Programme and Abstracts

Edited by Stig Walsh, Nick Fraser, Stephen Brusatte, Jeff Liston and Vicen Carrió

61st Symposium on Vertebrate Palaeontology and Comparative Anatomy

22nd Symposium on Palaeontological Preparation and Conservation

Geological Curators' Group

27th–30th August 2013

Edinburgh 2013

Foreword

Welcome to the 22nd SPPC and 61st SVPCA, hosted jointly by National Museums Scotland and the University of Edinburgh. It is 14 years since SPPC/SVPCA was last hosted in Edinburgh; it was also hosted here back in the days of the Royal Museum of Scotland in 1966 and 1975. We expect a lively meeting this year, particularly as the number of registered delegates hit an all-time high of 137. This year the University of Edinburgh welcomes its students at the beginning of September, so the meeting was brought forward from its more normal slot in the calendar to take advantage of the student accommodation at Pollock Halls. As a result, the meeting coincides with the tail end of the Edinburgh Fringe, which officially ends the day before the joint GCG/SPPC meeting starts. This will surely contribute to the lively feel of this year's meeting!

The meeting logo was designed by Sarah Stewart (National Museums Scotland). Palaeozoic deposits in Scotland have produced tetrapod finds of world-wide importance, and the logo design commemorates this by using the initials of the meeting to form the stylised body, head and limbs of a basal tetrapod. For those of you who purchased one of the yellow and red conference T-shirts, the logo was adapted by Jeff Liston into a design intended to commemorate the 'Lion Rampant' on the Royal Flag of Scotland. We hope you wear your 'Tetrapod Rampant' with pride!

This year the meeting includes a special symposium in honour of the life and contribution to palaeontology of the late field palaeontologist Stan Wood, which is sponsored by the Palaeontological Association and NERC. The vertebrate collections of National Museums Scotland include many fossils that were collected by Stan, and we hope the symposium on Friday will highlight how Stan's collecting activities have helped to kick start and further the careers of a great many of today's established palaeontologists. As a further departure from established SVPCA tradition, the usual *scala naturae*-style taxonomic order of oral presentations has been broken up. We hope those presenting talks on mammals for once will enjoy getting their presentation out of the way right at the start of the meeting.

The abstracts in this volume are arranged alphabetically by first author and have been grouped in four sections; oral (pages 9-12) and poster (pages 12-13) presentations for SPPC/GCG, and oral (pages 13-47) and poster (pages 47-66) presentations for SVPCA. The abstracts have been lightly edited for 'house style', and in some cases for obvious spelling and grammatical errors. A list of registered delegates can be found on pages 67-69. This version of the volume differs slightly from the one given out at the meeting in that it incorporates changes made to the schedule immediately before the conference.

Stig Walsh

Nick Fraser

Stephen Brusatte

Jeff Liston

Vicen Carrió

Schedule

Tuesday 27th SPPC/GCG registration and presentations at the Grant Institute, University of Edinburgh

0800–0850 Registration
0850–0900 Welcome
0900–0920 **Special care for historical collections – The Timor Collection at Naturalis Biodiversity Center (the Netherlands)**. Natasja den Ouden & Becky Desjardins.
0920–0940 **Why look at fossils in infra-red?** Nigel Larkin.
0940–1000 **'Kong Long Dan': excavation, export and experience**. Jeff Liston.
1000–1020 **The Trento Experience: building life-like models of extinct species and shipping them 1000 miles to Italy**. Robert Nicholls.
1020–1100 *Coffee break*
1100–1120 **The use of expansive demolition agents for the extraction of large and delicate dinosaur fossils from the Upper Cretaceous of South-Central Pyrenees (Catalonia, Europe)**. Angel Galobart, Albert Garcia-Sellés & Bernat Vila.
1120–1140 **Estimating the volumes and masses of big plaster field jackets**. Donald Henderson.
1140–1200 **The new Palaeobiology Store at National Museums Scotland**. Andrew Ross.
1230–1300 Transport to National Museums Collections Centre
1300–1400 *Lunch and poster session*
1400–1600 Tour of National Museums Scotland Collections Centre: Palaeobiology Store, Mineral Store, Taxidermy lab and Preparation Laboratory.
1900 on SVPCA registration and Icebreaker reception at the Royal Society of Edinburgh.

Wednesday 28th SVPCA registration and presentations at the Royal Society of Edinburgh.

0830–0840 Welcome by Stuart Monro of Our Dynamic Earth.
0840–0900 **The biomechanics of feeding in the Laotian rock rat, *Laonastes aenigmamus***. Philip Cox.
0900–0920 **The marsupial-placental mammal dichotomy revisited: new morphological data and the relevance of geography on evolutionary patterns of diversity and disparity**. Marcelo R. Sánchez-Villagra, Madeleine Geiger & Analía M. Forasiepi.
0920–0940 **Sorting through the wastebasket: a phylogeny of Palaeocene mammals**. Thomas J. D. Halliday, Paul Upchurch & Anjali Goswami.
0940–1000 **Zalambdodonty and the phylogenetic position of *Necrolestes patagonensis*: assessing the presence of a 45 million year dryolestoid ghost lineage**. Rachel O'Meara & Richard Thompson.
1000–1020 **Playing the evolutionary tape backwards: graduality of signalling and patterning of mammalian teeth**. Enni Harjunmaa, Kerstin Seidel, Ian Corfe*, Zhang Zhao-qun, Aki Kallonen, Ophir Klein, Jukka Jernvall.

Session chair: **Steve Brusatte**

1020–1100 *Coffee break and poster session*.

1100–1120 **Exploring the patterns of cranial and mandibular co-variation within the order Rodentia**. Elizabeth Kerr, Sam Cobb & Phil Cox.

1120–1140 **Modern tracks, ancient steps**. Sarita Amy Morse, Matthew R. Bennett & Robin H. Crompton.

1140–1200 **Postural stability during locomotion: the effects of object tracking and dual tasking**. Emma Webster, Russell Savage, Robin Crompton & Nathan Jeffery.

1200–1220 **Claddis: a new R package for automating disparity analyses based on cladistic datasets**. Graeme Lloyd.

1220–1240 **Trace elemental imaging of exceptionally-preserved fossils: palaeontological and taphonomical implications**. Pierre Gueriau, Cristian Mocuta, Didier Dutheil, Serge Cohen & Loïc Bertrand.

Session chair: **Steve Brusatte**

1240–1400 *Lunch*.

1400–1420 **DGM 1475-R, a fragment of three-dimensionally preserved pterosaur wing membrane from the Santana Formation of Brazil**. David Unwin, David Martill & Richard Hing.

1420–1440 **Pterosaur overlords of Transylvania: short-necked giant azhdarchids in Late Cretaceous Romania**. Mark Witton, Matyas Vremir, Gareth Dyke, Darren Naish, Stephen Brusatte & Mark Norell.

1440–1500 **The taxonomy of GSM 3166 *Parapsicephalus purdoni* Arthaber 1919, a three dimensional pterosaur skull from the Lower Alum Shale of Whitby**. Michael O'Sullivan.

1500–1520 **Air space proportion in pterosaur wing bones**. Elizabeth Martin & Colin Palmer.

1520–1540 **Cephalopods in the diet of pterosaurs: evidence from a *Rhamphorhynchus* coprolite**. David Hone, Donald Henderson, Michael Habib & Francois Therrien.

Session chair: **Darren Naish**

1540–1600 *Coffee break and poster session*.

1600–1620 **Terrestrial vertebrates from the Late Triassic of Portugal: new records of temnospondyls and archosauriforms from a Pangaean rift sequence**. Stephen L. Brusatte, Richard J. Butler, Octávio Mateus, J. Sébastien Steyer & Jessica H. Whiteside.

1620–1640 **The sexual selection debate: extravagant structures and 'species recognition' in Mesozoic dinosaurs and other animals**. Darren Naish, David Hone & Robert Knell.

1640–1700 **Making some headway: retro-deformation of a tectonically deformed chasmosaurine ceratopsian skull**. Donald Henderson.

1700–1720 **Wear pattern, dental function and jaw mechanism in the Late Cretaceous ankylosaur *Hungarosaurus***. Attila Ösi & Paul M. Barrett.

1720–1740 **Edinburgh Museum's dinosaur, Waterhouse Hawkins's *Hadrosaurus foulkii***. Michael Taylor.

1740–1800 **An unusual macrophagous metriorhynchid from the Late Jurassic of England**. Mark T. Young, Lorna Steel, Stephen L. Brusatte, Eliza A. Howlett, Matt Riley, Erich Fitzgerald, Brian L. Beatty, Casey Holliday.

Session chair: **David Unwin**

1900 Whisky tasting at the Royal Society of Edinburgh (TBC)

Thursday 29th SVPCA registration and presentations at the Royal Society of Edinburgh.

0830–0850 ***Barosaurus* revisited: the concept of *Barosaurus* (Dinosauria: Sauropoda) is based on erroneously referred specimens**. Michael P. Taylor & Mathew J. Wedel

0850–0910 **A giant, skeletally immature individual of *Apatosaurus* from the Morrison Formation of Oklahoma**. Matt Wedel.

0910–0930 **Biomechanical evidence of niche partitioning between sympatric sauropod dinosaurs**. David Button, Emily Rayfield & Paul Barrett.

0930–0950 **New data on Early Jurassic theropod diversity in the Lufeng Formation of Yunnan Province, China**. Jeff Liston & Darren Naish.

0950–1010 **Using the Character Completeness Metric to examine completeness of Mesozoic dinosaurs: a Maastrichtian high and a palaeoequatorial low**. Mark Bell, Paul Upchurch, Philip Mannion & Graeme Lloyd.

1010–1030 **Large geographic ranges confer little protection against extinction in terrestrial tetrapods across the T-J boundary**. Alexander Dunhill & Matthew Wills.

Session chair: **Mark Young**

1030–1050 *Coffee break and poster session*.

1050–1110 **Updating the Maastrichtian dinosaur record of the Southern Pyrenees (SW Europe)**. Bernat Vila & Albert G G. Sellés.

1110–1130 **Neogene auks (Aves, Alcidae) in North Atlantic cool waters - review and quest**. Ella Hoch.

1130–1150 **Studies of endocasts in extant and extinct birds: flying and behavioural implications**. Vincent Beyrand, Paul Tafforeau, Vincent Fernandez & Eric Buffetaut.

1150–1210 **Early evolution of the modern avian wing**. Gareth Dyke, Gary Kaiser & Darren Naish.

1210–1230 **The aerodynamics of feather asymmetry and implications for paravian flight**. Michael Habib.

Session chair: **Stig Walsh**

1230–1400 *Lunch*.

1400–1420 **Tooth replacement in durophagous placodont marine reptiles (Sauropterygia, Placodontia), with new data on the dentition of Chinese taxa**. James M. Neenan.

1420–1440 **Reassessment of the 'Paris Plesiosaur'**. Mark Evans & Michael A. Taylor.

1440–1500 **Understanding the hydrodynamics and ecomorphology of plesiosaurs - a computational and experimental approach**. Luke Muscutt.

1500–1520 **The early evolutionary radiation of Triassic marine reptiles**. Tom Stubbs & Michael Benton.

1520–1540 **A new rhomaleosaurid pliosaur from the Sinemurian (Lower Jurassic) of Lyme Regis, England**. Adam Smith & Ricardo Araújo.

1540–1600 **Morphological and hydrodynamical convergence in pelagic vertebrates**. Benjamin Moon.

Session chair: **Judy Massare**

1600–1620 *Coffee break and removal of posters*.

1620–1640 **A fresh look at the genus *Ichthyosaurus*: species characteristics, phylogeny and evolutionary drivers**. Jessica Lawrence Wujek, Darren Naish & Gareth Dyke.

1640–1700 **Variation in the forefin morphology of the lower Jurassic ichthyosaur genus *Ichthyosaurus***. Judy A. Massare & Dean R. Lomax.

1700–1720 **A first report on a nearly complete Middle Triassic mixosaurid ichthyosaur from Edgeøya, Svalbard archipelago**. Jørn Harald Hurum, Aubrey Jane Roberts, Hans Arne Nakrem, Jan Stenløkk & Atle Mørk.

1720–1740 **A new Upper Jurassic ophthalmosaurid ichthyosaur from central Spitsbergen**. Aubrey Jane Roberts, Jørn Harald Hurum & Patrick S. Druckenmiller.

1740–1800 **On the taxonomy, life history and evolutionary patterns of diversification of the basal actinopterygian fish *Saurichthys***. Erin E. Maxwell, Marcelo R. Sánchez-Villagra*, Torsten M. Scheyer, Leonhard Schmid, Laura A. B. Wilson & Heinz Furrer.

