY PROVIDE EVIDENCE FOR MASS EXTINCTION OF PTEROSAURS AT THE CRETACEOUS-PALEOGENE BOUNDARY  
*Nicholas Longrich et al.*
- 12:00 - 12:20 A SMALL BODIED, NON-JUVENILE AZHDARCHOID PTEROSAUR FROM THE AGE OF FLYING GIANTS  
*Mark Witton et al.*

- 12:20 - 12:40 GROWTH RATES AND LONGEVITY IN PTEROSAURS  
*Dave Unwin and Charles Deeming*
- 12:40 - 14:00 **Lunch**
- 14:00 - 15:20 LIGHTNING TALKS  
*Poster presenters*
- 15:20 - 17:00 **Coffee** followed by POSTER SESSION
- 19:00 - 22:00 ANNUAL AUCTION (THE CHAPEL, FORESIGHT CENTRE)  
In Aid of the Jones-Fenleigh Fund

## THURSDAY 25<sup>TH</sup> AUGUST

- 09:00 - 09:20 HOW BIG DID *BAROSAURUS* GET?  
*Mike Taylor and Matt Wedel*
- 09:20 - 09:40 NEW DATA SHEDS LIGHT ON TITANOSAURIFORM SAUROPOD DINOSAUR EVOLUTIONARY HISTORY  
*Philip Mannion et al.*
- 09:40 - 10:00 ENVIRONMENTAL PARTITIONING AND DIFFERENTIAL GROWTH IN SPECIES OF THE THYREOPHORAN DINOSAUR *STEGOSAURUS* IN THE UPPER JURASSIC MORRISON FORMATION, USA  
*Susannah Maidment et al.*
- 10:00 - 10:20 THE DYNAMICS OF ORNITHOPOD DENTAL EVOLUTION  
*Edward Strickson et al.*
- 10:20 - 10:40 CAMOUFLAGE PATTERNS IN AN ORNITHISCHIAN DINOSAUR AND RECONSTRUCTING THE HABITAT IT LIVED IN  
*Jakob Vinther et al.*
- 10:40 - 11:20 **Coffee**
- 11:20 - 11:40 TESTING THE BUOYANCY OF AN IMMERSED *SPINOSAURUS* (DINOSAURIA: THEROPODA) WITH A DIGITAL MODEL  
*Donald Henderson*
- 11:40 - 12:00 EXPLORING INTEGUMENT MASS PROPERTIES IN EXTANT ARCHOSAURS AND IMPLICATIONS FOR DIGITAL VOLUMETRIC MODELLING OF CENTRE OF MASS  
*Sophie Macaulay et al.*
- 12:00 - 12:20 INTRASKELETAL HISTO-VARIABILITY AND ITS ONTOGENETIC IMPLICATIONS IN THE LIMB BONES OF 'DINOBIRDS'  
*Edina Prondvai et al.*
- 12:20 - 12:40 THE RELATIONSHIP BETWEEN MAXIMUM CORTICAL BONE THICKNESS AND MAXIMUM CURVATURE OF METATARSAL BONES IN *PAN* AND *HOMO* AND ITS FUNCTIONAL RELATIONSHIP TO LOCOMOTION  
*Juliet McClymont et al.*
- 12:40 - 14:00 **Lunch**
- 14:00 - 14:20 EVOLUTIONARY TRENDS IN ICHTHYOSAURS: POST-TRIASSIC 'STAGNATION'?  
*Benjamin Moon*

- 14:20 - 14:40 A TALE OF TWO SPECIES: *ICHTHYOSAURUS COMMUNIS* AND  
*I. INTERMEDIUS*  
*Judy Massare and Dean Lomax*
- 14:40 - 15:00 TO CATCH A KIPPER: REASSESSMENT OF AN EARLY JURASSIC  
RHOMALEOSAURID PLESIOSAURIAN  
*Mark Evans and Adam Smith*
- 15:00 - 15:40 **Coffee**
- 15:40 - 16:00 ROLE OF AXIAL MUSCLES IN POWERING SUCTION FEEDING IN  
LARGEMOUTH BASS (*MICROPTERUS SALMOIDES*)  
*Ariel L. Camp et al.*
- 16:00 - 16:20 SCALING AND ACCOMMODATION OF JAW ADDUCTOR MUSCLES IN  
CANIDAE  
*Fey Penrose et al.*
- 16:20 - 16:40 PHYSIOLOGICAL CHALLENGES OF MULTI-METER NEURONS IN LARGE  
VERTEBRATES  
*Matt Wedel et al.*
- 16:40 - 17:00 THE NATURE AND MAGNITUDE OF VARIABILITY IN PLANTAR PRESSURE  
DURING HUMAN WALKING  
*Juliet McClymont et al.*
- 18:30 - 22:00 Annual Dinner (Victoria Gallery and Museum)

## FRIDAY 26<sup>TH</sup> AUGUST

- 09:00 – 17:00 FIELD TRIP TO CHESTER ZOO.

# SPPC ABSTRACTS

## TALKS

### **PSYCHO KNIVES AND WITHERS WEDGES - EXCAVATING A PLESIOSAUR**

**Richard Forrest**

*Plesiosaur.com*

The fossil of a juvenile *Cryptoclidus* was found by Darren Withers on a field trip to Must Farm Quarry organised by the Peterborough Museum on Saturday 25th June 2016. The excavation of the specimen had to be organised at short notice because of the risk of unauthorised collectors looting the site, and time constraints because of its location in a working pit. A detailed plan of action was drawn up with Peterborough Museum, and agreed by Fortera, the brick-making company who own the pit. The excavation was carried out over three days, from Wednesday 29th to Friday 1st July. It is in the nature of any such excavation that some data is lost, and careful records need to be made to reduce this. The approach usually adopted in such excavations is to trace the outline of individual bones on a plastic sheet laid over the area. This failed because the first full day of excavation was carried out in steady rain, and it was impossible to trace outlines on wet plastic. Photogrammetry was used to record the excavation area at various stages of excavation, which provides a scalable 3-D model of the disposition of the bones. In addition, photographs were taken of each element in situ with a marker tile recording a unique number and recorded in a log book. This has proved to be very successful. The specimen is now in Peterborough Museum where volunteers are cleaning and conserving the material.

### **MOULDING, CASTING AND LASER SCANNING OF DINOSAUR TRACKWAYS FROM THE LATE CRETACEOUS OF SOUTHERN ALBERTA, CANADA**

**Donald Henderson**

*Royal Tyrrell Museum of Palaeontology*

During the summer of 2015 latex peels were made in the field to record exceptional sets of dinosaur footprints from the Late Cretaceous St. Mary River Formation in southwestern Alberta. The peels were done to avoid the logistical nightmare of trying to recover the multi-tonne sandstone blocks that hosted the trackways from the bottom of high, steep river banks. With the peels successfully returned to the Museum we were able to make thin, strong casts of the peels to form a permanent record for housing in the Museum collections and for potential future exhibits. Very broad (2m wide, 3-4m long), but shallow (8cm deep) boxes were constructed from plywood and 2x4s for each of the peels. The dimensions of the boxes were such that the peel was able to lie perfectly flat, with only a small margin extending beyond their perimeters. As the peels were made on irregular, non-planar rock surfaces, a layer of sand was placed in the bottom of a box to provide continuous and easily adjustable support of the latex sheet to prevent it warping when the moulding materials were applied. Aqua resin was used to make the actual cast of the tracks, while fibreglass reinforced plaster was used as a rather dense, but very strong, backing, so only a thin layer would be required. Given the very shallow, eroded nature of many of the tracks, laser-scanning of the trackway casts was done to produce digital elevation models to possibly aid visualization, but with mixed results.

## **PART SEEN, PART REMEMBERED: THE PREPARATION, CONSERVATION AND CURATORIAL CHALLENGES OF VIRTUALLY RAISING LEVIATHAN**

**Jeff Liston**<sup>1,2</sup> and Glenys Wass<sup>2</sup>

*1 - National Museums Scotland*

*2 - Peterborough Museum & Art Gallery*

Over field seasons 2002 and 2003, the most complete specimen of the Middle Jurassic suspension-feeding fish *Leedsichthys* was excavated from the Star Pit, just outside Whittlesey, Peterborough. Over 100 days of excavation involving over 3,100 staff hours extracted over 2,300 parts, making it the longest dig for a single vertebrate specimen in Europe. The specimen was registered and deposited at Peterborough Museum and Art Gallery, and over the ensuing years over 11,750 hours of preparation time was applied to it by Alan Dawn and his team of volunteers in the palaeo lab. Specimens ranged in scale from gigantic plaster jacket slabs 1-2 metres in length, to 7x10cm ziplock bags of fragments. In between there were tissue-wrapped slabs of the excavation surface (taken from the field for time efficiency reasons), and bags bulging with individual gill rakers. Many of these specimens were prepared over this time, the clay prepared away, Paraloid B72 anointing the fragments to heal the fractures, and fibreglass jackets made to support these most fragile yet long bones.

Preparation work was only interrupted from 2010-2012 for the closure of the museum for a full redisplay. In July 2015, the Esmée Fairbairn Collections Fund (via the Museums Association) awarded a £65K grant to Vivacity-Peterborough to provide full curation of the specimen with a 'virtual display'. This was a key consideration: with new displays, there was no physical space to add a full display of this specimen – even if the building had had a gallery large enough to do so.

### **A DOCUMENTATION MYSTIFICATION**

**Emma-Louise Nicholls** and Joanne Hatton

*Horniman Museum and Gardens*

The Horniman Museum's Study Collections Centre houses the fossil collection of Walter Bennett, an early to mid-20th Century geologist, who collected much of the material himself. The collection was acquired from the Croydon Natural History and Scientific Society in the 1980s, and comprises approximately 175,000 specimens housed in 57 wooden cabinets. Whilst much of the fossil material was found in the UK, more prominent sites are also represented such as the Solnhofen limestone and the Burgess Shale. Its composition is around  $\frac{1}{4}$  vertebrate and  $\frac{3}{4}$  invertebrate, with fish, molluscs, and coral being well represented. The collection has been recognised as an important one that needs to be properly documented. The collection arrived with stratigraphy and locality, but varying levels of taxonomic identification. No numbering system existed however. In the 1990s a documentation project resulted in improved identifications and several folders of A4 hand written records, later transferred onto a database. To complicate matters further, accession numbers were allocated to these electronic records but not the specimens. Most recently a volunteer has spent five herculean years going through each drawer making an inventory of its contents on a spreadsheet. As the new Deputy Keeper of Natural History I am tasked with collating data from each of these four sources and numbering the specimens with unique numbers to tie the data together on the collections management database to make it accessible. With further complications yet to be explained, advice on the most efficient way of going about this would be welcome.

## **PREPARATION OF VERTEBRATE FOSSILS FROM THE MIOCENE CLAYPIT IN GRAM DENMARK**

**Frank Osbæck**

*Museum Sønderjylland*

The clay pit in Gram is of Upper Miocene age and is mostly known for its whale fossils. Besides a large invertebrate fauna it offers a rich insight into the Miocene vertebrate fauna with sharks, birds, tortoises, seals and Whales. During the last couple of months I have been working on a Stingray barb section, two bird “bones” and a tooth whale lower jaw which will be scientifically described when the preparation has been finished. The preparation of the fossils are mostly quite straightforward scalpel and dental tool work, as the dried clay is relatively easily cut but extremely fragmented. The basic problem is the pyrite, both in the clay prone to pyrite decay but also the pyrite encrusting the fossils themselves. On the dried clay water is not an option, so mechanical removal with the help of Acetone and Paraloyd B72 is used. The bones are partly perfectly preserved, smooth and fine, partly a grainy mess which tends to disintegrate if you just “look” at it. All together, business as usual.

I hope to give a little insight into the world of preparing Miocene fossils, seen through the eye of the Preparator (and his camera).

# SPPC ABSTRACTS

## POSTERS

### **A TON OF TROUBLE: CLEANING, CONSERVING AND MOUNTING A LARGE 300 MILLION -YEAR OLD GIANT CLUBMOSS PLANT FOSSIL FROM NORTH WALES FOR DISPLAY.**

**Nigel R. Larkin<sup>1</sup>** and Caroline Buttler<sup>2</sup>

1 - *Cambridge University Museum of Zoology*

2 - *National Museum Wales*

In 2004 a large and exceptionally well preserved Late Carboniferous giant clubmoss comprising a tall trunk and broad *Stigmaria* root structure was discovered in a newly exposed fossil forest site in an old steel works at Brymbo near Wrexham, North Wales. Cleaning, conserving and safely mounting the whole fossil for exhibition in 2016 was not easy as the specimen was in 90 pieces, weighed almost a ton and stood 2.25 m tall with a root span of 3.5 m. Also, as the specimen was to be displayed in various locations over time and would have to be dismantled and transported, a modular mount able to be easily assembled and disassembled was required. The mount was made in sections from welded steel lined with Plastazote foam, with robust lockable wheels underneath the main trunk. As the two uppermost sections of the trunk weighed approximately a quarter of a ton each, to reduce risk to the specimen and to people undertaking the mounting they were moulded and painted casts were mounted in their place. Large Carboniferous *Stigmaria* root systems associated with trunks are rare and few are on display. This specimen has proved to be a popular exhibit in Wrexham. The mounting system is strong but not too intrusive. The brackets supporting the roots have the appearance of rootlets that would have existed in life. It is fitting that the structure is created from steel, the material made for over a century on the heritage site where the fossil was discovered.