Session Chair: **Matt Wedel**

1900 Jones Fenleigh Fund auction at the Royal Society of Edinburgh

Friday 30th SVPCA registration and presentations at National Museums Scotland.

0840–0900 **150 million years of morphological evolution in neopterygian fish: implications for notions of teleost superiority**. John Clarke & Matt Friedman

0900–0920 **'Fin End of the Wedge': variability of pectoral fin shape in a group supposedly uniformly 'scythe-like'**. Jeff Liston, Anthony Maltese & Jesús Alvarado Ortega.

0920–0940 **Getting inside the head of Cretaceous-Palaeogene teleosts: new morphological and functional data from the exceptional fish fossils of the English Chalk and London Clay**. Roger Close, Hermione Beckett, Norman MacLeod, Zerina Johanson & Matt Friedman.

0940–1000 **Early pufferfishes and kin (Percomorpha: Tetraodontiformes) from the Eocene London Clay: new anatomical insights from computed tomography**. Matt Friedman, Roger Close, William Fowler & Zerina Johanson.

1000–1020 **A virtual view of early ray-finned fish endocasts**. Sam Giles & Matt Friedman*

Session chair: **Per Ahlberg**

1020–1040 *Coffee break and poster session*.

Stan Wood Symposium

1040–1050 Welcome by Jane Carmichael, Director of Collections, NMS.

1050–1110 **What made Stan such a successful collector?** Ian Rolfe.

1110–1130 **Stan loved a good fossil: some recent spectacular fossil fish finds from Gogo (late Devonian, Australia)**. John A. Long & Kate Trinajstic.

1130–1150 **Tournaisian tetrapods from Scotland**. Jenny Clack & Tim Smithson.

1150–1210 **A partial lower jaw of a tetrapod from the Tournaisian of Scotland**. Per Erik Ahlberg, Donglei Chen, Martin Brazeau & Henning Blom.

1210–1230 **Glencartholm revisited**. Margaret Elliot.

Session chair: **Tim Smithson**

1230–1400 *Lunch*.

1400–1420 **Lungfishes from Romer's Gap: experiments in tooth plate morphology**. Tim Smithson & Jenny Clack.

1420–1440 ***Ageleodus*: widespread mid-Palaeozoic sharks known only from teeth**. Susan Turner.

1440–1500 **Computed tomographic investigation of newly recognized specimens of *Tristychius*, a pivotal taxon in chondrichthyan phylogeny**. Michael Coates, Katherine E. Criswell, Ellen Verner & John Dick.

1500–1520 **Fossilized ontogenies: Gogo placoderms reveal embryonic development in 370 million year old early vertebrates**. Zerina Johanson & Kate Trinajstic.

Session chair: **Jenny Clack**

1520–1540 *Coffee break and poster session*.

1540–1600 **Fossils of early vertebrates and the evolution of the gnathostome face revealed by synchrotron imaging**. Vincent Dupret, Sophie Sanchez, Daniel Goujet, Paul Tafforeau & Per E. Ahlberg.

1600–1620 **Cranial roof bone names and homologizations between fishes and tetrapods. An old controversy revisited**. Ulf J Borgen.

1620–1640 **Palaeoneurology in Devonian lungfish: morphological diversity or conservatism in the neurological system?** Tom Challands.

1640–1700 Plenary session on the future of the SVPCA and Jones Fenleigh Memorial Fund.

Session chair: **Mike Coates**

1900 Annual Dinner at the Royal College of Physicians.

* indicates presenting author where the first author is not present.

SPPC/GCG Papers

Special care for historical collections – The Timor Collection at Naturalis Biodiversity Center (the Netherlands)

Natasja den Ouden & Becky Desjardins
Naturalis Biodiversity Center, Leiden, Netherlands.

The Indonesian island of Timor is rich in sediments dating from the Permian period. These sediments are of marine origin and contain a very large amount of representatives of marine invertebrate groups (corals, brachiopods, ammonites, belemnites, blastoids, crinoids). At the beginning of the 20th century the species richness and outstanding preservation of the fossil material was recognized and several expeditions were organized. Most notable are the expeditions organized by Prof. Molengraaff (Delft University) from 1910-1912 and Prof. Brouwer (University of Amsterdam) in 1937. Both collections are now housed at Naturalis Biodiversity Center in Leiden. Together they form the largest museum collection of Timor fossils worldwide and they are of great importance for the study and reconstruction of Permian marine ecosystems. As the material was collected a century ago, it is now suffering from degrading packaging material and fading ink on labels. A special project is underway to clean and repack the fossil material, digitize the information on the labels and photograph fading labels and type specimens. The project is part of a larger digitization program where a total of 37 million museum objects (fossils, rocks and minerals, recent plants and animals, but also registers and antique books and drawings) housed in Naturalis will be digitized and information made available on the internet. On top of this, our project is being carried out in the LiveScience hall of the museum, which means that visitors can see our work, monitor our progress and ask questions.

The use of expansive demolition agents for the extraction of large and delicate dinosaur fossils from the Upper Cretaceous of South-Central Pyrenees (Catalonia, Europe)

Angel Galobart, Albert Garcia-Sellés & Bernat Vila*
Universidad de Zaragoza, Zaragoza, Spain.

The uppermost Cretaceous fossiliferous rocks from Coll de Nargó (Lleida, Catalonia) mainly consist of cemented calcareous mudstones with strong lithological resistance. In these conditions, the use, for the first time, of expansive demolition agents (EDA) in rock volume containing fossils was found to be an efficient alternative to pneumatic hammers or heavy machinery. The use of expansive demolition agents is common in mining and quarrying. Recently, non-explosive agents have been also used as a successful methodology for removing rock blocks in palaeontological fieldwork. Here, we present two examples of the usage of EDA in palaeontological fieldworks consisting of the removal of large and heavy blocks containing delicate and/or small-sized fossils. The first example consists of the extraction of the largest dinosaur clutch described in Europe, containing 28 dinosaur eggs, which is 1 m^3 in volume and about 2 tonnes in weight. The second one involves a minute vertebrate skeleton in anatomical connexion. In both cases, multiple equidistant holes of 50 mm diameter were drilled around the fossil remains, and

then filled with the expansive demolition agent. After a few hours the agent reached its maximum pressure on the rock (9,000 tonnes/m^2), cracked the surrounding sediment and left the fossils intact to be removed with safety. Protective gypsum jacket, acrylic resins, polyurethane and even iron structures are good complements to protect and transport fossils to the restoration laboratory.

Estimating the volumes and masses of big plaster field jackets

Donald Henderson
Royal Tyrrell Museum of Palaeontology, Drumheller, Canada.

Recovering the fossil remains of dinosaurs and other large Mesozoic reptiles frequently involves creating and moving very large blocks of rock that can sometimes weigh up to several tonnes. Accurately knowing the mass of a fossil block greatly assists in planning how to move it, what equipment will be needed, and what sort of powered lifting in the forms of trackhoes, cranes, and even helicopters will be required. The storage of large blocks also requires knowing the masses of blocks as the loading capacities of shelves, tables and floors need to be taken into consideration. It has been our experience at the Tyrrell Museum that people typically tend to underestimate the masses of large fossil jackets. Using some recently collected large jackets as worked examples – a plesiosaur removed as six small to medium jackets and a very large partial *Triceratops* – several different techniques for making estimates of their masses were tried. These jackets were then weighed with a digital scale, and the percent error of the mass estimates were calculated. Approximating the shape and dimensions of plaster jackets with tri-axial ellipsoids produced the best estimates, but these tended to underestimate the true weight by 6-7%. In contrast, approximating a jacket with a rectangular box that fully enclosed it, tended to severely overestimate the mass by up to 140% is some cases.

Why look at fossils in infra-red?

Nigel Larkin
Natural History Conservation, Newport, UK.

Geology and palaeontology collections often contain specimens that require quite different environmental conditions from one another. Therefore the environmental conditions of museum stores are generally kept in the middle ground as far as practically possible. It would make sense to try to understand the subtle differences in conditions provided within a storage area so that the material can be arranged accordingly, but subtle differences in environmental conditions are difficult to measure. However, modern digital infrared thermal imaging technology can provide exactly the sort of data required, and in incredible detail: an infrared camera providing an image resolution of just 640 x 480 pixels will give 307,200 separate temperature data points within an image, with an accuracy of about 0.1 °C to 0.045 °C. Bearing in mind we can quantify how much the relative humidity will rise or fall for every degree of change in temperature, this equipment provides a level of environmental analysis of museum collections areas that other data logging equipment cannot match, and presents it in a highly visual format that is generally intuitively understood but also easily analysed with proprietary software. There are many factors influencing the accuracy and interpretation of the data, however, so training is required. Uptake of the technology for collections management purposes in

museums is currently in its infancy due to a lack of awareness of how the technology can be applied.

‘Kong Long Dan’: excavation, export and experience

Jeff Liston
Yunnan University, Yunnan, China.

Dinosaur eggs have been known from a variety of provinces of China for over 50 years. In the late 1980s, as large numbers were being unearthed by farmers, Chinese examples began to regularly enter collections throughout Europe, through the aegis of international fossil dealers. As small and discrete objects, they were appealing to museums, and presented a compelling object to swiftly capture the imagination of a public audience. From a research perspective, they were suddenly a new and accessible resource – the application of emergent scanning technologies to these objects (albeit with varying results) allowed the possibility of exploring the contents of unhatched eggs, in search of possible dinosaur embryos, and many research institutions acquired them with this in mind. Recently, moves have been made by the Chinese Government to repatriate such material, with some notable successes. This clearly presents some threats to museums and other institutions worldwide that either already hold such material, or are looking to acquire examples. Can this be legally done? What are the lessons in terms of acquiring material for either research work or museum collections? Perhaps more importantly, what are the potential dangers of repatriation of such objects in view of this new clampdown?

The Trento Experience: building life-like models of extinct species and shipping them 1000 miles to Italy

Robert Nicholls
Paleocreations, Bristol.

The new MUSE Science Museum in Trento, Italy was opened to the public on July 27th, 2013. I was commissioned to make life-like models (scale and life-size) of twenty extinct species for the museum. Great experience of dealing with complex technical problems was gained in the creation of these models. Slender invertebrate appendages require very different sculpting materials and techniques to those of the muscular bodies of larger vertebrates. So, how was a realistic finish achieved for such a wide variety of forms? And, once completed, how were these fragile one-of-a-kind items shipped undamaged 1000 miles from Bristol to Trento?

The new Palaeobiology Store at National Museums Scotland

Andrew Ross
National Museums Scotland, Edinburgh, UK.

The new Palaeobiology Store at the National Museums Scotland is now open for visiting researchers to study its collections. The Royal Museum on Chambers Street, Edinburgh (now part of the National Museum of Scotland) was refurbished with new exhibition galleries, which opened in 2011. As part of this project, all the Palaeontology collections that were in the Royal Museum were moved to the National Museums Collections Centre

(NMCC) at the north side of Edinburgh. A new extension to one of the existing stores was built and the Palaeontology collections are now housed on the ground floor. Moving of the collections commenced late 2010 and was finished by the summer of 2012. Since then the Palaeobiology curatorial team have been busy unpacking the specimens. The store is approximately 400 m squared with good environmental controls (temperature and humidity) and lights with motion sensors. There are two banks of mobile racking – 65 racks in all, 2 metres high. There are three types of storage – 1) 130 new lockable metal cabinets house the type & figured collection and part of the vertebrate collection; 2) the main racking houses the existing drawers and crates; 3) part of the racking has large open-span shelves to take some of the larger crates and slabs. So now the Palaeontology collections at National Museums Scotland (about 250,000 specimens) are housed in excellent conditions to safeguard them for future generations, and in one place – the first time for at least 50 years.

SPPC/GCG Posters

Pros and cons of restoration

Vicen Carrió[1] Fatima Marcos[2]
1 - National Museums Scotland, Edinburgh, UK.
2 - T.E. de restauración paleontológica de "Lo Hueco", Spain.