### **THE DISCOVERY IN A MUSEUM COLLECTION OF THE LARGEST KNOWN SKELETON OF *ICTHYOSAURUS* IN THE WORLD AND ITS RE-DISPLAY, INCLUDING 3D-PRINTING MISSING BONES.**

**Nigel R. Larkin<sup>1</sup>**, Dean R. Lomax<sup>2</sup>, Luanne Meehitiya<sup>3</sup> and Steven Dey<sup>4</sup>

1 - *Cambridge University Museum of Zoology*

2 - *The University of Manchester*

3 - *Thinktank Science Museum*

4 - *ThinkSee3D Ltd*

In 1955, a partial ichthyosaur skeleton was excavated from Lower Jurassic deposits in Warwickshire. Unusually for Lower Jurassic specimens, the skull bones largely retained their three-dimensional integrity and the skull was mounted for display at Birmingham Museum & Art Gallery. A recent conservation project to dismantle the skull and rebuild it more accurately involved micro-CT scanning some of the skull elements, mirroring the data, and printing accurate 3D models to replace carved pieces of wood that previously represented missing elements on one side of the skull. This process digitally recorded the bones for future research before replacing them within the skull. Whilst investigating the history of the specimen and looking for missing pieces the postcranial material, which was separated from the skull a long time ago, was rediscovered. Research revealed that this specimen can be identified as an *Ichthyosaurus*. With an estimated lower jaw length of 87 cm it is the largest example of the genus so far recorded. Therefore the entire skeleton was cleaned and conserved for display. To help visitors to understand the skeleton, missing portions of the postcranial skeleton were recreated. The left forelimb and pectoral girdle bones were CT scanned, the data mirrored, and the bones for the right side 3D-printed. The same process was undertaken for missing portions of the rear limbs. Missing vertebrae were represented by casts of adjacent vertebrae. The skeleton is now the centerpiece of the new permanent Marine Worlds gallery at Thinktank, including an interactive focused on the conservation.

# **JOURNAL OF PALEONTOLOGICAL TECHNIQUES: A FREE, OPEN ACCESS JOURNAL EXCHANGING KNOWLEDGE BETWEEN TECHNICIANS, PREPARATORS AND RESEARCHERS**

Emanuel Tschopp<sup>1,2,3</sup> & Femke Holwerda<sup>2,3,4</sup>

*1 - Università di Torino*

*2 - Universidade Nova de Lisboa*

*3 - Museu da Lourinhã*

*4 - Bayerische Staatssammlung für Paläontologie und Geologie*

The Journal of Paleontological Techniques (JPT) was established in 2006 in the Museu da Lourinhã (ML), Portugal, as a means to provide a platform for preparators of the ML to share ideas and knowledge with their peers. After this, it grew to be an open access, free journal, publishing mostly on the collecting, preparation, conservation, and exhibition of natural history objects, such as holotypes of extant species, fossils, and historical museum specimens. These natural history objects provide a wealth of information on past and present biodiversity. Because collection and/or conservation techniques might alter the objects in ways that could negatively influence the outcomes of future research, a detailed report of the methodologies used from acquisition to conservation of specimens is crucial. Despite the importance of such reports, until recently, no specific scientific publications existed for museum technicians and scientists to share knowledge between each other.

The Journal of Paleontological Techniques publishes a wide variety of articles, ranging from excavation reports and papers on preparation techniques to new methodologies in collection management and scientific study, among others. Manuscripts are subjected to peer-review to ensure scientific standards. Papers are published as single-paper volumes upon final approval of the proofs, and are available as .pdf under a CC-BY license.

The editorial board currently consists of an international group of early-stage scientists. Most editors have a palaeontological background, however, all have a unique expertise within that field (e.g. microscopy, photogrammetry, phylogeny, morphometrics, preparation, and microbiology). JPT welcomes your submissions!

# SVPCA ABSTRACTS

## TALKS

### HISTORICAL CLASSIFICATIONS AS A TEST OF BIOLOGICAL EVOLUTION

**Robert Asher**

*University of Cambridge*

For millennia, taxonomists have tried to make sense out of the world by visually and verbally organizing it. Pre-evolutionary thinkers have often suggested an affinity of humans to other mammals, among other relationships expressed in their taxonomies. The availability of a well-corroborated tree for living mammals enables me to ask if past authors succeeded in creating accurate taxonomies, and if specific methodological and theoretical advances (e.g., the recognition of evolution via descent with modification) are associated with improved taxonomies. They are. I find that different methods used over past centuries for building taxonomies (including pre-evolutionary, evolutionary, cladistic, and molecular) improves on its predecessor, although at varying rates and levels of significance. The French naturalist H.M.D. DeBlainville was an outlier among pre-evolutionary authors and produced substantially more accurate taxonomies than his contemporaries. Evolutionary authors constructed significantly more accurate taxonomies than their predecessors, and began at a higher level of accuracy than would be expected based on previously observed improvement over time. Cladistic methods show improvement at a greater rate than previous methods, but do not start at a level greater than expected based on improvement evident among pre-cladistic authors. Authors using molecular data, including datasets independent of the nuclear DNA key for recognizing the currently well-corroborated tree, began with levels of accuracy similar to those applying cladistic methods to morphology, but thereafter showed the greatest improvement in the shortest amount of time. All evolutionary methods (including cladistic and molecular) significantly outperform pre-evolutionary methods in recognizing well-corroborated mammalian groups.

### WHAT, IF ANYTHING, IS A POLYDOLOPIMORPHIAN? RESOLVING THE AFFINITIES OF A MAMMALIAN MOUTHFUL

**Robin Beck**

*University of Salford*

Polydolopimorphia is a diverse, extinct order within the mammalian clade Marsupialiformes (marsupials and their close fossil relatives). More than 50 species have been described, most known only from teeth and partial jaws. Most polydolopimorphians are from the Cenozoic of South America, but they are also known from the middle Eocene of Antarctica, and there are more questionable records from the Late Cretaceous of North America and Cenozoic of Australia. Early authors linked Polydolopimorphia with the South American marsupial order Paucituberculata (which includes the living “shrew opossums”), but more recently it has been suggested that it is closely related to the Australian diprotodontians (possums, koalas, wombats, kangaroos etc.), which would have important implications for the biogeography of Southern hemisphere mammals. *Epidolops ameghinoi* from the Eocene Itaborai fauna of Brazil is one of the few early Palaeogene polydolopimorphians known from a relatively complete skull, but this highly significant specimen has never been adequately described until now. Overall, the cranium of *Epidolops* is surprisingly plesiomorphic, with small palatal openings, a simple glenoid region and probably also an unossified floor of the middle ear. Isolated petrosal and tarsal bones can also be tentatively referred to *Epidolops*. Based on this collective material, there are no convincing apomorphies linking *Epidolops* with either Paucituberculata or Diprotodontia; in fact, it probably falls outside crown-clade Marsupialia. The Oligocene-Pliocene argyrolagids are currently also considered members of Polydolopimorphia, but they differ markedly from *Epidolops* and share several apomorphies with paucituberculatans. Phylogenetic analysis indicates that Polydolopimorphia, as currently recognised, is polyphyletic.

## **RESOLVING THE DIETS OF PTEROSAURS: SHIFTING FROM QUALITATIVE INFERENCES TO QUANTITATIVE METHODOLOGIES VIA 3D TEXTURAL ANALYSIS OF TOOTH MICROWEAR**

**Jordan Bestwick<sup>1</sup>, Richard Butler<sup>2</sup>, Donald Henderson<sup>3</sup>, Mark Purnell<sup>1</sup> and David Unwin<sup>1</sup>**

*1 - University of Leicester*

*2 - University of Birmingham*

*3 - Royal Tyrrell Museum*

Pterosaurs were a highly successful group of Mesozoic flying reptiles. For 150 million years they were integral components of continental and marginal marine ecosystems, yet their feeding ecology remains poorly constrained. The range of postulated pterosaur diets includes, but is not exclusive to, insectivory, piscivory and/or carnivory. A review of 120 published studies found that approximately 90% (N = 296) of all pterosaur dietary hypotheses were based on qualitative morphological assessments and fortuitous associations, including gut/throat content fossils and contemporaneous taxa. Many of these hypotheses are based on little data and/or speculations, highlighting the need for alternative approaches to provide more robust data for analysis. One such method involves quantitative analysis of the 3D micron scale textures of worn pterosaur tooth surfaces — dental microwear texture analysis. Microwear is produced as scratches and chips generated by hard food items combine to create characteristic surface textures on tooth surfaces. Microwear analysis has never been applied to pterosaurs, but we might expect microwear textures to differ between pterosaurs with different diets. An important step in investigating pterosaur microwear is to examine microwear textures of extant organisms with known diets to provide a comparative data set. This has been achieved through analysis of non-occlusal microwear textures in extant bats and crocodylians, clades within which species exhibit insectivorous, piscivorous and carnivorous diets. The results - the first test of the hypothesis that non-occlusal microwear textures in these extant clades vary with diet, - provide the context for the first robust quantitative tests of pterosaur diets.

## **SELECTION TOWARDS LARGER BODY SIZE IN BOTH HERBIVOROUS AND CARNIVOROUS SYNAPSIDS DURING THE CARBONIFEROUS**

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Body size is among the most important characteristics of an organism, impacting on the evolution of a great variety of ecological characteristics. One aspect receiving considerable attention is the influence of diet on body size, with previous studies on a variety of clades suggesting a greater tendency towards increased body size in herbivores than macro-carnivores. The earliest known high fibre herbivores and macro-carnivores in the synapsid (mammal-line) amniotes provide an ideal case study for examining body-size evolution in different dietary regimes. The Sphenacomorpha contains two lineages, one (Edaphosauridae) representing some of the most abundant high-fibre herbivores in the late Carboniferous and early Permian, while the second (Sphenacodontia) includes the largest and most abundant terrestrial carnivores of that time. Phylogenetic comparative analyses are used to compare trait evolution in sphenacomorphs, including a recently proposed Bayesian method for identifying branches along which positive phenotypic selection occurred. Neither Sphenacodontia nor Edaphosauridae show a gradual trend towards larger body size. Instead, only two branches show rapid increases in body size in the Late Carboniferous. The first of these shifts occurs in Edaphosauridae, along the branch leading to the herbivorous members of this family. The later shift towards larger body size occurs in Sphenacodontia, producing a clade of large carnivores. It is possible that the rapid appearance of large herbivorous synapsids in the Carboniferous provided the selective pressure for carnivores to increase their body size. Following these two body-size shifts, rates of trait evolution in edaphosaurids slow significantly, but the carnivorous sphenacodontians show further increases.

## CONTROLLING FOR THE SPECIES-AREA EFFECT REMOVES LONG-TERM DIVERSITY TRENDS IN MESOZOIC TERRESTRIAL VERTEBRATES

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Terrestrial tetrapods are highly diverse, with more than 30,000 living species. Expansionist models of tetrapod diversification have posited exponential increases in standing diversity through the Phanerozoic. Recently, we used sample-standardisation to examine long-term diversity trajectories for Mesozoic—early Palaeogene tetrapods. Our results were not consistent with expansionist diversification, and indicated at most a doubling of non-flying tetrapod diversity during the Mesozoic, despite the initial origins of hyper-speciose modern groups among squamates and mammals. The species-area effect is one of the best-known macroecological scaling patterns, and plays an underappreciated role in biasing species richness estimates in the fossil record. We re-analysed the Mesozoic—early Palaeogene tetrapod dataset using equal-coverage subsampling (SQS) and another recent method (TRiPs). This allowed us to estimate the diversities of penecontemporaneous subsets of fossil collections representing fixed palaeogeographic spreads of 4,500 km (minimum spanning tree size). This approach ensures that spatial sampling remains constant over time and between geographic regions. This procedure has a striking effect on estimated diversity patterns, revealing an essentially flat diversity trajectory, with standing diversity almost unchanged between the start of the Late Triassic and the end of the Cretaceous. A substantial increase in diversity across the K/Pg boundary is recovered, representing an abrupt quadrupling of diversity, although this increase may at least in part be an artefact of the greater diagnosability of Cenozoic mammalian taxa. Our results provide strong evidence for bounded diversification of non-flying Mesozoic tetrapods, and suggest that equilibrium levels were reset at a higher level following the end-Cretaceous extinction.

## ROLE OF AXIAL MUSCLES IN POWERING SUCTION FEEDING IN LARGEMOUTH BASS (*MICROPTERUS SALMOIDES*)

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Many fish capture their food with suction: rapidly expanding the feeding apparatus to accelerate water and prey into the mouth. This fast and forceful feeding behavior requires a highly kinetic cranial skeletal, as well as considerable muscle power. Both cranial and axial swimming muscles are active during suction feeding and can generate mouth expansion kinematics, but the relatively small cranial muscles may simply not be able to generate enough. While the axial muscles have long been hypothesized to contribute some power to suction feeding, it has been unclear which regions of these large muscles generate power during feeding, and whether their power is essential or merely augments cranial muscle power. We measured axial muscle shortening and instantaneous mouth volume during suction feeding in largemouth bass (*Micropterus salmoides*) using fluoromicrometry and X-ray Reconstruction of Moving Morphology, respectively. Together with buccal pressure recordings, these 3D, X-ray based measurements allowed us to calculate the power required for suction expansion. We found that large regions—over half the body—of the axial muscles generated power during suction feeding, and that peak suction expansion power far exceeded the capacity of the cranial muscles. These results highlight the dual-function of axial muscles for both swimming and feeding, suggesting that both of these behaviors may have shaped their morphology and evolution.

## AN ASSOCIATED NOTOUNGULATE SKELETON FROM PATAGONIA: POSTCRANIAL OSTEOLOGY AND BODY SIZE OF *THOMASHUXLEYA EXTERNA* (MAMMALIA, NOTOUNGULATA)

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South America was isolated during most of the Cenozoic and was home to a highly endemic fauna. South American native ungulates are a conspicuous faunal element of the Cenozoic in the continent, with an extensive fossil record that spans the Early Paleocene to Late Pleistocene. Notoungulata is the major clade within SANUs and exhibits a high taxonomic diversity and large morphological disparity. The earliest notoungulates are mostly known by isolated teeth. We describe one of the oldest skeletons of a notoungulate with associated craniodental and postcranial elements: *Thomashuxleya externa* (Isotemnidae) from Cañadón Vaca in Patagonia, Argentina (Casamayoran SALMA, Vacan subage, Middle Eocene). We noted differences in the scapulae, humerii, ulnae and radii of the new specimen in comparison with other specimens referred to this taxon. We test the congruence of body size estimates given by different elements of the skeleton, and described the bone histology of this specimen. We estimated a body size of 144 kg. Bone histology reveals features with increased loading in large mammals and shows the new specimen was skeletally mature. This demonstrates that notoungulates had acquired a large body size by the Middle Eocene, and provides an unusually complete anatomical basis to study the biology and phylogenetic position of an early member of toxodont notoungulates.

## PHYLOGENETIC ANALYSIS IMPLIES EARLY DIVERSIFICATION OF TETRAPODS IN THE TOURNAISIAN

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Five new tetrapods from the Tournaisian of Scotland are sufficiently well preserved to be diagnosed and included in a cladistic analysis. Some include anatomical information available only from micro-CT scan data. At least 10 other specimens represent new taxa insufficiently complete to be included in this analysis, but are nevertheless distinct and informative. The five new tetrapods represent new species and are spread across the tetrapod stem and into the crown group, showing no close relationship to each other. They exhibit different combinations of plesiomorphic and derived characters. Some cluster with Devonian forms, suggesting a possible relict fauna, others appear more crownward, even clustering near the base of the crown group. They are evidence of an early radiation of tetrapods during the Tournaisian, implying an Early Carboniferous date for the crown group split. These new forms also suggest a blurring of the Devonian-Carboniferous (D/C) boundary in respect of tetrapod evolution, a feature also noted in tetrapod remains from Nova Scotia. The appearance of large forms about three or four My above the D/C boundary suggests rapid recovery from the extinction event, and that large size was achieved quickly rather than slowly as some recent studies have indicated.

## ARCHES AND ACTINOPTS: HYOID BAR COMPOSITION NEAR THE BASE OF THE RAY-FIN TREE

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Hyoid arches are central to the structure of most fish heads; they contribute to jaw function and support, to opercular and branchiostegal activity, and link gill arch dynamics with mandibular and hyoid arch movement. In actinopterygians, the mandibular arch to hyoid arch coupling involves a set of specialized and in general quite small bones situated between the hyomandibula and ceratohyal. These specialized bones or cartilages, usually named as ‘interhyal’, ‘symplectic’ and/or ‘stylohyal’, are sometimes characterized as ‘accessory elements’ despite their centrality to hyoid arch structure and function. Attempts to systematize these hyoid arch parts and discover phylogenetically informative characters have not been entirely successful. Part of the problem results from rarity of well-preserved and articulated examples in Palaeozoic fish. Here, for the first time, the entire hyoid arch of a Lower Carboniferous ‘palaeoniscid-grade’ actinopterygian is revealed intact, articulated and barely disturbed from its in-life position. Remarkably, the complete set of ossifications closely resembles the hyoid arch of a living chondrosteian: the hyomandibula links to the ceratohyal via two bones in series, the uppermost of which articulates with the articular of the mandible, and the lowermost of which bears the last branchiostegal ray. But, like neopterygians, this arch includes a total of five ossifications ventral to the hyomandibula (chondrosteans have no more than four, and cladistians three). Thus, these data deliver no sudden resolution of the palaeoniscid problem. However, these data introduce new detail, new characters, new insight into early actinopterygian jaw mechanics, and expose problems with accepted views on hyoid arch-part homologies.

## FIRST *IN SITU* EVIDENCE OF REPLACEMENT OF THE MULTITUBERCULATE I2, AND NEW DATA ON MULTITUBERCULATE DENTAL DEVELOPMENT

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The multituberculate *Tombaatar sabuli* is known only from a single partial skull, lacking the lower jaws and dentition, from the Late Cretaceous Ukhaa Tolgod locality, Mongolia. Here we describe a juvenile of *T. sabuli* from the Late Cretaceous Toogreegeen Shireh locality of Mongolia, represented by a very well preserved skull and left dentary. The dentary and lower dentition of *Tombaatar* is described for the first time, and the skull, substantially more complete than the holotype, reveals features previously unknown for this genus. In addition, the skull has both deciduous and permanent upper incisors dI2 and I2 *in situ*, revealing the positioning of both of these, the anteriormost upper incisors of multituberculates, in the skull for the first time. It also shows the unworn cusp tip morphology of the permanent I2. Other features of the dental eruption and replacement sequence allow the specimen to be placed within the relatively early second ontogenetic stage of multituberculate growth, as the most complete example known. This completeness helps clarify aspects of the order and timing of dental development of ontogenetically young multituberculates. Unique features in this individual reinforce the degree of difference in dental development within the clade Djadochtatherioidea, and within Multituberculata as a whole. This find adds to the multituberculate diversity known from the Late Cretaceous Toogreegeen Shireh locality of Mongolia, and reinforces faunal links with other Late Cretaceous multituberculate bearing localities of Mongolia.

## TO CATCH A KIPPER: REASSESSMENT OF AN EARLY JURASSIC RHOMALEOSAURID PLESIOSAURIAN

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Rhomaleosaurids were the first clade of plesiosaurian to occupy the niche of large macropredator, ranging from the earliest Hettangian to the Callovian. Recent reassessment of the early Jurassic rhomaleosaurid “*Plesiosaurus*” *megacephalus* has resulted in the erection of the new genus, *Atychodracon*, and reinstated the holotype specimen from Street-on-the-Fosse, Somerset, UK which had been destroyed in 1940 but is represented by plaster casts. Previously a neotype specimen from the Planorbis zone (Hettangian) of Barrow-upon-Soar, Leicestershire, UK, known as the “Barrow Kipper”, had been erected. Recently published mapping suggests that *Atychodracon* is Sinemurian in age rather than Hettangian as was previously thought. The “Barrow Kipper” is here re-assessed in the light of these developments. Numerous differences between the “Barrow Kipper” and *Atychodracon* indicate that the two are distinct taxa. The premaxilla-maxilla sutures are sub-parallel as in *Rhomaleosaurus* rather than posteriorly converging, and the premaxillary rostrum is relatively longer and less expanded mediolaterally. The posterior interpterygoid vacuities are more elongate and lie posterior to the lateral ramus of the pterygoid, while the posterior parabasisphenoid is concave rather than convex and keeled. The preaxial margin of the humerus is convex for approximately two-thirds of its length rather than straight, and the proximal postaxial process is more pronounced. This morphology is also distinct from that of other Hettangian rhomaleosaurids such as *Eurycleidus* and *Macroplata*. The posterior dorsal centra are markedly waisted with dished dorsolateral surfaces. This potential apomorphy is absent in a second, incomplete specimen from Barrow-upon-Soar, indicating that this also represents a different taxon.

## THERIAN MAMMALS EXPERIENCE AN ECOMORPHOLOGICAL RADIATION DURING THE LATE CRETACEOUS AND SELECTIVE EXTINCTION AT THE K-PG BOUNDARY

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It is often postulated that mammalian diversity was suppressed during the Mesozoic Era and increased rapidly after the Cretaceous—Palaeogene (K—Pg) extinction event. We test this hypothesis by examining macroevolutionary patterns in early therian mammals, the group that gave rise to modern placentals and marsupials. We assess morphological disparity and dietary trends using morphometric analyses of lower molars, and we evaluate generic level taxonomic diversity patterns using techniques that account for sampling biases. In contrast with the suppression hypothesis, our results suggest that an ecomorphological diversification of therians began 10—20 Myr prior to the K—Pg extinction event, led by disparate metatherians and Eurasian faunas. This diversification is concurrent with ecomorphological radiations of multituberculate mammals and flowering plants, suggesting that mammals as a whole benefitted from the ecological rise of angiosperms. In further contrast with the suppression hypothesis, therian disparity decreased immediately after the K—Pg boundary, probably due to selective extinction against ecological specialists and metatherians. However, taxonomic diversity trends appear to have been decoupled from disparity patterns, remaining low in the Cretaceous and substantially increasing immediately after the K—Pg extinction event. The conflicting diversity and disparity patterns suggest that earliest Palaeocene extinction survivors, especially eutherian dietary generalists, underwent rapid taxonomic diversification without considerable morphological diversification.

## TESTING THE BUOYANCY OF AN IMMERSSED *SPINOSAURUS* (DINOSAURIA: THEROPODA) WITH A DIGITAL MODEL

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*Royal Tyrrell Museum of Palaeontology*

A recent interpretation of the fossil remains of the enigmatic, large predatory dinosaur *Spinosaurus aegyptiacus* proposed that it was specially adapted for an aquatic mode of life — a first for any predatory dinosaur. A detailed, three-dimensional, digital model of the animal was generated and the flotation potential of the model was tested using specially written software. It was found that *Spinosaurus* would have been able to float with its head clear of the water surface. However, a similarly detailed model of *Tyrannosaurus rex* was also able to float in a position enabling the animal to breathe freely, showing that there is nothing exceptional about a floating *Spinosaurus*. The software also showed that the centre of mass of *Spinosaurus* was much closer to the hips than previously estimated, implying that this dinosaur would still have been a competent walker on land. With regional body densities accounting for pneumatized skeletons and system of air sacs (modelled after birds), both the *Spinosaurus* and *Tyrannosaurus* models were found to be unsinkable, even with the air sacs substantially deflated. The conclusion is that *Spinosaurus* would still have been a competent terrestrial animal.

## DIVERSITY OF CHONDRICHTHYAN SKIN DENTICLES AND THE ORIGINS OF VERTEBRATE DENTITIONS

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Sharks and rays possess an external dermal skeleton comprising placoid scales (skin denticles), studied extensively to address the origin and evolution of teeth in jawed vertebrates. The skin denticles include large and tooth-like scales on the extended cartilaginous rostrum in sawsharks, sawfish and the fossil group Sclerorhynchoidea. In extant rays, these are also present on the braincase, synarcual (fused anterior vertebrae), more posterior neural arches, and the pectoral girdle. Using X-ray microtomography, we recorded the development and patterning of these scales to compare with tooth patterning in the oral dentition, to test current hypotheses of the evolutionary relationship between scales and teeth. These propose that teeth evolved from scales, predicting substantial shared developmental and patterning mechanisms, including addition and replacement. In sawsharks and fossil Sclerorhynchoidea, the rostrum tip represents a growth centre where new tooth-like scales are added. Scales along the rostrum are replaced, but only after loss, after which new scales develop lying flat in the vacated space and rotate into functional position. This developmental mechanism also applies to tooth-like scales on the batoid chondrocranium, neural arches and pectoral girdle. In fossil sclerorhynchoidea (Schizorhiza) tooth-like scales also rotate into position, but in an unusual two-step manner. Although regulated, these scales all differ from oral teeth in chondrichthyans and osteichthyans, where functional and replacing teeth are part of a successional series linked by tooth-producing tissues (e.g., dental lamina). In batoids and sawsharks, replacement is more comparable to regular placoid scales, providing no evidence to support current hypotheses of tooth evolution.

## **BAYESIAN MORPHOLOGICAL CLOCKS AND THE PHYLOGENY OF EARLY GNATHOSTOMES (JAWED VERTEBRATES)**

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Bayesian relaxed clock methods are being increasingly used in palaeontology to investigate macroevolutionary patterns. Utilisation of these methods on a new large-scale data matrix of early gnathostome fossils reveals that these methods can also have a significant effect on tree topology. The past decade has seen a consensus emerge on early vertebrate phylogeny where the placoderms, an extinct group of armoured fish, form a paraphyletic group of stem gnathostomes. However, the Bayesian morphological clock methods reveal strong support for placoderm monophyly, effectively re-rooting the tree. Uncertainty about the root position is likely due to the difficulty in polarising characters using fossil agnathan outgroups, and simulations suggest that Bayesian morphological clock methods outperform parsimony when outgroups are largely uninformative. Patterns of rate heterogeneity from trees known to have an incorrect root position match the patterns retrieved from analyses with constrained placoderm paraphyly. Reassessment of the evidence for placoderm paraphyly reveals that it is very weak, and the two different root positions are in fact equally parsimonious. If correct, the new phylogeny would overturn the idea that shared features of placoderms are ancestral for jawed vertebrates, and necessitate reassessment of the acquisition of a number of key traits during the evolution of gnathostomes. The potential for Bayesian relaxed clock methods to recognise incorrect topologies if they cause imbalances in rates of evolution may be a productive avenue for future research.

## **LEVIATHAN RISING: THE SHARK OF PUBLIC SECTOR DEADLINES BITING THE BLEEDING EDGE OF RESEARCH**

**Jeff Liston**

*National Museums Scotland & Peterborough Museum & Art Gallery*

Over field seasons 2002 and 2003, the most complete specimen of the Middle Jurassic suspension-feeding fish *Leedsichthys* was excavated from the Star Pit, just outside Whittlesey, Peterborough. Over 100 days of excavation involving over 3,100 staff hours extracted over 2,300 parts, making it the longest dig for a single vertebrate specimen in Europe. In the ensuing years, over 11,750 hours of preparation time was conducted on the specimen by Alan Dawn's volunteers at Peterborough Museum and Art Gallery. In July 2015, the Esmé Fairbairn Foundation (via Museums Association's Collections Fund) awarded a £66K grant to provide a 'virtual display' and full curation of the specimen. Virtual display was a solution to a very real practical problem: the bones of this fish, while occasionally large are always extremely fragile, and would require an exceptionally long and complex armature to display them — an armature for which no gallery in the museum was large enough. Furthermore, virtual display allowed the possibility of incorporating far more associated information with the specimen than would be permitted according to museum orthodoxy. Short timescales meant that identification and arrangement of the bones within the first ever skeletal reconstruction of this animal required research that was often completed only days before required delivery for the final product. The resulting website tells the story from first discovery through the entire excavation, the site map translates into the bones which then form the skeleton, fleshing to an animated reconstruction of the 9 metre long 'Ariston' specimen of *Leedsichthys* from Whittlesey.