The criteria for conservation and restoration of a specimen have always been problematic. Restoration has been an issue that has generated controversy: should we restore missing parts at all? How far should we intervene and interpret? What should we use? Do we have the proper training to do so? In palaeontological preparation the issue is even more complex. In most cases, the restoration is not for aesthetics, but to give stability to the specimen. We are rediscovering animals and plants that lived in the past, and in many cases, we do not know their anatomy. The collaboration between the researchers and the preparators will dictate the way in which the restoration will be undertaken, according to the scientific use of the piece. Common to all the criteria used is that the restoration must be reversible and recognizable, so that we can always return the piece to its original condition. Furthermore, all conservation materials used should be compatible with the original fossils. The characteristics of the added parts must be similar and not cause further damage or deterioration to the specimen. Currently, in conservation and restoration, we use a number of acrylic resins, which have been proven to be inert and reversible. Resins are used both in restoration for structural reinforcement, and for aesthetic restoration. These resins are miscible with various types of fillers that will modify their colour, texture or hardness. Different situations call for different mixtures of solvent, fillers and resins to be used. Depending on the amount of product to be mixed and the percentage of the resin with respect to the solvent, the 'characteristic' result product will be different, allowing us to apply it as the piece requires.

Storage enhancement of the Palaeontological Collection at Facultad de Ciencias (Uruguay): Quaternary vertebrates make the first move.**

Alejandra Rojas[1], Martin Ubilla*[1], Andrea Corona[1], Andrés Rinderknecht[1,2] & Fernanda Cabrera[1]
1 - Universidad de la República, Montevideo, Uruguay.
2 - Museo Nacional de Historia Natural, Montevideo, Uruguay.

The Palaeontological Collection at Facultad de Ciencias, Montevideo (FCDP) is the most representative collection of the rich Uruguayan fossil record in the country. Leaving behind past neglect, recent collection management activities have improved the care and condition of the FCDP fossil specimens. Some of the main problems of the FCDP are the virtual absence of a regular budget for supplies and the lack of space for the growth of the collection. However, a recent research project allowed the acquisition of three new cabinets, 2 m high, locked white metal made with 56 drawers each. As Uruguay represents an extremely small market, no specific natural history collection suppliers exist. Then, the new cabinets had to be designed and manufactured especially for the FCDP. These will allow the future growth of the collection and the relocation and reordering of pre-existing fossil specimens. The forefront in occupying the first drawers was the Quaternary continental vertebrates of the Sopas Formation of Uruguay, mostly represented by mammals. Almost 500 specimens and lots were moved. Many old fossil containers were replaced by lidded transparent boxes and the specimens were taxonomically ordered in the cabinets. Associated data was digitally recorded, taxonomic assignation was revised and updated and all specimens were imaged. The results of this effort are not only the evident enhancement of an important and well studied portion of the Uruguayan fossil record but also the highlight of the scientific and patrimonial value of the whole Palaeontological Collection.**Contribution to ANII/FCE-1-2009-2398 (M.U.)

SVPCA Papers

A partial lower jaw of a tetrapod from the Tournaisian of Scotland

Per Erik Ahlberg[1], Donglei Chen[1], Martin Brazeau[2], Henning Blom[1]
1 - Uppsala University, Sweden.
2 - Imperial College London, UK.

The posterior part of a right lower jaw ramus, NMS G. 1977.43.3, was collected by Stan Wood from Tournaisian strata near Tantallon Castle, North Berwick. Initially identified as a rhizodont, it is in fact a tetrapod jaw and contributes to the growing record of Early Carboniferous tetrapod diversity. The specimen was described and analysed phylogenetically by Chen, with assistance by Ahlberg, Brazeau and Blom. Although incomplete, it yields a surprisingly good phylogenetic data set. Its adductor fossa has a concave mesial margin and a straight lateral margin. The growth centre of the prearticular lies below the middle of the adductor fossa, and the bone carries a dorsal denticle field bounded ventrally by a horizontal ledge. The angular wraps round the ventral margin of the jaw to contact the prearticular mesially, posterior to a long

Meckelian fenestra. The mandibular sensory canal runs along the ventral margin of the jaw, in a largely open groove. There is a striking contrast between the ornament on the angular, which is coarsely sculptured, and that on the surangular which consists of fine radiating ridges. Only a short edentulous fragment of the posterior coronoid survives, but its cross-section shows a distinct dorsal crest which suggests that it may have carried a linear tooth row. A phylogenetic analysis places the jaw in an unresolved tetrachotomy with *Occidens*, *Pederpes* and [*Greererpeton* + higher tetrapods], one node above *Whatcheeria*; it is thus, like many other Early Carboniferous tetrapods, a crownward member of the tetrapod stem group.

Using the Character Completeness Metric to examine completeness of Mesozoic dinosaurs: a Maastrichtian high and a palaeoequatorial low.

Mark Bell[1], Paul Upchurch[1], Philip Mannion[2] & Graeme Lloyd[3]
1 - University College London, London, UK.
2 - Imperial College London, London, UK.
3 - University of Oxford, Oxford, UK.

A recently proposed metric for quantifying the completeness of fossil taxa is applied to Mesozoic dinosaurs; the Character Completeness Metric (CCM) measures the percentage of morphological characters available for scoring in phylogenetic data matrices. Calculating completeness is important for our understanding of the quality of the rock record and for any interpretations we may make of the resultant patterns. The source of data here is a compilation of 639 published character matrices. New code written in R calculates the mean CCM of taxa across all matrices. The mean CCM value for each stratigraphic stage was calculated through rarefaction of all species means for that interval. Spearman-rank correlations were conducted between mean CCM and dinosaur diversity (using both raw taxic and subsampled species diversity) as well as estimates of worker effort. Lastly, we examined the relationship between palaeolatitude and completeness in the Cretaceous. Dinosaurs show a decreasing trend in completeness between the Carnian and Cenomanian followed by an increase until the Maastrichtian. Significant positive relationships were recovered with taxic diversity and worker effort with no relationship recovered with subsampled diversity. The palaeolatitudinal completeness of dinosaurs shows a similar trend to that documented for their diversity, with peaks in palaeotemperate regions, and the lowest values near the palaeoequator. This pattern is most prominent in theropods and ornithischians. This study demonstrates that although dinosaur completeness varied throughout their evolutionary history, the decoupling from sample corrected diversity suggests that patterns of dinosaur diversity are not controlled by the quality of their fossil record.

Studies of endocasts in extant and extinct birds: flying and behavioural implications

Vincent Beyrand[1], Paul Tafforeau[2], Vincent Fernandez[2] & Eric Buffetaut[3]
1 - Guéret, France.
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Birds present an important variability in their type of flight depending on their behaviour and ecology. These differences involve important modifications in modes of environmental perception, and hence in the structures that integrate such information. The brain has the main role of integrating information from the environment and translating it into behaviour. While the brain is not fossilised along with other remains, the morphological similarities between the brain and the endocranial cavity in birds allow neurocranial studies of extinct taxa and give us crucial information about the evolution of flight in birds, from the Jurassic to present. Modelling endocasts may help to define organisational patterns in extant species with the aim of deducing the behaviour of fossil birds and to assess additional ecological and ethological information (flying, feeding behaviour). The results so far tend to show a relation between endocast shape and flying behaviour in birds. The morphological analysis of an Enantiornithes endocast highlighted a well-developed optic tectum together with a reduced cerebellum. The phylogenetic analysis confirmed a relationship between endocast shape and behaviour but surprisingly the absence of a clear phylogenetic signal. The generated tree displayed a marked locomotor distinction between flying and non-flying birds and within different types of flight (occasional or regular aerial or subaquatic flights). These results, together with recent anatomical studies, lead to the conclusion that Enantiornithes had evolved the neurological prerequisites for flight, in an intermediate position between occasional and regularly flying birds.

Cranial roof bone names and homologizations between fishes and tetrapods. An old controversy revisited

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In the mid-nineteen thirties Stanley Westoll changed the names of the cranial roof bones of osteolepiform fishes. This was based on a new interpretation of the homologies of these bones between osteolepiform fishes and tetrapods. His interpretation has gradually become dominating and is today followed by most palaeoichthyologists. It has influenced also the names used on the cranial roof bones in actinopterygians. This interpretation, which at that time was bold, innovative and seemingly logical, can now be seen as probably incorrect. Present knowledge reveals that Westoll's main arguments were wrong. Supporters of Westoll's interpretation have disregarded the prolonged snout of many of the early tetrapods and the results of this on cranial roof bones. Besides, they have disregarded the posteriad change in position of the so called pineal opening in the clade within osteolepiform fishes leading to tetrapods. Comparisons in bone and sensory canal patterns between osteolepiform fishes and tetrapods show that the so-called orthodox bone terminology, which was used by palaeoichthyologists previously to Westoll's suggestions, probably is correct.

Terrestrial vertebrates from the Late Triassic of Portugal: new records of temnospondyls and archosauriforms from a Pangaean rift sequence

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The Late Triassic (ca. 237-201.5 million years ago) was a transitional interval in the evolution of terrestrial ecosystems, during which 'modern' clades such as archosaurs and mammals were radiating while 'archaic' groups such as temnospondyl amphibians and basal synapsids remained abundant. Little is known about the Triassic terrestrial (non-marine) vertebrates of the Iberian Peninsula. The Algarve Basin of southern Portugal is an extensional rift basin formed during the breakup of Pangaea, which is filled with terrestrial, lacustrine, and marginal marine siliciclastics of the Grés de Silves Formation, interbedded with CAMP basalts that mark the end-Triassic extinction (radioisotopically dated to ~198-201.5 Ma). Since 2009, our field project in the Algarve has discovered numerous vertebrate specimens within the Grés de Silves, including a monodominant bonebed containing hundreds of specimens of metoposaurids, a peculiar group of temnospondyls that filled crocodile-like predatory niches in lacustrine and fluvial environments. These specimens appear to belong to a new species of *Metoposaurus*, similar to *M. diagnosticus* and *M. krasiejowensis* from central Europe but possessing several putative autapomorphies of the braincase and lower jaw. We also discovered a mandible of a phytosaur, the first specimen of these long-snouted, semi-aquatic archosauriforms from the Iberian Peninsula. These discoveries of characteristic Carnian-Norian taxa indicate that the fossil-bearing portion of the Grés de Silves is Late Triassic in age, and provide further evidence that metoposaurids and phytosaurs commonly occurred together in low palaeolatitudes during this time.

Biomechanical evidence of niche partitioning between sympatric sauropod dinosaurs

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The sauropod dinosaurs were the largest terrestrial vertebrates. Given the extreme nature of their biology, sauropods present many problems, not least how they secured sufficient food intake. Furthermore, many sauropod faunas are highly diverse, implying sophisticated resource partitioning between them. The high craniodental diversity differentiating sympatric sauropod taxa has often been cited as evidence of niche partitioning, especially so for the well-known and highly diverse Morrison Formation fauna. In particular, the abundant Morrison taxa *Diplodocus* and *Camarasaurus* represent extremes in the spectrum of sauropod craniodental morphology and have been hypothesized as being adapted towards branch-stripping and production of greater bite forces, respectively. However, these hypotheses have yet to be tested through comparison of these taxa within a rigorous biomechanical context. We rectify this deficit through cranial muscle reconstruction and finite-element modelling of a skull of *C. lentus*, allowing comparison with a pre-existing model of *Diplodocus*. Results

demonstrate significantly greater bite forces in *Camarasaurus* than *Diplodocus*. The skull of *Camarasaurus* is also 'stronger' under static biting than *Diplodocus*, although this is due to compensatory effects of greater size rather than greater structural efficiency. Modelling other hypothesized feeding behaviours indicates that *Camarasaurus* would have been capable of exploiting a varied feeding repertoire. The results here provide biomechanical evidence for niche partitioning between Morrison sauropod taxa, with *Camarasaurus* capable of employing higher bite forces and a range of behaviours to deal with a greater range of coarser foodstuffs than sympatric diplodocids, which were more specialized in their foraging behaviour.

Palaeoneurology in Devonian lungfish: morphological diversity or conservatism in the neurological system?

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Lungfishes (Dipnoi) serve a critical comparative role in our understanding of tetrapod evolution. As the sister group of tetrapods, lungfishes represent the closest extant divergent line in the evolution of the tetrapod neurosensory system. Examination of the neurological system in fossil lungfish is vital to establish if living lungfish retain the same neurological characters as primitive lungfish. In the absence of numerous endocasts of extinct primitive tetrapods and tetrapodomorphs, this will have a direct bearing on how suitable extant lungfishes are as a model for primitive tetrapod neurology. However, we do not know what neurosensory characters were present in Devonian Dipnoi and how they varied. A new digital endocast of *Chirodipterus* is presented here refining previous interpretations of the neurosensory system of this taxon based on observations of the endocranium. Furthermore, the structure of the forebrain of a Devonian dipnoan is revealed for the first time. The telencephalic floor is postero-ventrally expanded, unlike extant dipnoans, and the olfactory bulb is contiguous with the telencephalon, seen only in the African lungfish *Protopterus annectens*. The pineal organ is located antero-dorsally on the diencephalon which possesses a postero-ventrally expanded hypophysis to the hypothalamus as seen in *Protopterus annectens*. This study forms the first in a series to interrogate the Devonian dipnoan neurosensory system to establish morphological diversity or conservatism during the flourishing of the Dipnoi during the Devonian.

Tournaisian tetrapods from Scotland

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In 2012, our group reported new tetrapod taxa from the Tournaisian of Scotland. Stan Wood and Tim Smithson have each found further specimens. We report here on the challenges they present for interpretation and for potential understanding of tetrapod relationships. We introduce two enigmatic specimens from Burnmouth, with further information on one from Willie's Hole. Both Burnmouth specimens are small: one derives from a horizon about half way through the Tournaisian sequence, the other from somewhat higher up. The former consists of a disarticulated skull with postcrania. The jugal appears primitive with a long posterior extension and a shallowly embayed orbital

margin. A presumed tabular with a posterior 'horn-like' process bears overlap surfaces for two more medial bones. If interpreted correctly they suggest a tabular-parietal contact. A quadrate, an exoccipital and possible basioccipital are present. The postcrania include a lozenge-shaped interclavicle, both cleithra, clavicles and humeri, a radius, scapulocoracoid, ribs, centra and neural arches. The other specimen consists of a disarticulated skull with a primitive form of pterygoid, a jugal with a deeply excavated orbital margin, a distinctive lower jaw, teeth with folded enamel, and a parasphenoid with posterior wings. Specimens differ greatly from each other, neither resembles any previously known taxon. The Willie's Hole specimen superficially resembles that of a temnospondyl in outline, although key features cannot be seen. The pterygoid appears broad suggesting small or absent interpterygoid vacuities. These specimens illustrate unsuspected diversity and possible explosive radation of tetrapods in the earliest Carboniferous.

150 million years of morphological evolution in neopterygian fish: implications for notions of teleost superiority

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Neopterygian fishes represent over half of all extant vertebrate species, and comprise the diverse teleost lineage with ~29,000 species and their taxonomically depauperate holostean sister group, which contains a mere eight species. The stark contrast between these two clades has provided the basis for assertions of teleost 'superiority' and fuelled a series of evolutionary scenarios, many of which make explicit – and therefore testable – morphological predictions. However, few studies have explored the rich 250 Myr neopterygian fossil record from this perspective, rendering it an untapped resource for testing their predictions. We quantified morphological diversity for >350 neopterygian species across 150 million years of the Mesozoic and constructed a supertree of fossil neoptergyians to test the following hypotheses derived from neontological datasets: (i) holosteans are characterized by extremely low rates of evolution, implying that their low diversity today accurately reflects historical patterns; and (ii) genome duplication within the teleost stem lineage was responsible for elevated rates of morphological change in the group relative to holosteans. Our data reject both of these predictions. Firstly, the variety of holostean morphologies exceeds those displayed by teleosts across the Triassic. Secondly, the gar lineage, Darwin's original 'living fossil', exhibit high rates of morphological change and numerous rate shift increases. Thirdly, and perhaps most significantly, preliminary analyses reject notions that teleosts display elevated rates of morphological evolution. Overall rates in the holostean and teleost total groups appear similar, although shifts to higher rates are apparent in portions of the teleost stem lineage.

Getting inside the head of Cretaceous-Palaeogene teleosts: new morphological and functional data from the exceptional fish fossils of the English Chalk and London Clay

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Three-dimensional fossil fishes from the Late Cretaceous (Cenomanian-Campanian) English Chalk and Eocene (Ypresian) London Clay have been known and collected for nearly two centuries. Despite excellent preservation, fishes from these exceptional localities have received little attention outside of monographs that are all now over 50 years old. The application of computed tomography (CT) has permitted us to efficiently extract considerable new morphological and functional information from large numbers of fossil fishes from the English Chalk and the London Clay. Fishes from both deposits preserve features like articulated gill skeletons and inflated braincases, character-rich anatomical systems that are generally poorly preserved in flattened specimens found in lithographic limestones or shales. Here we focus on examples in which these new data have forced substantial revisions of previous taxonomic interpretations of fishes from the London Clay. In addition to providing a wealth of anatomical information on early representatives of many major eurypterygian lineages, CT scanning permits the acquisition of functional and ecomorphological measurements previously only accessible from neontological datasets. By harnessing the mature framework for quantifying feeding ecomorphology in fish, we are able to critically test previous hypotheses relating to changes functional diversity between the Mesozoic and Cenozoic in acanthomorph (spiny-finned) teleosts, one of the most successful radiations of modern vertebrates. Using ground-truthed measures of performance, we show a substantial increase in acanthomorph cranial functional diversity between the Late Cretaceous and Eocene, corroborating inferences drawn from sparse cranial landmark constellations applied to taphonomically flattened material from other localities.

Computed tomographic investigation of newly recognized specimens of *Tristychius*, a pivotal taxon in chondrichthyan phylogeny

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Fossil fishes have been collected from the clay-ironstone nodules of the Wardie Shales of the Viséan Lower Oil Shale Group (Edinburgh, Scotland) since the early 19th century. However, most specimens are pyritized and mechanical preparation is difficult. Wardie sharks collected by Stan Wood in the early 1970s formed the basis of John Dick's Ph.D. research, at which time certain specimens were set aside, anticipating the development of less destructive, investigative techniques. Thanks to this foresight, CT-scans of one such nodule, still unbroken and catalogued as containing a ctenacanth, reveal the complete, articulated, skeleton of the forequarters of *Tristychius arcuatus*, an anomalous dogfish-like species of uncertain phylogenetic affinity. CT-scans of additional Wardie specimens, including those studied by Dick as well as previously unexamined and uncatalogued material collected in 1870, deliver results that build upon existing descriptions and reveal a remarkably advanced shark relative to known contemporaries. Here, we present details from new specimens of the braincase, revealing new information on the articulation surfaces for the suspension of the mandibular arch and hyoid arch, the exterior and interior of the otic capsule, the rear wall of the orbit, and union of the postorbital process with the main body of the neurocranium. Recent phylogenies indicate that *T. arcuatus* lacks synapomorphies uniting holocephalans and early neoselachians;

here, we show that *T. arcuatus* is markedly neoselachian. In conclusion, Wardie nodules re-examined under this new light show that this long-known locality is a much richer source of data than previously considered.

The biomechanics of feeding in the Laotian rock rat, *Laonastes aenigmamus*

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The Rodentia is the largest mammalian order, comprising over 2000 extant species. Rodents show highly complex specializations of the masticatory apparatus, many of which have been used for taxonomic purposes. For example, the morphology of the lower jaw has been used to divide rodents into those that resemble squirrels (sciurognaths) and those that resemble porcupines (hystricognaths). Alternatively, the morphology of the masseter muscle has been employed to categorise the rodents into squirrel-like, porcupine-like and mouse-like forms (sciuromorphs, hystricomorphs and myomorphs respectively). The recently discovered Laotian rock rat (*Laonastes aenigmamus*) is unusual within rodents in combining a sciurognath mandible with a hystricomorph masseter morphology. In this study, the biomechanical implications of this rare combination of morphologies were investigated using finite element analysis (FEA), a computer-based technique that enables the reconstruction of stress and strain patterns in a digital object subjected to a load. FEA of the mandibles of a squirrel and guinea pig were also undertaken for comparison. Results demonstrate that the Laotian rock rat is very similar to the squirrel in its biting performance: it has a highly efficient incisor bite, but is less efficient than the guinea pig at molar chewing. This indicates that it is the geometry of the mandible, rather than the arrangement of the muscles that is the most important factor in the biomechanics of feeding in this species. This may have important implications for our understanding of the large amount of morphological convergence seen within the order Rodentia.

Large geographic ranges confer little protection against extinction in terrestrial tetrapods across the T-J boundary

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Triassic-Jurassic tetrapod clades with larger geographical range sizes are more resilient to extinction than those with smaller ranges. More generally, there is a positive correlation between range size and per lineage rates of diversity change. However, these relationships weaken, and subsequently break down close to, and across, the Late Triassic mass extinction boundary. These observations support the theory that clades with larger geographic ranges are more resilient to extinction than clades with smaller ranges during periods with background levels of extinction, but that this effect is diminished during global biotic crises. Although the fossil record of terrestrial tetrapods is notoriously patchy, with many intervals yielding sparse fossil material, the period studied here (Late Triassic) has one of the best Mesozoic terrestrial fossil records. The Paleobiology Database is providing increasingly detailed and accurate data for many groups. By devising novel methods to analyse these data spatially (using Geographic Information

Systems) there is enormous potential to understand spatial macroevolutionary patterns in the fossil record. This will be particularly valuable for groups whose fossil records were previously considered too poor to yield rigorous results.

Fossils of early vertebrates and the evolution of the gnathostome face revealed by synchrotron imaging

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Cyclostomes and gnathostomes have distinct face patterns. Cyclostomes possess a median nasohypophysial duct, an anterior hypophysis and a short telencephalon, contra gnathostomes possessing a pair of nasal sacs opening externally, a separate posterior hypophysis opening onto the palate and a long telencephalon. Embryonic development also differs. In cyclostomes, premandibular crest cells migrate forwards either side of the nasohypophysial placode, forming an upper lip; in gnathostomes they migrate between the hypophysial and nasal placodes forming the trabecular region. Supraoptic neural crest remains posterior to the nasohypophysial duct in cyclostomes but moves forward to create the nasal capsules in gnathostomes. Fossil stem gnathostomes illustrate a transitional sequence between these two patterns: 1) The galeaspid *Shuyu* (jawless stem gnathostome): nasohypophysial duct, short telencephalon, and anteriorly oriented hypophysis as in a cyclostome, but paired nasal sacs and hypophysis separated by a rudimentary trabecula. 2) The primitive placoderm *Romundina* (jawed stem gnathostome): short telencephalon, anteriorly directed hypophysis, trabecular region long and wide, nasal capsule located far behind the tip of the snout but just in front of the orbits. These features are interpreted as uniquely primitive among gnathostomes. The trabeculae of *Romundina* form an extensive precerebral region resembling the upper lip of extant cyclostomes and *Shuyu*. The position of the nasal capsule suggests that the supraoptic crest had not migrated forwards. 3) The arthrodire *Kujdanowiapsis* (a more derived placoderm): short telencephalon and vertically oriented hypophysis. The trabecula has been shortened anteriorly, making the nasal capsule terminal. These positional relationships are maintained in crown gnathostomes.

Early evolution of the modern avian wing

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The wing skeletons of flying vertebrates are highly conserved; the fossil record shows that even small structural modifications evolved extremely rarely within the three flapping lineages, birds, bats and pterosaurs. In birds, the forelimb comprises three basic components, retained from earlier theropod dinosaurs: the brachial wing supported by the humerus, the prebrachial wing supported by the radius and ulna, and the outer wing supported by the carpometacarpus and digits of the hand. The fossil record also shows that feathers, including pinnate 'primaries', first evolved outside of an aerodynamic context. As we discuss, all components of the 'avian wing' are present in maniraptoran taxa that diverged from the avialan branch prior to the appearance of *Archaeopteryx*. The present form of the avian outer wing, with reduced skeletal components and functionally

sophisticated primary feathers, was a recent evolutionary innovation long thought closely associated with flapping flight. We note that all described non-avialan theropods and early birds with preserved forelimb feathers evidence well-developed remiges attached to the manus and ulna along their posterior edges. No fossils show comparable feathers attached to the humerus or the proximal part of the wing closest to the body, a condition clearly present in living birds. This conserved wing pattern – the absence of remiges on the humerus – has often been depicted in phylogenetic reconstructions of wing evolution and is corroborated by fossils, but has thus far escaped discussion. We discuss, in combination with new fossil evidence, the functional and aerodynamic significance of this wing feathering pattern.

Glencartholm revisited

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Glencartholm in Dumfries and Galloway, Southern Scotland, is one of the most important Early Carboniferous fossil fish sites in the world. The fauna is remarkable in containing more than 30 species. Originally discovered in 1879, further collecting in the 1930s removed all the accessible fossiliferous strata. An excavation of a new exposure at Mumbie, 0.5 km north of Glencartholm Farm, was undertaken by Stan Wood in the 1990s. Three separate fish beds were identified and more than 200 specimens collected, including one possible new species. Differences in scale colour enables fishes from the different horizons to be distinguished. These differences should allow material collected previously to be more accurately assigned and assist palaeoecological analysis of the fish beds. The potential of the site for further exploration and training in field work is considered.