## **LATE MAASTRICHTIAN PTEROSAURS FROM THE TETHYS SEAWAY PROVIDE EVIDENCE FOR MASS EXTINCTION OF PTEROSAURS AT THE CRETACEOUS-PALEOGENE BOUNDARY**

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Pterosaurs were the first vertebrates to evolve powered flight, and the largest animals to ever take wing. Originating in the Late Triassic, the group persisted for over 150 million years, but it is unclear how and why the group became extinct. A single pterosaur family, the Azhdarchidae, has been shown to survive to the late Maastrichtian, suggesting that pterosaurs saw a long and gradual decline during the Late Cretaceous, with the K-Pg extinction eliminating the handful of surviving species. Pterosaurs are extremely rare as fossils, however, raising the possibility that the apparent decline in diversity is in fact due to a rarity of late Maastrichtian fossils. Here, we describe a diverse pterosaur fauna from late Maastrichtian marine deposits. The fauna includes the youngest known members of Pteranodontidae and Nyctosauridae, and dramatically increases the known diversity of late Maastrichtian pterosaurs. The gradual decline of pterosaurs in the Late Cretaceous is a sampling artifact; at least three families- Pteranodontidae, Nyctosauridae, and Azhdarchidae- persist into the late Maastrichtian, with both Nyctosauridae and Azhdarchidae staging radiations. Pterosaurs dominated at large sizes and in marine ecosystems. These patterns are consistent with a mass extinction of pterosaurs driven by the Chicxulub impact, and suggest that the evolution of large birds in the Cenozoic was made possible by the extinction of the pterosaurs.

## **EXPLORING INTEGUMENT MASS PROPERTIES IN EXTANT ARCHOSAURS AND IMPLICATIONS FOR DIGITAL VOLUMETRIC MODELLING OF CENTRE OF MASS**

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Feathers account for up to 19% of a bird's total body mass, and play an essential role in flight for many avians. Despite this, integument data are yet to be incorporated into models exploring avian mass properties. The consequences of integument on, for example centre of mass (CoM), therefore remain unknown. CoM is a primary determinant of an organism's stability at rest and in motion, and it is therefore crucial in determining posture and locomotor capabilities. As a result, CoM has been used extensively as an indirect predictor of these traits in fossil taxa, where they cannot be observed directly. However, our current inability to comprehensively model extant avians raises questions over the accuracy of applications to extinct taxa. Here, we present work seeking to address this issue by providing the first dataset on integument mass properties in extant archosaurs. In 29 specimens, including representatives from Aves, Crocodylia and Squamata, three key integument types (flight feathers, general body feathers and scaly skin) were sampled from all major body segments across specimens. Preliminary results indicate the addition of integument to models has a marked impact on CoM, suggesting integument should be considered in future models assessing mass properties in feathered taxa. This, along with other ongoing work will combine to provide a quantitative basis for future predictions of CoM in extant and extinct taxa. Additionally, this will enable the production of more detailed models than previously possible, the validity of which will be assessed through comparison with physical experimentation methods.

# ENVIRONMENTAL PARTITIONING AND DIFFERENTIAL GROWTH IN SPECIES OF THE THYREOPHORAN DINOSAUR *STEGOSAURUS* IN THE UPPER JURASSIC MORRISON FORMATION, USA

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Two species of the ornithischian dinosaur *Stegosaurus* are considered valid: *Stegosaurus stenops*, from Colorado, Utah, and Wyoming, and *Stegosaurus mjosi*, known only from Wyoming. In 2015, a new specimen of *Stegosaurus* was excavated near Livingston, Montana. The specimen can be confidently referred to *Stegosaurus mjosi* based on features of the dorsal vertebrae. Although relatively small in size, histological examination suggests that the animal was osteologically mature at time of death, and small stature appears to be a feature common to *Stegosaurus mjosi*. The stratigraphic location of the Livingston quarry, and all other specimens of *Stegosaurus* recorded in the Paleobiology Database, were mapped onto a new chronostratigraphic framework for the Morrison Formation. The distribution of all individuals of *Stegosaurus* contemporaneous with the Livingston specimen was examined. The ranges of *Stegosaurus mjosi* and *Stegosaurus stenops* did not overlap during the time interval in which the Livingston specimen is found. *Stegosaurus stenops* occupied the southern part of the Morrison depositional basin, while *Stegosaurus mjosi* occupied the northern part. A variety of sedimentological and palynological evidence, as well as climate modelling estimates, indicate that the southern part of the Morrison basin was more arid than the northern part, and thus segregation of the two species may have been environmental. Intriguingly, large body size has been suggested as an adaptation to aridity among living megaherbivores, and it is possible that the larger adult size displayed by *Stegosaurus stenops* may have been an adaptation to prevailing conditions in the south of the Morrison basin.

## NEW DATA SHEDS LIGHT ON TITANOSAURIFORM SAUROPOD DINOSAUR EVOLUTIONARY HISTORY

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Titanosauriforms represent the most diverse clade of sauropod dinosaurs, with >120 species, a global distribution and a temporal range extending from the Late Jurassic through to the end-Cretaceous. Interrelationships of this clade are poorly understood, especially for derived titanosaurs; however, a wealth of new data provides an opportunity to remedy this problem. Based on first-hand study of taxa, description of new remains, and an extensive review of the literature, here we present a revised phylogenetic analysis focused on titanosauriforms, comprising 83 taxa (including 30 titanosaurs) scored for 427 characters, many of which are novel to this study. After pruning of several unstable and highly incomplete taxa, analysis in TNT produces a well-resolved topology (24 MPTs, length 1731 steps). The 'French *Bothriospondylus*' is recognised as a new genus of brachiosaurid, and is the earliest known (Oxfordian) titanosauriform. Many analyses, including previous iterations of this matrix, have recovered a titanosaurian clade consisting of taxa known primarily from skulls. Our results place *Sarmientosaurus* as a basal titanosaur and remove *Rapetosaurus* from Nemegtosauridae, although *Tapuiasaurus* is still allied with the latter clade. We recover a diverse clade of Late Cretaceous South American (including *Epachthosaurus*, *Mendozasaurus* and *Notocolossus*) and Indo-Madagascan (*Jainosaurus*, *Vahiny*) lithostrotian titanosaurs. The latest Cretaceous Eurasian taxa *Lirainosaurus* and *Opisthocoelicaudia* cluster with the North American *Alamosaurus*, nested within a clade of South American (including *Baurutitan* and *Saltasaurus*) and Indo-Madagascan (*Isisaurus*, *Rapetosaurus*) lithostrotians. Biogeographic analysis indicates that many titanosaur lineages were widespread by the late Early Cretaceous, with regional extinctions leading to continent-scale endemism.

## A TALE OF TWO SPECIES: *ICHTHYOSAURUS COMMUNIS* AND *I. INTERMEDIUS*

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*Ichthyosaurus communis* (De la Beche and Conybeare 1821) and *I. intermedius* (Conybeare 1822) have been considered synonymous by some researchers, but distinct species by others. The type specimens of both are missing, complicating the problem and requiring a detailed analysis of the original literature. The distinction between the two species was originally based on tooth morphologies that are end members of a spectrum of variation. Moreover, tooth morphology varies ontogenetically. More informative was a sketch of the posterior skull of *I. intermedius*, which has been regarded as the type by some workers. The comparable illustration of *I. communis* is problematic and raises the question of what was actually being compared to *I. intermedius*. Subsequent descriptions by Owen did not clarify the distinction between *I. communis* and *I. intermedius*, although he retained both names. The issue was eventually resolved by the designation of a neotype specimen that was assigned the *I. communis* name. The neotype appears to display all of the characteristics of the *I. intermedius* ‘type’ but the name ‘communis’ had priority. Thus as defined, no morphological differences exist between *I. communis* and *I. intermedius*, supporting the synonymy proposed in the 1970s.

## THE RELATIONSHIP BETWEEN MAXIMUM CORTICAL BONE THICKNESS AND MAXIMUM CURVATURE OF METATARSAL BONES IN *PAN* AND *HOMO* AND ITS FUNCTIONAL RELATIONSHIP TO LOCOMOTION

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Hominoids practice a diverse array of locomotor behavior, from obligate terrestrial bipedalism to arboreal suspensory behavior, which is reflected in the variable morphology found in their foot bones. That hominin foot bones reflect locomotor behavior is also clear, but the forms of locomotor behaviors to be inferred are less clear. Pressure plate studies indicate that the center of pressure tends to move medially in the human foot during the last half of stance phase of bipedal gaits, while it tends to remain relatively more lateral in the bonobo and chimpanzee foot during the last half of stance phase. Here we present a comparative sample of metatarsal bones from *Homo sapiens* [n=22] and two species of *Pan* (*Pan paniscus* [n=15] *Pan troglodytes schweinfurthii* [n=22]) that explores differences in bone shaft thickness between *Homo* and *Pan* metatarsal morphology and foot function. Specifically, we postulate that cortical bone thickness is a functional marker reflecting habitual mean position of maximum change in geometry on the plantar surface in metatarsals.

# THE NATURE AND MAGNITUDE OF VARIABILITY IN PLANTAR PRESSURE DURING HUMAN WALKING

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Variability in step parameters during walking allows the body to adapt to changes in substrate or unexpected perturbations that may occur as the feet interface with the ground. However, there are as yet no studies that consider variability specifically at the body–environment interface. Here, we assessed the magnitude and spatial variability in plantar pressure across a range of controlled walking speeds using two measures of variability (mean square error and co-efficient of variation). We also examined how intra-subject (step-to-step) variability was influenced by sample size by conducting a random sub-sample analysis. To generate a large plantar pressure data set, sixteen healthy subjects walked barefoot on a foot pressure sensing treadmill for 5 minutes, generating over 500 pressure records per trial. Analysis of this data set revealed no consistent relationship between mean square error and absolute or normalised walking speed. However, a positive linear relationship was found between co-efficient of variation and absolute and normalised walking. Mean square error and co-efficient of variation gave juxtaposing pictures of how step-to-step variability was distributed across the foot: relatively high variability was consistently confined to the medial and lateral forefoot when measured by mean square error, while the forefoot and heel show high variability when measured by co-efficient of variation. Our random sub-sampling analysis demonstrates that a large number of steps are required before the range in mean square error values of randomly generated sub-samples reaches  $\leq 5\%$  of the full data set values. At low samples sizes typically used in basic science and clinical studies of plantar pressure (8-50 steps) only 25-50% of the variation is captured, suggesting that most previous studies have only captured a relatively low proportion of habitual variation in plantar pressure typically used during walking.

## EVOLUTIONARY TRENDS IN ICHTHYOSAURS: POST-TRIASSIC ‘STAGNATION’?

**Benjamin Moon**

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Ichthyosaurs are some of the most commonly found Mesozoic marine reptiles, and perhaps the most completely adapted to a marine existence. Despite 200 years of study, the relationships of ichthyosaurs are unstable and not certainly known. By constructing a new large phylogenetic supermatrix for ichthyosaurs and analysing and testing this using various optimisation criteria, regions of instability have been identified that correlate with periods of rapid radiation, such as the Early—Middle Triassic and Early Jurassic. Previous relations are confirmed, but the monophyly of some taxa is questioned. However, this supermatrix and the posterior sample of phylogenetic trees provides hypotheses of ichthyosaur evolution that can be used to examine their long-term evolutionary trends. We use cladistic morphometrics to show that there is a shift in morphospace occupation during the Late Triassic. While morphologically disparate in the Triassic, ichthyosaur disparity declined into the Early Jurassic and became more conserved, but until their extinction in the early Late Cretaceous. This differs from other diversity measures in ichthyosaurs and marine reptiles — e.g. ecospace and functionspace occupation. Associated with this is a deceleration of evolutionary rates in phenotypic characters: body size and skull size, although orbital ratio shows less obvious changes. Ichthyosaur remains are well known from several lagerstätten, but the paucity of diagnostic fossils from key periods of turnover makes for poor resolution of timescales at these events. Incorporation of phylogeny attempts to ameliorate these concerns, but leaves the likelihood of a hidden diversity at key intervals.

## PATTERNS IN THE PALAEOECOLOGY OF MODERN AND CRETACEOUS CHONDRICHTHYAN FAUNAS

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Albian and Maastrichtian sites were bulk sampled in the UK and Morocco for chondrichthyan material. The sites were specifically selected to allow for spatial, temporal and environmental comparisons of faunal diversity. Over 14,000 specimens were excavated and identified. Along with every known modern shark and ray, the fossil species were segregated into trophic-groups based on dentition type and predation technique; which directly relate to body morphology. Using all species within the study, 27 trophic-groups were identified. Modern analogues were used to infer the trophic-group for fossil species with no living representatives, such as the paleospinacids. It was found that patterns existed within trophic-groups that were able to co-habit an environment. Based on data from the primary fieldwork as well as published literature, these patterns appear to have remained constant over millions of years, even when large numbers of species within a trophic-group have gone extinct. Furthermore, in areas of more stable environmental conditions these same patterns still exist today. This means that studying modern sharks and rays using this technique can give us an insight into the ecology of poorly understood fossil faunas. Conversely, it also means that a well-studied prehistoric ecosystem can be used to model how modern ecosystems will react to the extinction (global or local) of species, based on their trophic-group and those with which they co-habit. With the rate at which modern shark and ray populations are declining, this could become an important conservation tool.

## SIZE ISN'T EVERYTHING: RE-EXAMINING *STEREOGNATHUS HEBRIDICUS* (TRITYLODONTIDAE, SYNAPSIDA) FROM THE MIDDLE JURASSIC OF SKYE, SCOTLAND

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Despite being the first Tritylodontid genus identified, *Stereognathus* remains one of the most poorly understood. The genus includes *S. ooliticus*, comprising multiple isolated and fragmentary teeth, the holotype three molars in a fragment of maxilla, and an edentulous jaw fragment. In the 1970s a new species was named: *S. hebridicus*, from Skye on the West coast of Scotland. It was initially represented by four damaged molars which were never fully described, being only briefly outlined in 1972 and named a new species based solely on their size. Recent fieldwork on Skye has recovered new, more complete material, leading us to reassess this genus. We have carried out a full descriptive and taxonomic review of all available *Stereognathus* material. We compared size and morphology between *S. hebridicus* material and *S. ooliticus* specimens, as well as looking for morphological markers that may distinguish these two species. We find no support for the species *S. hebridicus* based on size. However we do identify potential non-species-related size clustering. Given similar size clusters in the recently described and closely related genus *Montirictus*, we explore the possibility that size variation within *S. ooliticus* and *S. hebridicus* specimens may be explained by intra-species variation - such as sexual dimorphism, ontogeny, or geographic distribution. Changes along an individual tooth row must also be considered due to the continuous nature of tritylodontid tooth replacement. We also discuss morphological characters, including genus level apomorphies and those that may still potentially separate these two species, pending more complete future fossil discoveries.