Reassessment of the 'Paris Plesiosaur'

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The 'Paris plesiosaur' (MNHN A.C.8592) was recently identified as Mary Anning's second plesiosaur find from the Lower Lias of Lyme Regis. It was bought in 1824 by Constant Prévost on behalf of Georges Cuvier, who figured it in 1825. In fact, Cuvier also figured it, albeit in a less prepared state, in 1824, attributing its collection to a Captain Waring. We are, elsewhere, researching these and other problems in the specimen's history. Cuvier's before and after drawings show that the pectoral girdle was originally disarticulated, and was artificially replaced in life position. The tail is absent in the pre-preparation figure but is present in the existing specimen and may be from a different individual. Close inspection of a cast of the specimen reveals further repositioned elements, such as metacarpals now placed back to front in a purportedly articulated manus. This is further evidence that the 'improvement' of vertebrate fossils has a long history. The specimen has previously been referred to the plesiosauroid taxon *Plesiosaurus dolichodeirus*, with slight differences from the holotype interpreted as intraspecific variation or possible sexual dimorphism. However, in our view the

differences are too extensive to support this referral. In particular, the radius and ilium show characters seen in the Microcleididae. In a phylogenetic analysis the specimen is a member of a clade which includes the microcleidids but excludes *P. dolichodeirus*. This increases the known diversity of plesiosauroids at the classic Lower Jurassic locality of Lyme Regis. Other specimens previously referred to *Plesiosaurus dolichodeirus* should be reassessed.

Shastasaurid ichthyosaurs and other lost critters from the French Rhaetian

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Recent advances in the phylogeny and evolution of diversity of ichthyosaurs have recognized a smaller number of more intense turnovers compared to the previous understanding of their evolutionary history. One of these crucial turnovers occurred during the Late Triassic, when all ichthyosaur clades but a minor subset, the parvipelvians, went extinct. The timing and, hence, the severity of this event is however poorly understood and may have been protracted over the entire middle Norian–latest Rhaetian interval, more than 15 million years. The iconic, whale-sized shastasaurid ichthyosaurs are regarded as early victims of this turnover, disappearing by the middle Norian. In 1883, Henry Emile Sauvage (1842–1917), a famous French palaeontologist, described reptilian remains from a Rhaetian bonebed near Autun in eastern France. But this material was subsequently lost and disappeared from the literature. We have re-discovered most of this material in the fossil vertebrates collections of the Katholieke Universteit Leuven, Belgium. Reassessment of this material indicates the presence of very large shastasaurid ichthyosaurs (*Ichthyosaurus rheticus*, *Rachitrema pellati* [partim]), probable choristoderes (*Actiosaurus gaudryi*) and plesiosaurs (*Plesiosaurus bibractensis*). The occurrence of shastasaurids in Rhaetian strata is corroborated by recent findings in a new locality in southern France. This suggests that the final extinction of this important Triassic clade coincides with the rapid radiation of neoichthyosaurs, forming a short but extremely profound turnover that drastically impacted the evolutionary history of ichthyosaurs.

Early pufferfishes and kin (Percomorpha: Tetraodontiformes) from the Eocene London Clay: new anatomical insights from computed tomography

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The earliest crown-group tetraodontiform fishes (pufferfishes and their allies) are early Palaeogene in age, and consist almost exclusively of highly compressed body fossils and isolated dentitions. To date, only a single three-dimensionally preserved skull has been described from this important interval of tetraodontiform history: an incomplete specimen from the early Eocene (Ypresian) London Clay Formation assigned to the extant genus *Triodon* (Triodontidae; three-toothed puffers). With the aid of computed tomography, we reassess this specimen and describe two new tetraodontiform skulls from the London Clay, one of which was recently acquired by the Natural History Museum. Tomographic

reconstructions of these exceptionally preserved fossils reveal greater cranial detail than that available in compression fossils of similar age, especially with respect to the character-rich braincase, suspensorium and gill arches. Although we can corroborate the triodontid affinities of the previously reported London Clay tetraodontiform, at least one of the new specimens presents a combination of characters unknown in any other member of the order. Like a triodontid, it has a beak-like dentition, pelvic girdle and pleural ribs, but it bears a remarkable dorsal fin that inserts over the orbit and is composed of broad, plate-like spines. The unusual and unexpected morphologies apparent in these early Eocene specimens are particularly relevant in the context of recent molecular analyses that strongly contradict hypotheses of tetraodontiform interrelationships based on anatomy.

A virtual view of early ray-finned fish endocasts

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In many vertebrates, the endocast – a sediment infilling of the endocranial cavity – can provide information about the shape and proportions of the brain. Due to the close fit between the brain and the endocranial cavity in some groups of fishes, the endocast can be studied with particular success to provide data on the structure of the brain. However, specimens in which the endocranial cavity is preserved in an accessible way are uncommon, and previous studies of endocranial anatomy have tended to rely on destructive methods that cannot be applied to rare or delicate fossils. Computed tomography (CT) scanning provides a non-destructive and repeatable alternative to traditional approaches. We applied CT scanning to fossil crania of two taxa that have featured prominently in studies of early actinopterygian (ray-finned fish) phylogeny: *Mimipiscis*, from the Late Devonian of Western Australia; and *Kentuckia*, from the early Carboniferous of Kentucky. The resultant models largely confirm previous hypotheses of brain structure in early bony fishes, but reveal certain unexpected morphological features in the endocast of *Mimipiscis*. These features, such as the presence of small optic lobes and anterolaterally-directed olfactory tracts, are absent in younger ray fins including *Kentuckia*, but are seen elsewhere in outgroups of ray-finned fishes, most particularly in lobe-finned fishes. Such findings corroborate the placement of *Mimipiscis* as a particularly deep branch in ray-finned fish phylogeny, while adding detailed anatomical information to our understanding of primitive conditions in the early members of this successful clade.

Trace elemental imaging of exceptionally-preserved fossils: palaeontological and taphonomical implications

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The interpretation of flattened fossils remains a major challenge due to compression of their complex anatomies during fossilization, making critical anatomical features

invisible or hardly discernible. Key features are often hidden under well-preserved decay-prone tissues, or an unpreparable sedimentary matrix. A method offering access to such anatomical features is of paramount interest to resolve taxonomic affinities and to study fossils after the least possible invasive preparation. Unfortunately, the widely-used X-ray micro-computed tomography, for visualizing hidden or internal structures of a broad range of fossils, is generally inapplicable to flattened specimens, due to the very high differential absorbance in distinct directions. Using synchrotron X-ray fluorescence spectral raster-scanning coupled to spectral decomposition or statistical analysis, we imaged exceptionally-preserved fossils from the Late Cretaceous without needing any prior delicate preparation. The contrasting elemental distributions, particularly from trace elements, greatly improved the discrimination of skeletal material from both the sedimentary matrix and fossilized soft tissues. Quantification of these elements opens new ways for fossil description but also for palaeoenvironmental and taphonomical studies.

The aerodynamics of feather asymmetry and implications for paravian flight

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The presence of asymmetric feathers has been used as an indicator of flight capacity in fossil birds and non-avian dinosaurs. However, most of the flight feathers in living flying birds are not highly asymmetric. Only the lateral primaries show extreme asymmetry, and secondaries are typically symmetrical. The effects of feather asymmetry are more complex than simple presence or absence metrics indicate. Feather asymmetry is not required for lift production. Rather, washout twisting occurs in the lateral primaries of living birds, which delays stall at high angles of attack. This effect only tends to occur in feathers with vane depth ratios over 4:1 (with the lateral vane being the smaller of the two surfaces). Because the centre of lift sits near 1/4 chord, feathers with vane depth ratios (VDR) of 4:1 or less are loaded primarily in bending. Vane measurements demonstrate that the feathers transition from torsion-dominated to bending-dominated morphology near primary position III to V in most taxa. The degree of asymmetry is therefore related to specific position on the wing, just as predicted by fluid loading theory. *Archaeopteryx* has previously been shown to possess functionally symmetric primaries, but the aerodynamic effects appear largely overlooked. Lateral primaries with a VDR far less than 4:1 will tend to twist in a stall-promoting fashion. Vane morphology therefore supports a non-flight function for the wings in *Archaeopteryx*, though this does not preclude other aerodynamic actions.

Sorting through the wastebasket: a phylogeny of Palaeocene mammals

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The Palaeocene is an extremely important interval in mammalian evolution. Prior to the Cretaceous-Palaeogene extinction, the mammal fauna is largely, though not exclusively, restricted to scansorial or terrestrial insectivore niches; afterwards, a broad diversity of large herbivores and carnivores, and subsequently gliders, flyers and aquatic forms quickly evolve. The majority of taxa known from the Palaeocene, however, belong to

'wastebasket' taxa or clades of unknown affinity – including cimolestids, pantodonts, and 'condylarths'. Only Rodentia, Carnivora and possibly Primates have well-supported Palaeocene members. Clarifying Palaeocene mammal relationships is thus essential for any macroevolutionary study into early placental mammal evolution, and yet no large-scale study has been conducted. We present the results of the first extensive cladistic study of Palaeocene mammals, focusing on Laurasiatheria and possible laurasiatheres. 171 taxa were coded for 681 morphological characters, treating continuous characters as both continuous and discretised. A phylogenetic scaffold was erected to preserve known relationships of extant orders. Strict consensus after pruning least stable taxa yields highly resolved relationships for many clades of enigmatic Palaeocene mammals, including many 'condylarth' groups. Relationships between extant taxa are largely upheld, though in neither analyses are Eulipotyphla and Euarchontoglires recovered. In both continuous and discrete datasets, 'condylarths' are found to be polyphyletic, though some subgroups are consistently recovered as ancestral to modern orders. Cretaceous taxa are consistently resolved as stem Eutheria, with the exception of *Gypsonictops*. This consistent basal position of early groups supports the Palaeocene as the period in which the placental radiation occurred.

Playing the evolutionary tape backwards: graduality of signalling and patterning of mammalian teeth

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Evolutionary transitions appear as a result of subtle modifications in developmental processes. However, most experimental evidence from developmental biology is from drastic alterations in gene expression, resulting in large, discontinuous morphological change. Using the mouse dentition as a model, we address the question of graduality in development and evolution by progressively modifying signalling in an organ undergoing morphogenesis. Eda (ectodysplasin) null mutant mice have a maximally reduced cuspal pattern. We first rescued the mutant phenotype by adding EDA protein in organ culture; as concentration increased, gain and loss of cusps in the mutant teeth followed the appearance of cuspal features during wild-type mouse tooth development. This in turn roughly parallels the evolutionary order of cusp acquisition in mammalian ancestry. Cultured teeth resemble the basal tribosphenic pattern of mammalian cheek teeth, with one exception: a fusion of distal/talonid cusps occurs in culture. To experimentally engineer fully tribosphenic teeth, we prospectively adjusted cusp spacing by inhibiting sonic hedgehog (SHH) signalling in the Eda null mutant teeth. Combining modifications caused an increased separation of cusps, mirroring tribosphenic morphologies. To further refine the phenotypes, we inhibited SHH signalling in Eda null mice *in vivo*. The resulting mouse cheek tooth morphologies manifested many characteristic tribosphenic features, leading to precise mimicry of ancestral fossil morphologies, such as those of *Tribosphenomys*, a member of the Rodentia sister clade, in extant mutant mice. Our

results show progressive changes in EDA signaling can account for many of the gradual changes observed in the evolution of mammalian teeth.

Making some headway: retro-deformation of a tectonically deformed chasmosaurine ceratopsian skull

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In 2007 the skull of a new type of chasmosaurine ceratopsian was collected from the St. Mary River Formation (Late Cretaceous, early Maastrichtian) in southwestern Alberta, Canada. The isolated cranium (no mandible or teeth) was found resting upright on a hard bench of sandstone. Being situated in the foothills of the Rocky Mountains, the skull experienced two deformation events associated with the past 60 million years of mountain building – 1) antero-postero contraction and associated lateral expansion of the entire cranium, and 2) upwards deflection of the snout relative to the occlusal plane of the mouth and a similar flexure of the parieto-squamosal frill relative to the skull table. The rock enclosing the specimen was full of disarticulated bivalve shells, and these supplied sufficient calcium carbonate to rapidly cement the fossil and enclosing rock and make the skull resistant to any flattening during subsequent deep burial. Examination of the specimen indicates that the original volume of skull bone material has only been reduced by some minor crushing on one side. In combination with the conservative nature of chasmosaurine skulls, the near-constant volume of the specimen enables the generation of two three-dimensional, retro-deformational transformations that can be applied to a digital model of the skull to restore it back to its original shape. There are sufficient anatomical details preserved that are not tectonically warped to be certain that the new specimen is different enough to merit it being a new genus.

Cephalopods in the diet of pterosaurs: evidence from a *Rhamphorhynchus* coprolite

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Numerous lineages of pterosaur have been interpreted as having been primarily piscivorous. In particular this hypothesis has been advocated for the basal pterosaur *Rhamphorhynchus*, and is supported by the functional morphology of the skull and teeth and by several specimens preserving parts of, or entire, fish skeletons as stomach contents. In general, the term 'piscivory' seems to have been applied to pterosaurs to imply a diet that consisted exclusively of fish, although some authors have noted that other ecologically equivalent aquatic prey – cephalopods, most obviously squid – may have also been taken. Here we present the first direct evidence for such an interaction based on a previously undescribed specimen of *Rhamphorhynchus* preserved with an extruded coprolite containing a mass of cephalopod hooklets. The chest cavity of the specimen also contains indeterminate bony stomach contents that do not appear to belong to a fish, suggesting a tetrapod was also ingested. These finds provide evidence that the

diets of at least some pterosaurs were likely more widely varied than currently appreciated, and given the limitations of aquatic invertebrate preservation it is possible that cephalopods such as squid were a common, even preferred, part of the diet of pterosaurs such as *Rhamphorhynchus*.

A first report on a nearly complete Middle Triassic mixosaurid ichthyosaur from Edgeøya, Svalbard archipelago

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During the 2007 field work on Edgeøya, scientists found the skeletons of several ichthyosaurs on a plateau at Muen, a mountain on western Edgeøya, Svalbard archipelago. This was the first documented find from the Botneheia Formation on this Island. As a co-operation between Norwegian Petroleum Directorate, The Natural History Museum, University of Oslo, and SINTEF Petroleum Research, permission was granted from the Governor of Svalbard to excavate the skeletons in 2008. One skeleton in particular (PMO 219.250) was fairly complete and partially articulated, it consists of a vertebral column of 86 fully preserved to partially preserved vertebrae. Six impressions of vertebrae were also observed, giving a total of 92 vertebrae. Also present were a laterally compressed skull, fragmented pectoral girdle, two partial fore fins, and a partial pelvic girdle with articulated partial hind fins. PMO 219.250 can be placed confidently in the family Mixosauridae on the basis of the following synapomorphies which the specimen clearly shares with members of the family: the premaxilla is posteriorly pointed, distinctively high and narrow neural spines extending to the caudal peak, mid-caudal vertebral centra with increased size, posterior teeth more robust than anterior ones, distal carpal 1 slightly larger than other distal carpals, humeri relatively short but still retaining constricted shafts. It is referred to the genus *Phalarodon* sp. based on the following synapomorphies: nasal region with pronounced narial shelf and that the premaxilla forms the anterior half of the ventral border of the external naris.

Neogene auks (Aves, Alcidae) in North Atlantic cool waters - review and quest

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Extant auks comprise 11 genera and 23 species of marine, wing-propelled pursuit-divers found in cool waters of the northern hemisphere. Diving depths may exceed 100 metres in the larger forms such as *Uria lomvia*. Recent genera in the North Atlantic region are *Uria*, *Alca*, *Cepphus*, *Alle*, *Fratercula* (and occasionally *Aethia*). *Pinguinus* was exterminated in the 19th century. Continuous sea ice limits northern auk distribution. Southern occurrences include Neolithic *Pinguinus impennis* in Morocco and wintering *Alca torda* and *Fratercula arctica* around the Balearic Isles. Palaeocene auks probably evolved in the Pacific region. Major changes in the ocean-climate system with

decreasing temperature trends from a mid-Miocene climatic optimum are associated with increased marine productivity and auk radiation. At least 11 species of early Pliocene auks were recorded from eastern North America, none of them representing *Uria*, which may have reached the Atlantic waters from the Pacific in the Pleistocene. Auk fossils from Europe will be critically summarized. Based on humeral features, a late Miocene specimen from Danish Gram Clay is assigned to the puffin group cf. *Fratercula*. Other Miocene specimens may need restudy. A quest for auk remains hidden in literature and collections will be initiated.

Fossilized ontogenies: Gogo placoderms reveal embryonic development in 370 million year old early vertebrates

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Placoderms, representing basal phylogenetically jawed vertebrates and successive sister taxa to crown-group gnathostomes, are critical to our understanding of the polarity of character transitions within the crown-group. However, ontogenetic stages of placoderms are generally poorly known, with a few exceptions (e.g.,, from the Miguasha Formation, Canada). We focus on the exquisitely preserved placoderm specimens from the Gogo Formation, Australia, including embryonic material. Not only do these embryos provide information about the ontogenetic development of skeletal elements such as head and trunkshield plates, dentitions, and vertebral elements, but also about placoderm reproduction. Information is preserved in both the Ptyctodontida and Arthrodira, including the presence of multiple embryos in pregnant females, embryos of differing sizes, and of different sexes (e.g.,, male claspers preserved in certain embyros). By comparison to well-studied chondrichthyans, we can make inferences as to the nature of vertebrate reproduction at the evolutionary transition from jawless to jawed vertebrates.

Exploring the patterns of cranial and mandibular co-variation within the order Rodentia

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Morphological co-variation is the occurrence of correlated variation between two anatomical modules or discrete structures. Potential variation results from phylogenetic and developmental processes, but patterns of co-variation may also be constrained by selection pressures. In Rodentia, the incisor-dominated cranial and mandibular morphology has successfully adapted to a wide array of ecologies and diets. The versatility of rodent morphology and the developmental plasticity shown in laboratory studies suggest that patterns of co-variation in Rodentia may be capable of rapid evolution. Geometric morphometrics (GMM) encapsulates detailed 3D shape information, enabling complex quantitative analysis. GMM using anatomically homologous fixed landmarks was used to compare shape variation and co-variation of 28 rodent species from 24 families, sampling across the majority of the order. Principal

component analysis described the variation within the structures independently. Two-block partial least squares analysis described and statistically analysed the co-variation between the skull and mandible. An independent contrast with a nexus file tested for significant shape patterns irrespective of phylogeny. The shape variation was described, and distributions of phylogenetic and functional groups were compared. There was a clear phylogenetic pattern in the relative size of braincase and rostrum, orbit placement, length of the coronoid process and robustness of molar region. Possible dietary effects were seen in the mandibular ramus angle, zygomatic robustness and cranium rotundity vs. linearity. The co-variation corrected for phylogeny is significant, however the non-phylogenetic effects appear to be complex and require a study sample with detailed ecological comparisons.

New data on Early Jurassic theropod diversity in the Lufeng Formation of Yunnan Province, China

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Over 70 years since it was first reported by Yang Zhongjian ('CC Young'), the Hettangian-Sinemurian Lufeng Formation of Yunnan Province continues to provide fresh insight into the Early Jurassic evolution of dinosaurs and other terrestrial fauna, with material recently smuggled out of China forming the basis of a Nature paper on dinosaur embryology earlier this year. In November 2010, excavation for a relocated ironworks at Qingliangshan, Lufeng County, recently yielded the remains of a new specimen of the sauropodomorph *Yunnanosaurus* represented by disarticulated cranial material, most of the vertebral column, and limb girdle elements. The delicacy of the skull required virtual preparation after scanning with computerised tomography and subsequent digital reconstruction. A mount for the specimen was constructed following 3D modelling. Three shed theropod teeth, ranging from 25-30 mm in crown height, were recovered among the specimen's pelvic elements. Global knowledge of Hettangian-Sinemurian theropods is sparse and one of the few known specimens – the holotype of *Dilophosaurus sinensis* (also associated with the remains of a *Yunnanosaurus*) – is from the Lufeng Formation of Qinglongshan, Jinnin County. A second, near complete specimen of *Dilophosaurus sinensis* was excavated near DaWaShan in 1997, where an isolated footprint of a medium-sized theropod, consistent with the 5.5 metres size estimate for this taxon, was discovered last year. Morphometric analyses of the teeth show that they plot separately from *Dilophosaurus*. These specimens thus significantly augment our knowledge of Early Jurassic theropod evolution.

'Fin End of the Wedge': variability of pectoral fin shape in a group supposedly uniformly 'scythe-like'

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Pachycormids as a family have been defined in terms of their pectoral fin shape, ubiquitously described as 'scythe-like'. As such an early consensus character for the group, it has tended to receive less scrutiny with each newly identified taxon than it perhaps should have. This is despite the wide disparity in niche demonstrated by these animals, from swift medium-sized predator, to large suspension-feeder, with the associated massive differences in cruising speeds and different lifting surfaces required to achieve these lifestyles. What might perhaps have been misinterpreted as preservational distortion or damage has often subsequently proved to be a consistent feature and form. This variation in pectoral fin shape was first noted in *Asthenocormus*, deviating from the accepted pachycormid 'scythe' to a 'fascicular' morph, recalling the form of a tightly-bound series of parallel twigs/sticks. Recent preparation has similarly demonstrated that the first-ever recovered pectoral fin of *Leedsichthys* appeared similarly divergent, to the form of a more splayed axe-head. Preparations of the second pectoral fin will hopefully provide some indication whether this was distorted or actually representative, but the in place preservation of the finest (millimetre diameter) terminal ends of the lepidotrichia of the first fin argues against substantive post-mortem movement of this structure prior to burial. The question of pachycormid pectoral shape will be considered in the light of new specimens from Scotland, the south of France, México and the US Mid-west.

Claddis: a new R package for automating disparity analyses based on cladistic datasets

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Vertebrate palaeontology has adopted cladistic measures of disparity with increasing frequency in recent years as a means of tackling a broad range of macroevolutionary questions. However, there has been comparatively little innovation in terms of both methodology and implementation, with many workers stringing together different software packages in order to achieve their aims. Here I present a novel R package that attempts to automate the entire process of taking a cladistic dataset, converting it into a distance matrix, performing an ordination, and extracting disparity measures. In addition I implement some novel methodological improvements, primarily to deal with the missing data problem. These include re-scaling techniques (Gower dissimilarity and a new method based upon maximum possible observable distances) and a likelihood method for estimating both ancestral and terminal character states. I illustrate the package's functions using an example dataset of theropod dinosaurs.

Stan loved a good fossil: some recent spectacular fossil fish finds from Gogo (late Devonian, Australia)

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Despite over 50 years of collecting since the Late Devonian 3-D preserved Gogo Formation fish fossils of Western Australia were first studied by the British Museum researchers, significant new material still keeps turning up. The Museum Victoria-ANU

2005 and 2008 Gogo Expeditions uncovered the first Gogo shark fossils (two specimens, both new taxa), the first acanthodian (*Halmacanthodes ahlbergi*), the first coelacanth fishes (two specimens, new taxon) and the first embryo recognised from any placoderm fish (*Materpiscis attenboroughi*). The tetrapopomorph *Gogonasus* is now known from another new complete specimen found on the 2011 Curtin University Gogo Expedition. In addition, new species of arthrodires and the antiarch *Bothriolepis* are still being prepared out and studied. There are now five basal ray-fin fishes in the fauna, including the most generalised of all known actinopterygian neurocrania. The lungfish fauna from Gogo is the most diverse known for the Devonian with 10 genera and 12 species, recently including *Rhinodipterus kimberleyensis,* the first marine lungfish to demonstrate osteological signals for air-breathing. Using micro-CT and synchrotron imaging techniques, the exceptional preservation of these acid-prepared fossils yields extraordinarily fine detail of their morphology and histology. Perhaps the most significant new discoveries are of soft tissue preservation, showing complete sets of neck and body musculature, stomach and gut preservation, as well as other as yet unidentified soft tissue structures. Through their exceptional preservation of both hard and soft tissues the Gogo fishes remain crucial for resolving key debates on the diversification, physiology, biomechanics and phylogenetic relationships of early gnathostomes.

A small, enigmatic terrestrial lissamphibian from the Crato Formation of Brazil: a preliminary analysis of the first articulated caudatan from the Mesozoic of South America

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A small lissamphibian from the Early Cretaceous (Aptian) Crato Formation of northeast Brazil is assigned to a new genus and species. It is characterised by short forelimbs with a manus bearing four digits and considerably longer hind limbs with pes bearing five digits. Digits of the manus and pes bear proportionally large unguals. Aspects of the skull osteology are also distinctive, but crushing makes some sutures difficult to determine. The new taxon is the first fossil caudatan reported from the Early Cretaceous of South America and is tentatively placed in the Noterpetontidae.