## SCALING AND ACCOMMODATION OF JAW ADDUCTOR MUSCLES IN CANIDAE

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The morphological variety of the masticatory apparatus of wild canids is reflected in the diversity of head shapes seen across species. Here we focus on the jaw adductor muscles to explore the interplay between allometry, function, and phylogeny in defining interspecific variations of cranial shape. We describe the gross structure of the jaw adductor muscles of several species of canid, and then examine how the muscles are scaled across the range of body sizes, phylogenies, and trophic groups. We also consider how the muscles are accommodated on the skull, and how this is influenced by differences of endocranial size. Data were collected for a suite of morphological metrics, including body mass, endocranial volume, and muscle masses and we used geometric morphometric shape analysis to reveal associated form changes. We find that all jaw adductor muscles scale isometrically against body mass, regardless of phylogeny or trophic group, but that endocranial volume scales with negative allometry against body mass. These findings suggest that head shape is influenced by the need to house isometrically scaling muscles on a neurocranium scaling with negative allometry. Principal component analysis suggests that skull shape changes, such as the relatively wide zygomatic arches and large sagittal crests seen in species with higher body masses, allow the skull to accommodate a relative enlargement of the jaw adductors compared with the endocranium. Next we use empirical muscle and CT data to build finite element analysis models to explore how head shape and gape influence bite force along the dental arcade.

## INTRASKELETAL HISTO-VARIABILITY AND ITS ONTOGENETIC IMPLICATIONS IN THE LIMB BONES OF ‘DINO-BIRDS’

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The superprecocial — altricial ontogenetic spectrum in birds which reflects the differential energy allocation into growth vs. functional maturation of tissues is also evident in the skeletal development of different individuals as well as among different elements within one skeleton. To get insight into this ontogenetic aspect at the dawn of bird evolution, we examined the histology of limb bones in five extinct paravian dinosaurs, *Anchiornis*, *Aurornis*, *Eosinopteryx*, *Jeholornis* and a yet unnamed taxon assuming that many osteohistological traits (e.g. vascularity, osteonal development, secondary remodelling) indicate growth rate and mechanical maturity of the bone tissue. Diverse growth dynamics and osteohistological indicators of different exposure to mechanical demands were detected among bones of the same skeleton in all taxa. Even though humeri often appear to have grown the fastest and mature the latest among all limb bones, no general maturation pattern could be revealed that was consistent in all specimens. Multivariate histomorphometrics showed that variability is higher within than between skeletons, and neither the overall ontogenetic state of specimens, nor their phylogenetic position is reflected in their alignment in histomorphospace. Instead, element length and functional maturity ranks explain most of the variance, although this pattern is not evident in all specimens, either. Inclusion of comparative data from birds is crucial to explore whether the maturation sequence of the forelimb may relate to the ontogenetic onset and extent of arm-assisted grasping, climbing, or in some taxa even gliding or flying.

## PHYLOGENETIC RELATIONSHIPS OF THE ‘HIGHER HETEROSTRACANS’

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The Heterostraci is the largest clade of extinct boney jawless vertebrates (ostracoderms) and a key member of the jawed vertebrate (gnathostome) stem. Within the Heterostraci the two largest clades, the Cyathaspididae and Pteraspidiiformes, comprise Janvier’s ‘higher heterostracans’ and are described as a sister groups. However, they lack a reliable phylogeny, meaning inferences regarding vertebrate evolution and diversity dynamics are questionable. We propose a new phylogeny including all known Pteraspidiiformes and Cyathaspididae genera, combining discrete and continuous data. Our results show the Cyathaspididae are a paraphyletic group leading to a monophyletic Pteraspidiiformes. Furthermore, we show that the Anchipteraspididae are positioned as basal Pteraspidiiformes, despite a reinterpretation of their bauplan to a cyathaspid type anatomy. The results provide a framework to consider the intra- and inter-group relationships more broadly. Once this is achieved inferences about the early evolution of vertebrates can be made including ancestral morphotypes, character transitions and the timing of tempo of these innovations.

## BIOGEOGRAPHIC AND PHYLOGENETIC IMPLICATIONS OF THE GIANT MADTSOIID SNAKE *GIGANTOPHIS GARSTINI* FROM THE EOCENE OF NORTH AFRICA

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Madtsoiidae is a speciose family of extinct snakes, which achieved a wide Gondwanan and trans-Tethyan distribution by the Late Cretaceous, surviving until the late Pleistocene. *Gigantophis garstini*, the first and largest described madtsoiid, was recovered from the late Eocene of Fayum, Egypt, over 100 years ago. The 20 vertebrae that comprise the type specimen have only received a brief description, hindering the referral of specimens to this taxon and our understanding of madtsoiid interrelationships. A detailed re-description of the holotype material demonstrates the validity of *Gigantophis*, diagnosed by five vertebral autapomorphies in addition to a unique combination of characters. Using a model of morphological variation in extant snakes, we estimate that *Gigantophis* was 7 m long. Vertebrae recently referred to *Gigantophis* from the Paleocene of Pakistan differ significantly to the type material, and we restrict *Gigantophis* to the late Eocene of North Africa. A phylogenetic analysis using the largest sample of putative madtsoiids (19 OTUs) and a revised and augmented character taxon matrix (148 characters), places *Gigantophis* within a clade of latest Cretaceous Indian snakes, as sister taxon to *Madtsuia pisdurensis*. This relationship might be interpreted to mean that biotic links existed between Indo-Madagascar and Africa in the Late Cretaceous. However, the lack of consensus on Gondwanan dispersal routes, coupled with the widespread distribution of the clade in the Late Cretaceous, suggests that the Gondwanan dispersal of Madtsoiidae had occurred by the mid-Cretaceous. Nonetheless, the presence of Madtsoiidae in the latest Cretaceous of Europe might have resulted from trans-Tethyan dispersal.

## RE-EVALUATION OF *PHOLIDOSAURUS PURBECKENSIS* (CROCODYLIFORMES: TETHYSUCHIA) FROM THE EARLY CRETACEOUS OF ENGLAND, WITH IMPLICATIONS FOR THE EVOLUTION OF PHOLIDOSAURIDAE AND DYROSAURIDAE

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*Pholidosaurus* is a genus of longirostrine crocodyliforms reported from the Early Cretaceous of southern England, north-western Germany, south-western France and western Denmark. Due to the lack of large comparative analyses, the number of valid species within this genus is unclear, and the characteristics that unite these taxa under one genus are in disrepute. This taxonomic uncertainty reflects the wider instabilities associated with this region of the crocodyliform tree, as recent phylogenetic analyses do not agree upon the monophyly of Pholidosauridae, its internal relationships, nor its sister taxon. Comparative anatomical study of the English *Pholidosaurus* specimens supports their referral to a singular taxon, '*Pholidosaurus*' *purbeckensis*. Results based on the first-hand re-scoring of '*P.*' *purbeckensis* for two different phylogenetic datasets (both in preparation modifications of published datasets) consistently recover a polyphyletic *Pholidosaurus* and a monophyletic Pholidosauridae as the sister taxon to a sub-clade uniting the enigmatic tethysuchian *Fortignathus felixi* with Dyrosauridae. *Pholidosaurus schauburgensis*, the type species, is consistently recovered nested within Pholidosauridae whilst '*P.*' *purbeckensis* is found in association with *F. felixi* and the basal dyrosaurid *Chenanisuchus lateroculi* in both matrices. Continued referral of '*P.*' *purbeckensis* to *Pholidosaurus* in light of the polyphyly recovered in both analyses, and a suite of anatomical differences, is here considered misleading. Thus a new genus for '*P.*' *purbeckensis* is necessary. This work highlights the uncertainty associated with including taxa in phylogenetic analyses based on incomplete and outdated descriptions, and the necessity of re-evaluative work in elucidating the anatomy and alpha taxonomy of poorly known crocodyliform taxa.

## THE DIVERSE DENTITION OF EARLY CARBONIFEROUS LUNGFISH: AN ADAPTIVE RESPONSE TO THE END-DEVONIAN EXTINCTION?

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The dentition of post-Devonian lungfish typically consists of paired pterygoid and prearticular tooth plates, bearing cone-shaped teeth arranged in radiating rows. Rostral bones, with marginal teeth, have rarely been described. Recently, a diverse collection of lungfish tooth plates, representing at least nine new forms, has been recovered from eleven localities in the Tournaisian of northern Britain. They display a range of previously unknown morphologies with tooth shape and wear patterns not seen in other post-Devonian forms. At least two have rostral marginal teeth in adult fish. Comparison of tooth ridge number and tooth ridge angle in lungfishes from the Famennian, Tournaisian and Viséan reveals marked differences between late Devonian and early Carboniferous taxa. Following the end-Devonian extinction, two completely new tooth plate shapes evolved, one, the *Ctenodus* pattern, had a low tooth ridge angle and parallel tooth ridges, the other, the *Xylognathus* pattern, had a high tooth ridge angle and extremely divergent tooth ridges. This high level of morphological diversity over a narrow time period is evidence of a previously unrecorded radiation of lungfishes. It probably exploited the gaps in ecospace left by the extinction of major groups of fishes following the Hangenberg event. The appearance of marginal teeth in new taxa in the Carboniferous demonstrates how adaptable the lungfish dentition was and possibly explains why they were able to radiate so quickly.

## THE DYNAMICS OF ORNITHOPOD DENTAL EVOLUTION

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Ornithopods were key herbivorous dinosaurs in Mesozoic terrestrial ecosystems, with a variety of tooth morphologies. Several clades, especially the ‘duck-billed’ hadrosaurids, became hugely diverse and abundant almost worldwide. Yet their evolutionary dynamics have been disputed, particularly whether they diversified in response to events in plant evolution. Here we focus on their remarkable dietary adaptations, using tooth and jaw characters to examine changes in dental disparity and evolutionary rate. Ornithopods explored different areas of dental morphospace throughout their evolution, showing a long-term expansion. There were four major evolutionary rate increases, the first among basal iguanodontians in the Middle-Late Jurassic, and the three others among the Hadrosauridae, above and below the split of their two major clades, in the middle of the Late Cretaceous. These evolutionary bursts do not correspond to times of plant diversification, including the radiation of the flowering plants, and suggest that dental innovation rather than coevolution with major plant clades was a major driver in ornithopod evolution.

## HOW BIG DID BAROSAURUS GET?

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The diplodocid sauropod *Barosaurus* is best known from the spectacular mounted skeleton in the atrium of the American Museum of Natural History (AMNH). Apart from the disproportionately long neck it is similar in size to *Diplodocus* — but did *Barosaurus* get bigger? BYU field jacket 3GR was collected from the Jensen/Jensen quarry, Utah, in 1966 but only recently prepared. It contains three cervical vertebrae, designated A, B and C, anterior to posterior. They belong to *Barosaurus* based on elongation, broad prezygapophyseal facets, “hinged” prezygapophyseal rami with dorsomedial and dorsolateral faces, narrow, posteriorly set diapophyses bearing posterior tubercles, and wing-like postzygadiapophyseal laminae. Based on spine bifurcation, vertebra C is C9—C11. The centra of the AMNH cervicals C9—11 are 685, 737 and 775 mm long. That of vertebra C measures 1220 mm, making it 1.57—1.78 times longer. This suggests a neck length of 13.3—15.1 m based on 8.5 m for the AMNH specimen. BYU 9024 is an even larger cervical vertebra, referred to *Supersaurus* but indistinguishable from C9 of *Barosaurus* based on the characters above. At 1370 mm in total length, it is exactly twice the length of the AMNH C9, suggesting a neck 17 m long. *Dystylosaurus* has also been referred to *Supersaurus*. Although the holotype and only vertebra is clearly a diplodocid anterior dorsal (it has dual centroprezygapophyseal laminae, a large cotyle and “drooping” parapophyses), its tall, unsplit neural spine and pronounced ventral keel prevent assignment to any known diplodocid. It may be a valid, distinct genus.

## SEA LEVEL REGULATED TETRAPOD DIVERSITY THROUGH THE JURASSIC/CRETACEOUS TRANSITION

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Reconstructing deep time trends in biodiversity remains a central goal for palaeobiologists, but our understanding of the magnitude and tempo of extinctions and radiations is confounded by uneven sampling of the fossil record. In particular, the Jurassic/Cretaceous (J/K) boundary, 145 million years ago, remains a poorly understood interval. Here, we apply a rigorous subsampling approach to a comprehensive tetrapod fossil occurrence dataset (12,476 occurrences representing 1954 genera) to assess the group's macroevolutionary dynamics across the J/K transition. Although much of the signal is exclusively European, the total diversity loss was high, but not reflected in the extinction of many suprageneric taxa. Groups such as pterosaurs and sauropods began their decline before the J/K boundary, whereas others (including mammaliaforms and ornithischians) declined subsequently in the earliest Cretaceous. However, the majority of clades document their greatest magnitude of decline through the J/K boundary, indicating that the overall extinction tempo was staggered and occurred in a 'wave' through the J/K transition. This decline is coupled with elevated extinction rates in almost all tetrapod groups, far exceeding background rates for the rest of the Jurassic—Cretaceous interval. Subsequently, strongly suppressed origination rates characterised the remainder of the earliest Cretaceous, and the magnitude and timing of the subsequent recovery appears to be linked with the origins and/or diversification of major extant tetrapod groups, including birds and squamates. Variation in eustatic sea level was the primary driver of these patterns, controlling diversity through availability of shallow marine environments and via allopatric speciation on land.