Air space proportion in pterosaur wing bones

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Air Space Proportion (ASP) is a measure of how much air is present within a bone, which allows for quantifiable comparison of pneumaticity between specimens and species. Measured from zero to one, higher ASP means more air and less bone. Conventionally, it is estimated from measurements of the internal and external bone diameter. Thus far, very little ASP work has been done on pterosaurs, and what has been done previously is by visual inspections of sectioned bones within matrix. Computed tomography (CT) scans were used to calculate ASP in several pterosaur wing bones (mainly phalanges) and

to assess how the values varied throughout the bone. These results show higher ASPs than previous pterosaur ASP studies, and more significantly, higher ASP values in the heads of wing bones than the shaft. This is not expected as it means that pterosaur bones are more pneumatised in the heads, despite extensive trabecular bone. This may mean that pneumaticity has been underestimated previously in other animals when shaft cross-sections are used to estimate ASP. Furthermore, ASP values in pterosaurs are higher than those found in birds and sauropod dinosaurs, giving them the highest ASP values of animals studied so far, supporting the view that pterosaurs were the most pneumatised animals to have lived.

Variation in the forefin morphology of the lower Jurassic ichthyosaur genus *Ichthyosaurus*

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Forefin morphology of Lower Jurassic ichthyosaurs is sufficiently distinct that it can easily distinguish among genera. Historically, Lower Jurassic ichthyosaur specimens with a wide forefin have been assigned to the genus *Ichthyosaurus*. Recent work has indicated that, in addition to five or more digits, an anterior digital bifurcation and a wide, robust fifth digit are diagnostic for the genus. But the forefin morphology of *Ichthyosaurus* is extremely variable. We looked at the variation in more detail than had been done previously, and found morphological differences among forefins that include: the extent of contact between the radius and ulna, the relative size of some proximal elements, the shape of the intermedium, the specific digit that bifurcates, the row in which the bifurcation occurs, the number of accessory digits, and the presence of notching on some anterior elements. A cluster analysis using 17 characters, however, did not produce species groups based on forefin morphology. Instead, individual species are spread across the entire range of morphologies, confirming that morphology is highly variable within species. Our preliminary results agree with earlier workers who suggested that, at the species level, forefin morphology is not useful taxonomically. Some aspects of variation might be ontogenetic, and some may be influenced by environment and how the fin was used.

On the taxonomy, life history and evolutionary patterns of diversification of the basal actinopterygian fish *Saurichthys*

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Saurichthys is a basal ray-finned fish that had a worldwide distribution in the Triassic. Swiss Middle Triassic localities yield hundreds of specimens from a controlled stratigraphical and palaeoecological context, and offer the chance to study morphological variation within species flocks, usually only possible in living species. We investigated two aspects of this variation: opercle shape and the structure of the axial skeleton.

Outline-based geometric morphometrics and traditional measurements provided a quantitative framework for morphological evolution of opercle shape in six species of *Saurichthys*. Interspecific differences reflected compression on a horizontal plane of the anterior and posterior margins, and this variability can be used to identify species. Histological study of opercles showed a unique mode of growth in *Saurichthys*, compared to closely related living species, preventing age estimation based on annual growth marks. *Saurichthys* is characterized by an elongated body, generated by a novel mechanism. The exceptional preservation of soft tissues in a specimen of *S. curionii* provides new information on the relationship between the musculature and the skeleton: the increasing length results from doubling the number of neural arches per axial segment rather than increasing the length or number of vertebra. Two neural and haemal arches correspond to one muscle block, thus confirming that the intercalaries have become expanded in this species. Doubling of the number of skeletal elements without increasing the number of embryonic segments represents a unique way of generating an elongate body plan in vertebrates, and demonstrates the evolutionary lability of the axial skeleton in basal fishes.

Morphological and hydrodynamical convergence in pelagic vertebrates

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Convergence is a key topic in evolution, and it has bearings on systematics, adaptation and molecular developmental biology. However, much of the study in this area relies on qualitative comparisons between disparate groups; few quantitative studies are available. In pelagic vertebrates, body shape is dominated by the need for streamlining. Ichthyosaurs are noted for their morphological similarity to modern pelagic fishes and cetaceans, and they are here used to test morphological and hydrodynamical convergence between the groups. Their long and comprehensive fossil record includes several konservat-lagerstätten, with skin impressions and body outlines preserved, allowing accurate reconstructions. Previous studies have used regressions between body and caudal fin dimensional ratios; here I extend this to a two-dimensional landmark morphometric technique that reports more of the shape variation. Against the dominant PC axes, ichthyosaurs follow a trend through their phylogeny towards the morphospace occupied by extant fishes, indicating increased similarity in their form. A further test on the hydrodynamical effects of this uses orthogonal two-plane computational fluid dynamics to approximate a three-dimensional body form. Velocity and turbulent kinetic energy were used to quantify the action of fluid flow around the body. The results corroborate the morphometrics: the body forms of derived ichthyosaurs exhibit the properties of extant pelagic vertebrates. Early and Middle Triassic ichthyosaurs show poor dorsal development of the caudal fin and have the long tails characteristic of scyliorhinid sharks, whereas derived ichthyosaurs approximate the morphology of fast-swimming carcharhinid and lamnid sharks, as previously suggested.

Modern tracks, ancient steps

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Evidence is mounting that our early hominin ancestors displayed a style of walking broadly similar to our own. To that aim, it is important that we study our own tracks in order to accurately interpret those left behind in the sedimentary record. Many of the tracks made by our ancestors owe their existence to the simple need for water. This led hominins and many other animals to isolated pools of water loaded with fine-grained sediment where they generated tracks. A modern day muddy estuary on the Wirral, UK, provides an easily accessible space with which to run extended experiments in track formation in a natural setting with the substrate bedding intact. We have conducted a study that looks at a range of factors (sediment size and moisture content of the substrate; BMI/weight and speed of trackmaker). The tracks were recorded photogrammetrically for analysis in 3D with the goal of parsing out the factors that led to some of the structures we see in ancient prints. We then attempt to compare structures made during modern human bipedality to those made by ancestral walking, while removing factors that are irrelevant to the mode of bipedalism. This is an inexpensive study that, repeated by teams around the world in varying substrate conditions, could lead to an objective and detailed understanding of the factors that modern human bipedality displays when creating tracks. This work would be enhanced by repeating it using subjects who are habitually unshod.

Understanding the hydrodynamics and ecomorphology of plesiosaurs - a computational and experimental approach

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Plesiosaurs are thought to be unique in the natural world in that they swam using four flippers for propulsion. Previous work on the locomotion strategy of plesiosaurs has focused on their functional morphology and kinematics, but no quantitative experimental data has ever been collected. It is generally agreed that plesiosauromorphs (with their long necks and short heads) were ambush predators, and pliosauromorphs (with their short necks and large heads) were active pursuit predators. However, there is no consensus on how their flipper-like limbs moved to accomplish these predation techniques. Two primary research questions have been identified which are intrinsic to the problem. Firstly, what was the stroke type of a single flipper, e.g.,, was it similar to that of a penguin, a turtle, or a sea lion? Secondly, what was the phasing between the flippers, i.e., how did the fore and hind flippers move in relation to each other? In this project plesiosaur locomotion is assessed from an engineering perspective, by investigating the factors related to the hydrodynamics of their flippers. Simulations have been conducted which investigate the stroke type of a single flipper and phasing between the two sets of flippers, and progress towards experiments has been made. Separate flipper kinematics for high thrust and high efficiency elucidate the differences between the hunting strategies that disparate plesiosaurs may have utilised.

The sexual selection debate: extravagant structures and 'species recognition' in Mesozoic dinosaurs and other animals

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The term sexual selection refers to the set of evolutionary phenomena relating to reproductive success. In extant animals, extravagant structures like horns, frills and crests are typically associated with sexual selection and there is every reason to think that they evolved under similar pressures in fossil groups. A tradition within palaeontology is to interpret extravagant structures within 'mechanical' paradigms such that they are imagined as solar panels, windsails or counterweights. Some of these ideas involve misinterpretation and fail to withstand critical analysis. The caveat that extravagant structures are typically multi-functional is not missed: pressures of natural selection may influence their evolution and social signalling may be involved as well, but sexual selection seemingly remains the primary driver. Another popular notion is that extravagant structures evolved within the context of 'species recognition' and did not have a role in sexual selection. This view is problematic for several reasons, an obvious one being that extravagant structures do not function this way in extant taxa; another being that the hypothesis requires sympatric speciation to have occurred via sexual selection. Testing for the presence of sexual selection in fossil taxa remains difficult, even though the weakness of analogy has probably been over-stated. Data from sexual dimorphism and the ontogenetic change, extravagance and 'costliness' of a structure can all indicate the presence of sexual selection in fossil taxa. However, sexual selection is evidently at play where dimorphism is absent: mutual sexual selection is widespread in extant taxa and was conceivably present in fossil ones.

Tooth replacement in durophagous placodont marine reptiles (Sauropterygia, Placodontia), with new data on the dentition of Chinese taxa

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Placodontia is a clade of Triassic sauropterygians that inhabited the eastern and western margins of the Tethys Ocean, and represents the most extreme specialization to a durophagous diet of any known reptile. Exceptionally enlarged crushing tooth plates on the maxilla, palatine and dentary bones worked together to form efficient 'crushing areas' in the buccal cavity. However, the extreme size of these teeth combined with the way they cooperated as functional units must have required a specialized method of tooth replacement. Using a large μCT dataset of ten taxa that span all geographic regions and morphotypes, tooth replacement patterns were investigated. Results appear to follow a phylogenetic trend. The plesiomorphic *Placodus gigas* and *Placodus inexpectatus* show many replacement teeth at various stages of growth, with little or no discernable pattern. On the other hand, the more derived cyamodontoids tend to have fewer replacement teeth growing at any one time, replacing functional teeth diagonally across the palate and/or in functional units. *Cyamodus kuhnschnyderi*, *Sinocyamodus* and *Macroplacus* in particular show strong modularity, with unilateral replacement of teeth that form functional units.

The highly nested placochelyids *Psephoderma* and *Psephochelys* have a reduced dentition and, as a result, only have one or two replacement teeth in the upper jaw. This indicates a somewhat different feeding style in these taxa, especially considering the edentulous rostra common to both. Importantly, all specimens show at least one replacement tooth growing at the most posterior palatine tooth plates, possibly indicting increased wear at this point.

Zalambdodonty and the phylogenetic position of *Necrolestes patagonensis*: assessing the presence of a 45 million year dryolestoid ghost lineage

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The phylogenetic position of the enigmatic Miocene mammal *Necrolestes patagonensis* has long been the subject of discussion, with its highly apomorphic characters being linked to both eutherian and metatherian lineages. Strikingly, a recent phylogenetic analysis resolved *Necrolestes* within the Meridiolestida, a clade of non-therian dryolestoids known chiefly from the Cretaceous of South America. This placement implies a ghost lineage of almost 45 million years. We address several aspects of the original study which may, otherwise, weaken the assignment of *Necrolestes* to the Meridiolestida. By varying the coding of cusp homologies of *Necrolestes* we assess the original assumption that its cusp identities conform to the pattern common in zalambdodont eutherians, while by adding zalambdodont metatherian taxa to the analyses we explicitly test the important, previously articulated, hypothesis that *Necrolestes* has metatherian affinities. Both parsimony and Bayesian analysis show that these possible sources of bias have little effect on topology, permitting much greater confidence in *Necrolestes'* position as a meridiolestidan and, hence, in its lengthy ghost lineage. Additionally, the position of the Australosphenida in our Bayesian analysis raises interesting questions. This group resolves as the sister-taxon to Zatheria, contrasting both with the position commonly used to support the dual-origin of tribospheny hypothesis, and that used in favour of the single-origin view. This highlights the importance of using multiple analytic methods on a single dataset, contributing to discussion regarding the use of palaeontological data in Bayesian analyses, as well as to debate surrounding the dual-origin of tribospheny hypothesis.

The taxonomy of GSM 3166 *Parapsicephalus purdoni* Arthaber 1919, a three dimensional pterosaur skull from the Lower Alum Shale of Whitby

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In the 1800s, several pterosaur specimens were described with partial three-dimensionality (e.g., Goldfuss 1831, Wagner 1861), but were strongly crushed or only partially exposed. The first fully three-dimensional skull (GSM 3166) was discovered in the Lower Jurassic Alum Shales of Whitby by the Reverend D.W. Purdon and described by Newton (1888). It is a 140mm long skull of a rhamphorhynchid which has suffered only slight compaction on the right side. Preparation by Newton revealed a 3D endocast of the brain. Currently accessioned in the BGS, GSM 3166 was originally identified as a

new species of *Scaphognathus* before being assigned its own genus, *Parapsicephalus* (Arthaber 1919), but more recently was synonymised with the coeval *Dorygnathus* (Unwin 2003). Despite taxonomic revision, and its importance as a three-dimensional skull, *Parapsicephalus* has no well-supported characters for its placement in *Dorygnathus*. As part of a wider study of British Jurassic pterosaur taxonomy, *Parapsicephalus* has been examined with the aim of testing the hypothesis that GSM 3166 represents a new genus or is a junior synonym of one of the above genera. Several autapomorphies, particularly within the palate, have been identified which suggest that GSM 3166 is distinct from both *Scaphognathus* and *Dorygnathus*. It is recommended the genus *Parapsicephalus* be maintained. Recently, GSM 3166 has undergone CT-scanning with the intention of examining its neuroanatomy. GSM 3166 is particularly valuable here as the endocast appears wholly uncrushed, unlike basal pterosaur brain casts used in previous studies (Witmer et al. 2003).