## GROWTH RATES AND LONGEVITY IN PTEROSAURS

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The rate at which pterosaurs grew is controversial. Current opinions range from relatively slow, as typified by extant reptiles, to relatively rapid, as found in extant birds and bats, or possibly somewhere in between. The standard approach for estimating growth rates in extinct tetrapods, using histological data (principally, 'lines of arrested growth' (LAGs) that are thought to delimit annual cycles) is frustrated in pterosaurs by the hollowness of their long bones, the walls of which only ever record a limited portion of the life history of an individual. In this study we took advantage of histological data that has been generated for several species of pterosaur including post-natal growth series of the rhamphorhynchid *Rhamphorhynchus muensteri* and the ctenochasmatid *Pterodaustro guinazui*. Using an approach developed for estimating the age of dinosaurs, we generated composite reconstructions of femur growth and determined a minimum age from the number of LAGs likely to have been present in mature individuals if no bone erosion had occurred. Growth rates (g/day) were calculated by combining the age data with estimates of mass. All estimated growth rates for pterosaurs fell well within the point cloud for extant reptiles and remote from the point cloud for extant birds, species of which typically exhibit growth rates ten times those of reptiles of comparable mass, and usually achieve maturity in less than a year. Even relatively small pterosaurs (~1 kg) took several years to reach osteological maturity and the largest forms may have taken many decades to attain full size.

## A NEW LOOK AT *RADOTINA* - A UNIQUE DIVERSITY OF BASAL GNATHOSTOMES IN THE EARLY DEVONIAN OF THE PRAGUE BASIN

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The revision of the genus *Radotina* from the Lower Devonian (Lochkovian and Pragian) of the Prague Basin (Czech Republic) has significantly altered our knowledge of primitive placoderms. What was previously thought to be a well described and understood partly tessellated acanthothoracid genus turns out to be a remarkably diverse association of basal gnathostomes. Three genera, including the true *Radotina*, are characterized by an "upper lip" or anterior prenasal expansion of the trabecular region, a primitive gnathostome character shared with *Romundina*, *Brindabellaspis* and a few other forms. In one new genus the "upper lip" represents at least one quarter of the whole length of the endocranium and contains a dense canal network. Only the central and nuchal plates of the dermal skull roof are known in this taxon, the prenasal region lacks dermal cover. Although the specimens are dorsoventrally flattened and partly disarticulated many display previously unknown parts of the cranial and postcranial morphology including parts of the visceral arch skeleton, shoulder girdle, vertebral column and body scales. One Pragian specimen of *Radotina* also contains part of the visceral arch skeleton preserved in full 3D. The historical taxon *Holopetalichthys*, previously synonymised with *Radotina*, is revalidated. It is characterized by an unusual combination of basal gnathostome morphological characters. The endocranium has a long preorbital region, but the nostrils are facing anterodorsally. The dermal skull roof cover is entirely macromeric. A partly articulated 3D specimen of *Holopetalichthys* is preserved embedded in the infill of a large orthocone cephalopod shell.

## CAMOUFLAGE PATTERNS IN AN ORNITHISCHIAN DINOSAUR AND RECONSTRUCTING THE HABITAT IT LIVED IN

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Countershading is a common colour pattern in the animal kingdom and is typically expressed as a dark dorsum and light venter. It has been shown that this pattern act to counter-illuminate the shadow, cast on the body. Many visual systems and brains use shape-from-shading cues to tell three-dimensionality, which explains the selective pressure for minimising shadows cast on the body, resulting in a more optically flat appearance. Indeed, it has been shown that there is a strong correlation to lighting environment and the appearance of countershading that match the mode shadows are cast, depending on latitude and open/closed habitats. We have studied an extremely well preserved specimen of *Psittacosaurus ?lujiatunensis* from the Yixian formation of Northeast China. This specimen preserve impressions of the skin across the body, expressed as a thin film of calcium phosphate residues from the hardened keratin as well as melanin. We have mapped the scale and pigment patterns and projected them onto a life-size 3D model, which has carefully been constructed based on the skeletal information and volumetric considerations. We observe a light ventral surface, which is expressed on the lower abdomen and tail, while the lateral body and dorsum was darker. Various reticulating, finer patterns are also observed as well as a dark face pigmentation. In order to investigate the lighting environment that this psittacosaur lived in, we needed to investigate what sort of shadow this particular countershading would counter illuminate. We took another cast of the psittacosaur and painted it uniformly grey and photographed it under different weather and habitats, such as under a canopy and under open sky. The images were then cropped and inverted and compared to the observed patterns. From this, we can infer that this small ornithischian dinosaur lived in a closed habitat, which conforms to evidence of petrified wood in several lacustrine sites of the Jehol Biota as well as pollen data, suggesting a 90% dominance of the coniferous species, *Schizolepis*.

## PHYSIOLOGICAL CHALLENGES OF MULTI-METER NEURONS IN LARGE VERTEBRATES

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All extant vertebrates have some primary sensory neurons that extend from the brainstem to the most distal extremities. To investigate physiological challenges imposed by multi-meter neurons in large extant animals, we physically traced the longest nerve pathways in mounted elephant, giraffe, hippo, and rhino skeletons. The elephant had the longest conduction pathway, 4.85m from the foramen magnum to the pedal phalanges, in an individual 2.6m tall. In a world record 4m-tall elephant the same nerve pathway would be 7.5m. As well as transmitting nerve impulses, axons also are conduits for intracellular cargoes. Because the cell bodies of primary sensory neurons are located at the midpoint of the cell, materials need be transported over only half the total length of the neuron - less than 4m in the largest elephants. The recurrent laryngeal nerve (RLN) of the giraffe has a longer axon transport path. In the neurons of the RLN, axonal cargoes must run the length of the neck twice. In a 4.1m-tall giraffe, we measured the RLN pathway at 3.9m; in a world record 5.9m-tall individual, it would be 5.6m. Even at 20-40cm/day, fast axonal transport would take 2-4 weeks to traverse the RLN, and at 0.2-8mm/day, slow axonal transport would take between 2 and 77 years to cover the same distance. Either large animals must have faster axonal transport than has been documented in small laboratory animals, or their axons must receive more physical support from local glial cells than has been generally accepted, or both.

## A SMALL BODIED, NON-JUVENILE AZHDARCHOID PTEROSAUR FROM THE AGE OF FLYING GIANTS

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Campanian-Maastrichtian pterosaur faunas are remarkable for the large or giant size of most species, some of which were the largest flying animals of all time. Pterosaurs with wingspans less than 2.5 m are virtually unknown from this interval, a phenomenon attributed to a perceived reduction in pterosaur diversity and disparity towards the end of the Mesozoic. The recovery of small, associated pterosaur remains (comprising a humerus, partial notarium, free dorsal vertebrae and other fragments) from the Campanian Northumberland Formation (Nanaimo Group) of Hornby Island, British Columbia, provides rare data on a small-bodied pterosaur from the end of the Cretaceous. The elements have features typical of Azhdarchoidea, an identification consistent with dominance of this group in the Campanian-Maastrichtian, but indicate a small wingspan of ca. 1.5 metres. Histological data and axial bone fusions indicate the Hornby pterosaur was approaching maturity at time of death, and was thus likely a member of a small species, and not a juvenile of a larger taxon. We propose that diminutive pterosaur species were not entirely absent from Late Cretaceous faunas and question the significance applied to their rarity in the fossil record. Specifically, we note that fossil evidence for small juveniles of large species — animals which must have existed — is extremely rare, suggesting a preservational bias against small bodied pterosaurs (juvenile or otherwise) in the Late Cretaceous. If such biases are operating on the pterosaur record, caution should be applied to any interpretation of latest Cretaceous pterosaur diversity and success.

# SVPCA ABSTRACTS

## POSTERS

### ASSESSING THE PHYLOGENETIC PERFORMANCE OF MORPHOLOGICAL PARTITIONS OF BIRDS

Leah Callender-Crowe and Robert Sansom

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Analysing morphology is essential for reconstruction of phylogenies and inference of evolutionary histories. Unfortunately convergence and non-independence of characters undermines the use of morphology in this context. Here the performance of empirical morphological character partitions is investigated using molecular data as a benchmark. Our meta-analysis of 13 morphological datasets of (non-passerine) birds finds osteological characters to be significantly more congruent with molecular trees than and non-osteological characters are ( $p < 0.001$ ). This congruence indicates that osteology may be a better indicator of evolutionary history than non-osteology. This knowledge may help us to better utilise morphological data for the purposes of evaluating major evolutionary events.

### DINOSAUR ENVIRONMENTAL NICHE MODELLING IN THE LATE CRETACEOUS OF NORTH AMERICA

Alfio Alessandro Chiarenza<sup>1</sup>, Peter A. Allison<sup>1</sup>, Dan J. Lunt<sup>2</sup>, Philip D. Mannion<sup>1</sup> and Paul J. Markwick<sup>3</sup>

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An understanding of the environmental dynamics of past ecosystems can have important implications for how we view biogeographic and evolutionary patterns. Ecological niche modelling (ENM) is a computational technique for estimating modern species requirements by correlating known species occurrences with environmental features. This approach can also be applied to fossil data. The Campanian and Maastrichtian of North America have yielded considerable data on dinosaur distribution and diversity, capturing the lead-up to the K/Pg mass extinction, and was a time of dramatic environmental change. Coupled with its high-resolution stratigraphy and long history of study, this spatiotemporal window is an excellent case study for ENM. We used high-resolution palaeogeographic maps for regional-scale interpretations. Climatic outputs of several physical parameters (e.g. temperature and precipitation) were modelled over these palaeotopographies, and a series of ENMs for latest Cretaceous dinosaurs were produced. Dinosaur occurrences were extracted from the Paleobiology Database and superimposed onto past climatic and geographic envelopes, elaborated with the Maximum Entropy algorithm; a prediction of the niche distribution in the Danian (Early Paleocene) was also projected. These preliminary results show that the distribution of dinosaur fossils is spatially correlated with high precipitation areas, and that there was a niche contraction after the K/Pg event. Habitat modelling and estimated variation in niche ranges and contraction could be a good proxy of biodiversity variation through time. Our study offers new insights into the dynamics of past ecosystems, providing a case study using the only available register of past fluctuations in biodiversity, the fossil record.

## **A SELECTION OF CRETACEOUS VERTEBRATE FOSSILS LOCATED IN TIME, SPACE AND ENVIRONMENT**

**Bobby Clark**

*Huish Episcopi Academy*

As the last and longest period of the Mesozoic Era, the Cretaceous presents us with a wide array of sedimentary rock outcrops that can be very productive in terms of fossils. The extensive warm shallow seas that covered much of the continents during this period led to the diversification of marine habitats and encouraged the evolution of a great diversity of new animals that exploited these new environments (eg. mosasaurs, sharks and bony fishes). The high sea levels also resulted in the fragmentation of the terrestrial land masses and increased the regional diversity land animals in both the northern and southern hemispheres (eg. different spinosaurid theropods in the northern and southern hemispheres). The Cretaceous is also when many modern animals groups first appear (eg. lamniform sharks, snakes and birds). Simultaneous with the first appearance of flowering plants in the Early Cretaceous, was the appearance of new forms of herbivorous dinosaurs such as the diverse iguanodontids and their later descendants, the possibly even more diverse hadrosaurs. This poster will present images of fossils representing the above mentioned forms, as well as others, and locate them in time and space using palaeogeographic maps to demonstrate some of the richness of the Cretaceous vertebrate fossil record.

## **TOOTH REPLACEMENT IN PYCNODONT FISHES**

**Sally Collins<sup>1</sup>**, Alison Longbottom<sup>2</sup>, Martha Richter<sup>2</sup> and Charlie Underwood<sup>1</sup>

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The Pycnodonts are a diverse, monophyletic group of extinct ray-finned fishes with crushing dentitions, whose phylogenetic position among the actinopterygians is still not firmly established. They inhabited mostly marine waters from the Late Triassic to the Eocene. One set of important coded characters utilised in the cladistic analyses concerns the arrangement of the teeth. These are typically either arranged in rows, or are distributed in seeminglyno organised pattern. It is not clear what determines tooth arrangement; genetic, ontogenetic or environmental factors, whether rows are replaced in an orderly manner during an individual's life time, or sporadically, for instance in response to tooth damage during feeding. We have Micro-CT scanned the dentigerous bones of a number of pycnodont species to determine how tooth replacement occur in distinct taxa. Here we present the result of the study of two jaws of *Pycnodus* sp. from Middle Eocene of Mali, Africa. Preliminary results indicate that tooth replacement occurred following tooth damage and loss, and the replacement teeth present a very distinct anatomy to that of the original ones.

## A NEW PHYLOGENY OF BASAL SAUROPODOMORPH DINOSAURS USING A SUPERMATRIX APPROACH

Omar Rafael Regalado Fernandez<sup>1</sup>, Paul Barrett<sup>2</sup>, Philip Mannion<sup>3</sup> and Paul Upchurch<sup>1</sup>

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Since the description of the first basal sauropodomorphs in the late 19th century, roughly 40 valid genera have been recognised. The most recent basal sauropodomorph phylogenetic analysis, based on a matrix of 363 characters (226 discrete characters, and 137 continuous characters treated as discrete), resolved that most of the taxa are members of a paraphyletic grade, with none of the previously hypothesised groupings recovered, e. g. Massospondylidae and Plateosauria. However, although this is the largest published matrix for this part of the tree, it does not sample all of the characters proposed as relevant to basal sauropodomorphs. A new and heavily revised character list was produced based on an extensive review of the literature, resulting in 625 discrete characters and 225 continuous characters. This includes many modified characters, based on splitting or combined existing characters, and many have been quantified. We have homogenised the terminology of each character and illustrated all states to enable objective scoring and increase understanding between researchers. A preliminary analysis based only on the 625 discrete characters, combining previous scores with the results of first-hand assessments of specimens from China and Germany, finds evidence for a group of core prosauropods, comprising Plateosauria and Massospondylidae, plus an Anchisauria group that comprises Sauropoda and several non-sauropod anchisaurians that were traditionally known as prosauropods, such as *Anchisaurus* and *Melanorosaurus*. Study of specimens from other continents, combined with the inclusion of continuous characters, will provide a revised view of basal sauropodomorph evolution, including the transition to gigantism and quadrupedality.

## SAVANNAHS FROM THE PAST AND PRESENT: AN ANALYSIS ON THE MORPHOSPACE OCCUPATION OF UNGULATES

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The ungulate ecomorphological diversity of the mid-Miocene of North America has often been compared with that of present-day savannahs of East Africa. We compared the ecomorphology of Serengeti ungulates with those of the early Clarendonian (~12 Ma) Burge Quarry fauna from Nebraska. Ecometric traits, indicative of dietary preference and habitat choice were obtained from the skull and postcrania from 24 species of ungulates (excluding rhinos) from the Serengeti and 24 species from the Miocene. Correspondence analysis of these traits provides a visualisation of the morphospace occupation of the extant ungulate fauna (bovids, giraffids and equids); Miocene ungulates (ruminants, camelids and equids) were then added for comparison. Despite the differences in taxonomic composition of these two faunas, some interesting results were obtained. The Miocene ruminants mostly clustered with extant small to medium-sized browsers like duikers or bushbuck. Miocene equids, with the exception of the brachydont (presumed browsing) anchitheriines, were similar to present-day grazing antelopes and zebras. For the most part, Miocene camelids do not have modern analogue; however, the majority of them occupy the morphospace area of the extant common eland, *Taurotragus oryx*, an arid habitat mixed feeder. The significant diversity of camelids in this morphospace indicates that the mid-Miocene of North America was more arid than the present-day Serengeti. In conclusion, the Miocene ruminants and grazing equids constitute similar ecomorphs to those seen in the Serengeti, while the diversity of camelids is divergent from the modern African fauna, and is suggestive of habitat differences.

## CRANIAL HISTO-VARIABILITY IN *METOPOSAURUS KRASIEJOWENSIS* (TEMNOSPONDYLI) FROM SOUTHWEST POLAND AND BIOMECHANICAL IMPLICATIONS

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In this study, results of the histological analysis of the skull of *Metoposaurus krasiejowensis* from the Upper Triassic of Poland are presented. The temnospondyl cranium is long, wide and flat. To reconstruct its life history and ecological niche, it is important to characterize its biomechanical performance across ontogeny, and stress loading during feeding. Histological thin sections were acquired from one 40 cm long skull. Firstly, the cranial sutures were analysed. It was revealed that only the compression-resistant type of bone suture occurs, which is known as an adaptation to biting during prey capture in terrestrial taxa. Subsequently, the microanatomical and histological variability of selected bones from the skull were analysed. The specific position of the skull bones and their histological framework, expressed in bone thickness, porosity and Sharpey's fiber arrangement, depends on the biomechanical stress distribution. The bone loses strength and stiffness with increasing porosity, but this can be partly compensated for by increasing the thickness of the bones sections. The bones from the anterior and posterior parts of the skull roof, exhibit the strongest histological architecture (high thickness and low porosity). On the other hand, the bones from the palatal side, show the weakest mechanical configuration (low thickness and high porosity). The presence of thick and dense clumps of Sharpey's fibers, especially in the quadratum and exoccipital, suggest that strong skeletal muscles and tendon attachments played an important role during jaw opening and closing.

## A NEW ADVANCED SAUROPODIFORM DINOSAUR FROM THE LATEST NORIAN/RHAETIAN OF SWITZERLAND

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Sauropods most probably originated from small bipedal/quadrupedal basal sauropodomorphs. However, their early evolution and origin is not well understood, and the transition from more basal forms to sauropods remains poorly studied. Depending on the definition of Sauropoda adopted, phylogenetic studies indicate this transition must have taken place between the Late Triassic (Norian/Rhaetian) and the late Early Jurassic. Although the Triassic of Europe has yielded a wealth of sauropodomorph material, with exception of the enigmatic *Camelotia*, all Triassic taxa recorded so far are basal, non-sauropodiform taxa. Apart from taxa such as *Plateosaurus*, *Camelotia* and *Gresslyosaurus*, there is also material that has not yet received much attention. The University of Zurich's Palaeontology Museum holds such material, found at Schleithem in the Kanton of Schaffhausen, Switzerland, which is tentatively dated to be latest Norian to Rhaetian in age. The material had been previously assigned to *Plateosaurus*. The material consists of several presacral and caudal vertebrae, a partial humerus, ilium, partial femur, and other fragmentary appendicular elements, most probably derived from one individual. An extensive phylogenetic analysis retrieves this specimen as a derived sauropodiform or even a basal sauropod, depending on which definition of sauropoda is used. It is more derived than *Antetonitrus*, but more basal than *Isanosaurus*, *Pulanesaura* and *Vulcanodon*, placing it within the phylogenetic range of the sauropodomorph-sauropod transition. This not only confirms the presence of more derived sauropodomorphs in the Late Triassic of Europe, but also proves a greater diversity of sauropodomorphs in the Late Triassic of Europe than previously assumed.

## HABITAT USE BY LATEST CRETACEOUS/EARLIEST PALAEOGENE MAMMALS: A VIEW FROM THE ELBOW JOINT

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The elbow joint is an excellent indicator of habitat in mammals: terrestrial mammals use their forelimbs in very different ways from arboreal ones. We first investigated the correlation of the proximal ulna morphology in extant small (> 5 kg) mammals, using photographs of 21 species of marsupials and 44 species of placentals, divided into three categories: arboreal (17), semi-arboreal (21) and terrestrial (27). Two-dimensional geometric morphometrics was used to capture the shape of the proximal ulna in articular and medial views, using both landmarks (6/7) and semilandmarks (26/23). Principal Components Analysis was performed on Procrustes corrected data. One-way NPMANOVA analyses were employed to test for the significance of the differences between the three habitat groups. Most analyses distinguished among the three locomotor groups with a high degree of significance, although in the articular view the semiarboreal forms were not always correctly classified. Phylogenetic differences were found between marsupials and placentals, but were insufficient to affect the overall results. Twentyone fossil specimens from western North America (mostly latest Cretaceous but including three from the earliest Palaeocene) were then added to the analysis of the semilandmarks in medial view, and a Canonical Variates Analysis was conducted on the landmarks in medial view. The fossil taxa were about equally divided between scansorial and terrestrial forms, with little evidence of specialized arboreal forms (three species were classified as arboreal in the PCA, but none in the CVA). These results suggest that no early therians were specialized for arboreality prior to the evolution of primates.

## REMAINS OF SMALL VERTEBRATES FROM THE RÖT (LOWER TRIASSIC) OF GOGOLIN (OPOLE REGION, POLAND)

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Accumulations of vertebrate remains discovered near Gogolin over the last years represent one of the oldest assemblages of Mesozoic reptiles known to date. Increased understanding of that ecosystem and its components will likely improve insight in the early Mesozoic evolution of several lineages. The remains occur in a thin littoral limestone/marl sequence just below the Röt/Muschelkalk boundary (Olenekian, ~247 Mya) where they were concentrated in at least three horizons deposited at the surface of cyanobacterial mats. The fossil assemblage is dominated by skeletal elements of fishes and reptiles, which are accompanied by unidentified bones and invertebrate remains. Although vertebrate skeletons are completely disarticulated, the bones show little evidence of abrasion that may indicate transport. A portion of the bones suffered brittle deformation from postdepositional compressive compaction, which complexifies reconstruction after chemical preparation (dissolution of rocks in acetic acid). Fishes are represented mainly by ganoid scales, which morphologically correspond to the osteichthyan genus *Paleoniscus* sensu lato, and by teeth typical for the chondrichthian family *Hybodontidae*. Less common skull bones and other fish remains (e.g. vertebrae, fin rays, ribs), can sometimes be classified as the genus *Saurichthys*. Reptilian remains are represented mainly by vertebrae (intercentra or neural arcs, sometimes articulated), ribs, long bones and isolated teeth, although fragments of skulls or pelvic and pectoral girdles have also been collected. Pachypleurosauria dominate in the lower and middle bone horizons, where they are accompanied by other reptilian material, most probably Ichthyosauria and Protosauria. In the uppermost horizon, which forms the physical Röt/Muschelkalk boundary (but is still of Olenekian age), nothosaurian bones and teeth appear apart from the all others. Many of the remains are still problematic, but may include lariosaurian vertebrae, plagiosaurian scales and crushed reptilian eggshells.

## LIMB AND FEATHER PROPORTIONS IN PARAVIAN THEROPODS: IMPLICATIONS FOR THE IMPORTANCE OF FEATHERS ON THE HINDLIMB FOR FLIGHT, THE EVOLUTION OF FLIGHT SURFACES AND BODY MASS

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Some basal Mesozoic birds, such as *Microraptor*, have integumentary features on the hindlimb similar to the flight feathers on the wings of modern birds. This means that Mesozoic birds have four planar surfaces that can generate lift (excluding the tail, which only counts as a fifth aerodynamic surface in some taxa) rather than the two seen in modern birds. However, the aerodynamic function and significance of these extra aerofoils is highly debated and not many hypotheses have been proposed to address their evolutionary significance. Here, the temporal trends in hindlimb bone and feather length were studied to see if the function behind these hindlimb feathers could be found. Also, it was seen if these trends could be linked to mass as a cause. It was found that hindlimb feathers decreased in length through the phylogeny and that there could be a link between hindlimb feather length and mass. Through this, a hypothesis explaining why birds went through a stage of having hindwings in their evolution could be theorised: to compensate for the large legs that they inherited from their theropod ancestors, basal birds had flight feathers on their hindlimbs to reduce the resultant excess drag and help them stay in the air. This theory would revolutionise our understanding of flight evolution and how dinosaurs transitioned to birds. However, this theory requires extensive experimentation to determine its validity and thus is the starting point for further research involving aerodynamic modelling of the limbs of all the basal birds in this study.

## RECONSTRUCTION OF *CRYPTOCLEIDUS EURYMERUS* HUMERUS MUSCLES, MUSCLE FORCES, AND LINES OF ACTION: IMPLICATIONS FOR PLESIOSAUR HUMERUS FINITE ELEMENT STRESS ANALYSIS

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Commonly bones are viewed as bending structures. Yet, recent studies show that all skeletal elements are loaded under a compressive regime, which is established by agonistically and antagonistically acting tension cords (ligaments, tendons, and muscles). The energy uptake is lowered by this design because it cancels out tensile stress. Therefore bones are biologically optimized lightweight constructions. Our study is designed to test this hypothesis and apply it to the humerus of an extinct probable underwater flyer, a plesiosaur. Plesiosauria are a highly successful clade of pelagically adapted marine reptiles inhabiting the Mesozoic oceans from the Late Triassic to the Cretaceous-Paleogene mass extinction. Unique to plesiosaurs are their four almost identically looking limbs that were modified into hydrofoil flippers, the dominant bone of which is the humerus, respectively the femur. To reconstruct muscles inserting, spanning, and originating on the plesiosaur humerus, we made use of the myology of extant phylogenetic brackets of plesiosaurs, i.e., Lepidosauromorpha, Archosauromorpha, and Testudines. Lines of action were deduced from the mounted skeleton of *Cryptocleidus eurymerus* in the Goldfuß Museum, University of Bonn, Germany. Finite element (FE) models were created from micro-CT scans of the right humerus of this specimen. The scans were edited and meshed with Simpleware ScanIP 5.1 and transferred to the finite element software ANSYS 12.0 to compute compressive stress distribution. The *Cryptocleidus eurymerus* humerus displays evenly distributed compressive stresses throughout, corroborating the hypothesis that bones are energetically optimized lightweight structures.

## THE DISCOVERY OF A RARE NEONATE *ICHTHYOSAURUS COMMUNIS* SKELETON AT THE LAPWORTH MUSEUM OF GEOLOGY AND THE RESEARCH TO DETERMINE ITS LOST PROVENANCE

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In 2016 a practically complete neonate ichthyosaur skeleton (no. BU5289) in the collection of the Lapworth Museum of Geology (University of Birmingham) was conserved and cleaned for display. The specimen is an example of *Ichthyosaurus* and is of particular note as relatively few neonate skeletons of *Ichthyosaurus* are known, although embryos have been described. Significantly, the specimen is identified as *Ichthyosaurus communis* based on the hindfin, pelvis and skull morphologies and it is the first definitive neonate example of this species reported. Much of the skeleton, but especially the phalanges of the fore and hind fins and also the humerus and vertebrae, bear a spongy-like cartilaginous texture which suggests the elements are not fully ossified. The skeleton was MicroCT scanned to aid the study of the bones that lay partly embedded in matrix. Unfortunately the specimen lacked any provenance information. However, during the conservation project a small (12g) sample of the matrix was taken to be analysed for microfossils. The results indicate that the specimen is the same age as the JF3 Foraminifera Zone, spanning the very latest Hettangian to very early Sinemurian in the Lower Jurassic. A possible source location is Hock Cliff, Gloucestershire. This project demonstrates the usefulness of conservation to research and highlights the potential use of microfossil analyses to provide an age and possible source site for the many marine reptile specimens in museum collections that currently lack a provenance, thereby greatly increasing their research potential.

## LIFE AFTER DEATH: SUBAERIAL AND SUBTERRANEAN NECROPHAGOUS INVERTEBRATE ACTIVITY IN DINOSAUR BONE FROM THE WEALDEN GROUP (EARLY CRETACEOUS), ISLE OF WIGHT, UK

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Invertebrate bioerosion including unusually large borings are reported for the first time in dinosaur bone from the Vectis Formation (Early Cretaceous, Barremian-Aptian) of Compton Bay, Isle of Wight. Sub-circular tunnels of up to 15mm diameter and 60mm maximum length penetrate trabecular bone from a large theropod (cf. *Baryonyx* sp.) pelvis. The specimen from a channel-fill sandstone, shows evidence of prolonged subaerial weathering and associated borings probably made by ossiphagous beetles. This suggests the occurrence of at least seasonally extended dry periods during the transitional stage from alluvial flood plain to deltaic-lagoonal complex. From the underlying Wessex Formation we describe subterranean burrows passing through an articulated skeleton of the small ornithomimid *Hypsilophodon foxii*, leaving a trail of bone-chips. The skeleton also displays borings and other destructive behaviour especially around the long bone epiphyses, with associated burrows indicating post-burial activity. There is no evidence for pupal chambers. The growing literature on continental Mesozoic bone macro-borings reflects their utility when reconstructing the palaeoclimate, palaeoenvironment and taphonomic history of a carcass, usually with adults or larvae of dermestid beetles (Coleoptera, Dermestidae) as the inferred trace makers. However the reported examples do not correlate well with the behaviour of extant species and we evaluate the roles of other invertebrates as scavengers of dinosaur bone in the Early Cretaceous.

## AN ALLIGATOROID FROM THE PALEOCENE OF NORTH AFRICA AND THE POST-EXTINCTION DISPERSAL OF ALLIGATORS

Polly Russell and Nicholas Longrich

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The Alligatoroidea, including alligators and caimans, are a freshwater clade within crown Crocodylia that extend back to the Late Cretaceous of North America. To date, all putative alligator remains from Africa have been deemed too fragmentary to be diagnostic. Here we describe a new species of *Diplocynodon* from the Paleocene/Ypresian phosphates of Morocco. The exceptional preservation of the fossil provides the first conclusive alligatoroid remains from Africa, and the new species positions amongst the stratigraphically earliest members of the clade, Diplocynodontidae. Biogeographic analyses indicate that this dispersal into Africa was an isolated event in the early history of this exclusively European clade. The appearance of alligators around the world in the Paleogene is suggestive of a post-extinction dispersal, with alligators dispersing to occupy niches left vacant by the K-Pg mass extinction.

## A TALE OF ICE AND CAMPFIRES: THE INFLUENCE OF HOMINIDS AND CLIMATE CHANGE ON THE BRITISH QUATERNARY CARNIVORAN GUILD

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The mammalian order Carnivora is a diverse clade occupying a wide range of environments and ecological niches. Around 2 Ma ago in Africa, early hominins acquired derived dietary strategies and increasingly invaded the carnivore niche space, effectively competing with large carnivores. We examined how the British carnivoran guild changed during the Quaternary period (2.58 Ma to present), when Britain underwent cycling glaciation events and was successively colonised by four *Homo* species. We analysed functional richness and evenness of the carnivoran guild at consecutive time intervals, using craniodental data of fossil and extant species. The impact of glacial cycles, prey abundance, and arrival of hominins on carnivorans was assessed using phylogenetic comparative statistics. The Late Pliocene-Early Pleistocene guild was considerably taxonomically different, yet similar in functional richness and evenness, to early Cromerian complex faunas. The Cromerian (0.8-0.478 Ma) includes several glacial cycles and the arrival of *Homo heidelbergensis*. By late *H. heidelbergensis* occupation, carnivoran numbers and large carnivore morphospace clustering were much decreased. *H. heidelbergensis* is associated with substantial evidence of tool usage, butchery, and possibly fire usage. Competition from *H. heidelbergensis* and carnivoran relatives, and reduction in prey species, are plausible drivers of this change. During British *Homo neanderthalensis* occupation there were no significant carnivore guild changes. All remaining large carnivores disappeared from Britain after *Homo sapiens* arrived, resulting in impoverished functional richness values. These patterns are similar to the decline of the African carnivoran guild, starting ~1.8 Ma ago, attributed to climate change and competition with early hominin species.

## A NEW GENUS OF OXFORD CLAY PLIOSAURID, WITH UNUSUAL TOOTH WEAR, STOMACH CONTENTS AND AVASCULAR NECROSIS

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CAMSM J63532-J63671 is a small, previously unknown pliosaurid from the Oxford Clay (Callovian) of Peterborough. It is well preserved, rich in anatomical detail and comprises most of the skull, mandible, teeth, vertebrae, ribs, partial pectoral girdle, pubes, humeri, femora and a near-complete paddle. Comparative studies have shown that it is remarkably similar to NHMUK R3891, a stratigraphically coeval specimen previously assigned to "*Pliosaurus*" *andrewsi*, and also comprising cranial and postcranial material. Recent phylogenetic analysis did not recover *P. andrewsi* within, nor as a sister taxon to *Pliosaurus* and for a long time its taxonomic status remained uncertain. This study shows that CAMSM J63532-J63671 and NHMUK R3891 are generically separate from all other currently valid Oxford Clay taxa and merit inclusion in a new taxon. Both are medium sized mesorostrine pliosaurids (distinct from *Marmornectes*, *Liopleurodon*, *Peloneustes* and the brevirostrine *Simolestes*). Their lateral rostral margins do not expand anteriorly as in *Peloneustes* and they differ from *Pachycostasaurus* by premaxillary and symphyseal tooth number and lack of extensive pachyostosis. The propodials closely resemble those of *Marmornectes* but cranial characters differ. In addition, there are features indicating similar lifestyles. CAMSM J63532-J63671 and NHMUK R3891 have teeth with unusual patterns of wear, suggesting a specialised diet. Further clues are derived from stomach contents in CAMSM J63532-J63671. Also the propodials of both specimens exhibit subsidence of cortical bone at their proximal articulations. This feature may be associated with avascular necrosis from rapid decompression following deep dives.

## COMPARATIVE ANALYSIS OF MORPHOLOGY AND COMPOSITION OF THE SYNARCUAL IN EXTINCT AND EXTANT BATOIDS (SKATES AND RAYS)

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Batoidea (Chondrichthyes) comprise approximately 550 species, inhabiting almost all marine ecological niches. Identified by their dorsoventrally depressed body and, endoskeletally, by their synarcual (fused anterior vertebrae). Research into the batoid vertebral column and synarcual has predominantly focused on overall morphology, but a detailed study of the individual vertebral elements, (including tesseræ -surfacial cartilage mineralisation- and centra) across the synarcual is lacking. This information will provide a better understanding of the growth processes involved whilst also highlighting the evolutionary changes of the synarcual; for example, interspecific variation in these features occurs as the synarcual becomes an increasingly more important part of the axial skeleton in extant versus extinct batoids. Computed tomography (CT) scans of the synarcual from each major order of extant batoids were 3D-rendered, allowing observations on the shape, size and density variations of tesseræ to be made, and incorporation of dorsal and ventral vertebral elements, and anterior centra. Tesseræ shape was highly variable surrounding the anteriormost centrum among extant batoids which, in turn, appears only partially formed. More derived taxa (*Raja clavata*) showed less centrum distortion and more regularly shaped tesseræ immediately surrounding centra. In less derived taxa (*Rhinobatos formosensis*), tesseræ were irregularly shaped and the centra distorted. In extinct batoids (†*Asterodermus platypterus*) the synarcual was shorter, while centra extended through the synarcual and were undistorted. Future work will focus on absence of mineralised centra in the synarcual of extant batoids (possible resorption), including comparative studies into the functionality of morphologically different tesseræ within each taxa.

## MACROEVOLUTION OF THE CROCODYLOMORPHA

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Extant crocodylians might be considered something of a failure. Since the emergence of the Crocodylomorpha in the Late Triassic their diversity has declined to just 23 species, compared to over 10,000 species in their sister clade, the birds. The extant crocodylians also show low morphological disparity, with all species being semi-aquatic ambush predators with a similar body plan. This low diversity and long fossil range has led to the crocodylians being described as 'living fossils', but is this justified? The Crocodylomorpha in the fossil record show great morphological diversity, including terrestrial, cursorial, fossorial and marine forms, insectivores, omnivores, herbivores and durophages. In this study we present a new super tree phylogeny of the Crocodylomorpha and evaluate the tempo and mode of crocodylomorph evolution using morphology. We find extreme conservatism of in the evolution of body size in the Crocodylomorpha and a number of its subclades. Rates of evolution are predominantly stable, but punctuated by environmental changes with rate-shifts in the crown-group associated with mass extinctions. Time-series modelling of Crocodylomorph diversity and morphological disparity compared with environmental variables finds evolution to be driven and constrained by temperature and the diversity of competing clades such as dinosaurs. We conclude that the Crocodylomorpha adhere strongly to the punctuated equilibrium and Court-Jester models of evolution. Therefore the limited diversity and disparity of the extant Crocodylomorpha is likely a reflection of their rather narrow range of ecological tolerances when compared to birds, and massively changed global environmental conditions that restrict the potential diversity of the group today.

## NEW INSIGHTS FROM HISTOLOGICAL STUDIES ON *METOPOSAURUS KRASIEJOWENSIS* LIMBS

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2 - University of Bonn

For the past 15 years various studies has been performed on the fossil material of a temnospondyl amphibian *Metoposaurus krasiejowensis*. The histological data sheds new light on various aspects on that animal's biology: In recent studies applied on various bones one analyzed the ecological adaptation in order to get information about biology and mode of life of this species, others focused on skeletochronological imprints or on skull mechanics of this animal. Here assessed long bones of *M. krasiejowensis* include humeri, femora, tibiae and fibulae. The material originates from Krasiejów, a Late Triassic locality in southeastern Poland. Evaluation of the tested bones shows two distinct growth patterns. Majority of bones represents Histotype I, which is characterized by an alteration of thick zones and annuli of the same thickness. Strong remodeling is present throughout the entire cortex with a vascularization that ranges from poor to moderate. Contrary to this is Histotype II which is characterized by a highly vascularized and extremely thick zone. The annulus is incipient and in some bones completely absent in the entire section. These results can be interpreted as intraspecific variability on the level of a population diversification. Here we favor a population diversification occurring due to a separation in space and/or time. The histotypes can be interpreted as two representatives of different populations of metoposaurids that were once living in the ponds of Krasiejów. A less likely explanation for the different growth patterns is sexual dimorphism. We do not support a hypothesis in which the histotypes represent taxonomic diversity.

# INVESTIGATING THE HYDRODYNAMIC IMPLICATIONS OF THE LONG NECK IN PLESIOSAUROIDEA (REPTILIA, SAUROPTERYGIA) USING COMPUTATIONAL FLUID DYNAMICS

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The Plesiosauroidea are iconic extinct marine reptiles that exhibit one of the longest necks relative to body length amongst vertebrates. An understanding of why the Plesiosauroidea had long protruding necks is still lacking; the clade is extinct and there are no modern analogues. Various hypotheses have been proposed regarding the use of the long neck, primarily concerning feeding strategies. These include snapping at fast moving fish, or extending the feeding envelope from a relatively static position, either floating at the surface or lying immobile at the bottom. However, the biomechanical implications of such a long neck on fundamental functions such as steady-state locomotion remain untested. Even the extent to which the neck could bend - the range of motion - has been understudied. We used computational fluid dynamics to explore the hydrodynamic effects of the long neck, both held straight and curved, during forward locomotion. Analyses include a series of simulations of an idealized 3D plesiosaur model carried out at different velocities (and consequently Reynolds numbers). Drag and flow passing over the 3D model were measured and visualized. Results show that when the neck is curved over a 90° arc, drag increases by ~50 % regardless of velocity. A curved neck creates a more complex flow pattern including zones of low velocity. We hope that this and further research will help to shed light on the biomechanical implications of the long neck in this clade and more broadly inform hypotheses concerning the lifestyle and evolutionary history of the Plesiosauroidea.

# IN AND AROUND LIVERPOOL

## Quick Bites

### 1. The Waterhouse Café at the Victoria Gallery & Museum

*Ashton Street, L69 3DR*

*Open 9am-4pm*

A selection of traditional soups, sandwiches, salads and hot dishes, all served within the beautiful Victoria Gallery & Museum.

### 2. 92 Degrees Coffee

*24 Hardman St, Liverpool L1 9AX*

*Open 7:45am-7pm*

Locally roasted coffee, along with pastries, cakes, and sandwiches.

### 3. Cuthbert's Bakehouse

*103 Mount Pleasant, Liverpool L3 5TB*

*Open 9am-6pm*

A bakery and tea shop, serving lunch sandwiches and soups from 11am to 5pm.

### 4. Lovelocks Cafe

*Unit 6 Old Haymarket, Liverpool L1 6ER*

*Open 8am-6pm*

If you're near the Museums or train station, this is a great spot for a quiet coffee or sandwiches

## Drinks

### 5. The Augustus John

*Peach St, Liverpool L69 7ZL*

*Open 11:30am-11pm*

Run by the University of Liverpool and a local favorite, with outdoor benches for enjoying the summer weather.

### 6. The Pen Factory

*13 Hope St, Liverpool L1 9BQ*

*Open 12pm-12am*

Housed in its namesake, it offers a variety of drinks, and a selection of nibbles and small plates from a daily menu, and plenty of room for a group—either indoors or out on the patio.

### 7. Fly in the Loaf

*13 Hardman St, Liverpool L1 9AS*

*Open 12pm-11pm*

While it's no longer a bakery, this pub has kept the traditional façade and a food menu, and is an excellent place for a chat over a few pints.

## Eating out

We recommend taking a walk down Bold Street, where the options include:

### Mowgli Street Food

*69 Bold St, Liverpool L1 4EZ*

Indian small plates and street food.

### The Italian Club

*85 Bold St, Liverpool L1 4HF*

Traditional Italian paninis, pizza, and pasta.

### Bakchich

*54 Bold St, Liverpool L1 4HR*

Lebanese street food

### Crust

*25 Bold St, Liverpool L1 4DN*

Pizza, pasta, beer, and all-day breakfast.

## Things to see

### 8-10. Liverpool Library & Museums

*William Brown St, Liverpool L3 8EW*

The World Museum and Walker Art Gallery flank the Central Library, with its Grade II listed Pictor Reading Room and Hornby Library. While you're there, pick up a drink and burgers at the Ship & Mitre (133 Dale St, Liverpool L2 2JH).

### Bold Street

Mostly pedestrianized, Bold Street has a quirky and eclectic mix of cafes and independent shops.

### 11. The Albert Dock and Liverpool Waterfront

Once a major seaport, the docks now house the Tate and Maritime Museums, along with pedestrian walkways, shops, and restaurants.

### 12. St Luke's Church

*Corner of Hardman and Bold St, L1 2TR*

St Luke's is a former church from the 1800's that was damaged during the Liverpool Blitz, and its roofless—but beautiful—shell remains as a memorial.

### 13. Liverpool Cathedral

*St James Mt, Liverpool L1 7AZ*

In contrast, the Liverpool Cathedral is an imposing Gothic-style structure, with gardens and view looking over the city.