Wear pattern, dental function and jaw mechanism in the Late Cretaceous ankylosaur *Hungarosaurus*

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Feeding in thyreophoran dinosaurs was thought to be uniform, with relatively simple orthal jaw closure and no, or very limited, tooth – tooth contact – a mechanism termed 'orthal pulping'. Recent studies on the basal thyreophoran *Scelidosaurus* and ankylosaurids (*Euoplocephalus* and *Saichania*) have demonstrated unambiguously the occurrence of dental occlusion and, in ankylosaurids, a retractive powerstroke during mandibular movement. Jaw mechanics of nodosaurid ankylosaurs, however, have remained unstudied. *Hungarosaurus tormai* is a basal nodosaurid from the Santonian of Iharkút, western Hungary. The marked curvature of its tooth rows in both the horizontal and vertical planes and the extensive wear facets on the in situ mandibular teeth clearly indicate a complex jaw mechanism in this taxon. Wear facets, covering up to 80% of the labial surface of the crown are steeply inclined and usually extend from the apex to the base of the cingulum. The wear pattern is dominated by scratches, rather than pits, and two scratch generations can be distinguished. The first generation scratches (<2 mm) are mainly on the apical two-thirds of the crown and are subparallel to the crown axis, whereas the second type (<3 mm) are on the basal third of the wear facet and are mesiobasally–apicodistally oriented. These features suggest an initial slicing phase associated with orthal movement followed by a retractive powerstroke with significant occlusal contact. These results demonstrate that complex jaw mechanisms with dental occlusion were more widespread among thyreophorans than previously thought and palinal movement appeared in various ankylosaurian lineages.

A new Upper Jurassic ophthalmosaurid ichthyosaur from central Spitsbergen

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From 2004-2012, eight seasons of extensive fieldwork in the Late Jurassic black shales of the Slottsmøya Member in the central Spitsbergen Sassenfjord area, has yielded numerous skeletal remains of marine reptiles. A partial skeleton of an ichthyosaur (PMO 222.654) from the Upper Jurassic (Middle Volgian) Slottsmøya Member of the Agardhfjellet Formation, Svalbard, represents a new genus and species. The specimen includes a partial laterally compressed skull, partial left forefin, right humerus, near complete shoulder girdle, near complete pelvic girdle, cervical vertebrae and accompanying ribs, caudal vertebrae and gastralia. PMO 222.654 was placed into the family Ophthalmosauridae on the basis of morphological characters found in the members of this group. These included a reduction of the extracondylar area of the basioccipital, an anterior preaxial accessory element on the humerus, an anterior twisting dorsal process on the humerus and long lateral exposure of the angular. Preliminary phylogenetic results show that Spitsbergen's Upper Jurassic ichthyosaurs could represent a monophyletic group, which could shed light on the palaeogeographic distribution of marine reptiles in this region.

What made Stan such a successful collector?

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This was the question I was once asked by one of Stan's relatives, so I asked those who knew him best for their answers. First of all was his unremitting persistence and passion. It took him two years to find his first fossil fish in 1971 at Wardie, in north Edinburgh. As Stan put it, "At this demanding locality frustration should be considered but a prologue to elation: the more intense the former the more excessive the latter!". Curiosity, close observation and focus, aided by a photographic memory. Not only of relevant rocks, but also of media which might lead him to new discoveries, like in 1974 the Dora Bone Bed, that also needed energy and physical strength to lift. Education: 'getting his eye in' by studying collections at various museums, guided by curators there. Knowing and owning the literature and gaining an OU degree. Training in fossil preparation by Alec Panchen at Newcastle 1976-9. Unconventionality and willingness to take risks, shown by him remortgaging his home to pay for opening a quarry in the middle class, academic-inhabited, Glasgow suburb of Bearsden in 1982. This exemplified his palaeoecological thinking - enlarging the catchment area to find top predators. Faith in his own judgement and ability. Enthusiastic, inspiring communicator - at all levels. Stan was not 'just a collector'. He was a larger than life character who made himself into a scientist, able to observe, deduce what might be found, and then go and find it!

The marsupial-placental mammal dichotomy revisited: new morphological data and the relevance of geography on evolutionary patterns of diversity and disparity

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Placentals occupy a larger morphospace and are taxonomically more diverse than marsupials, even considering the rich ecomorphological diversity of fossils. This contrasting evolutionary pattern has been coupled with biases introduced by marsupials' developmental features, including altriciality and functional requirements around birth and postnatal life. For example, unlike placentals, marsupials maintain many epiphyseal growth plates separated throughout life, most likely the derived state. The relevance of life history features in imposing constraints on morphological evolution is at best speculative. There are numerous cases of circumvention of developmental biases, such as the autopodial specializations of marsupial moles and the ever growing sabre-tooth of thylacosmilids. These suggest that other factors produced the marsupial pattern of restricted morphospace. Phylogenetic and geographic data offer new insights on this issue. In the Cretaceous and Palaeogene faunas from North and South America, metatherians have been more than or as diverse as eutherians. There are no positive tests of competitive displacement of metatharians by eutherians. The diversification of Marsupialia, including the differentiation into its major clades occurred about 20 Ma, more recently than that of Placentalia. The geographic pattern of taxonomic and morphological diversity within Placentalia mirrors that of placentals versus marsupials: northern clades are more diverse (ca. 4,800 spp.) than southern ones (200 spp.) and include those that are outliers in taxonomic (rodents; bats) and ecomorphological (whales; bats) richness. The differential diversity and disparity among therians is more a reflection of 'opportunity' than a bias in the production of morphological variants during development in marsupials.

A new rhomaleosaurid pliosaur from the Sinemurian (Lower Jurassic) of Lyme Regis, England

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An excellently preserved rhomaleosaurid pliosaur (Sauropterygia: Plesiosauria) from the Sinemurian (Lower Jurassic) of Lyme Regis, England, consists of a complete cranium, mandible, and articulated cervical vertebral column. The material is taxonomically distinct and its occurrence is noteworthy because pliosauroids are rare from this stratigraphic horizon. The new taxon is diagnosed by a single autapomorphy: a pronounced pit on the posterior margin of the dorsal ramus of the squamosal. It also possesses the following unique combination of characters: premaxillary rostrum short (length and width subequal), five premaxillary alveoli, premaxilla-maxilla sutures parallel anterior to the external nares, frontals contact on the midline, prefrontal-frontal suture convex and gently curved medially, mandibular symphyseal region spatulate and short (length and width subequal), robust rod-like axis neural spine with a circular transverse cross section, and cervical neural spines with a laterally expanded apex. The taxon shares some characters with older (Hettangian) rhomaleosaurids (e.g., *'Rhomaleosaurus' megacephalus*), and other characters with younger (Toarcian) rhomaleosaurids (e.g., *Rhomaleosaurus sensu stricto* and *Meyerasaurus*), and it is therefore morphologically and proportionally intermediate between these two groups.

Lungfishes from Romer's Gap: experiments in tooth plate morphology

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The rediscovery of the type locality of the lungfish *Ctenodus romeri*, in rocks of the Ballagan Formation near Coldstream in the Scottish Borders, marked the beginning of our current exploration of Romer's Gap in northern Britain. Lungfish remains have now been found at Tournaisian sites along the River Tweed, Whiteadder Water and on the coast at Burnmouth, and most recently along the River Coquet in Northumberland. Four different tooth plate morphologies have been identified. The fan-shaped tooth plate of *C. romeri*, with up to 12 rows of cusps, is the most common. A broader, sub-rectangular tooth plate, with up to 20 parallel rows of cusps, has been found at sites on the River Tweed and Whiteadder Water. A small fan-shaped tooth plate with up to five rows of cusps is known from the River Coquet. The fourth type is present in a new lungfish discovered by Stan Wood at Burnmouth. Represented by numerous incomplete body fossils, the new form has unique tooth plates with four rows of cusps; two long rows arranged one behind the other and aligned parallel to the jaw margin, and two much shorter labial rows, where the two long rows meet. By elongating the anterior lingual row and the posterior labial row this new lungfish appears to have produced a marginal dentition. The slightly younger lungfish *Uronemus*, from the Namurian of Scotland, also achieved a marginal dentition by elongation of the anterior lingual row only.

The early evolutionary radiation of Triassic marine reptiles

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The diversification of Mesozoic marine reptiles represents an exemplary evolutionary radiation. It began in the Triassic, when numerous reptilian clades radiated in the marine realm following the Permian-Triassic extinction event. Fossil evidence suggests these groups evolved a varied range of feeding ecologies and morphological innovations as early as the Anisian, rapidly establishing trophically diverse marine communities. In this study we quantify and examine the proliferation of ecological variation during the early stages of Mesozoic marine reptile evolution, using an analysis of morphological and biomechanical variation (disparity) in lower jaw elements. Results from morphospace analyses show that Triassic marine reptiles evolved an exceptional array of lower jaw morphologies and biomechanical characteristics, associated with diverse and divergent feeding ecologies. These included very robust lower jaws with large coronoid processes and durophagous dentition, characteristic of shell crushing placodonts and thalattosaurs. In addition to slender jaws with sharp and conical teeth found in ichthyosaurs and eosauropterygians, that preyed upon fish and soft-bodied invertebrates. Calculating morphological and biomechanical disparity through time reveals that Triassic marine reptiles became very disparate by the Anisian and this level of variation was maintained until the Triassic–Jurassic boundary, despite faunal turnovers and a large decline in species diversity during the Late Triassic. Overall this study quantitatively supports the notion that Triassic marine reptiles became ecologically diverse early in their history, and reveals that marine reptiles persisting into the Norian and Rhaetian remained trophically diverse.

Edinburgh Museum's dinosaur, Waterhouse Hawkins's *Hadrosaurus foulkii*

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'Benjamin Waterhouse Hawkins (1807-1894), best known in Britain for his dinosaur reconstructions at the Crystal Palace Park in London, is notable also for his mounted facsimile skeletons of *Hadrosaurus foulkii* (part casts, part restorations) at Philadelphia (1868) and elsewhere. In the 1980s, as the result of an inquiry by Don Baird, it was realised that the Edinburgh Museum of Science and Art (a precursor of National Museums Scotland) had the last of the casts. This cast was commissioned for display at the US Centennial Exhibition of 1876 at Philadelphia, and then transfered to the Edinburgh Museum by the Museum Director, one of the Commissioners for the 1876 Exhibition. It was the first modern (bipedal) display mount of a dinosaur in a museum in Europe, and would today be of enormous historical importance. However, it was discarded as out of date in 1928, its armature having gone for scrap during the Great War. A photograph of this mount has recently been discovered in the NMS archives. The display strategy used is discussed.

Barosaurus revisited: the concept of *Barosaurus* (Dinosauria: Sauropoda) is based on erroneously referred specimens

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The sauropod dinosaur *Barosaurus lentus*, from the Upper Jurassic Morrison Formation of the western United States, is a regular in popular dinosaur books. It is invariably illustrated and described as virtually identical to *Diplodocus* but with a proportionally longer neck. It has even been suggested that that *Barosaurus* and *Diplodocus* are sexual dimorphs. This popular interpretation of *Barosaurus* is based primarily on the referred specimen AMNH 6341. However, its cervical vertebrae do not closely resemble those of the holotype YPM 429. The best-preserved of the type vertebrae is a posterior cervical designated 'R', probably C14. This vertebra resembles those of brachiosaurids more than those of diplodocids: the neural arch is set forwards on the centrum, the articular surfaces are anteriorly inclined, and the neural spine seems to be unsplit, with the spinozygapophyseal laminae forming a diagonal cross in dorsal view and converging to a low point. The vertebra also has unique features, notably its extremely broad, wing-like, prezygapophyseal rami. The situation is further confused by other referred *Barosaurus* specimens, including CM 1198, CM 11984, ROM 3670 and two separate juvenile individuals, probably belonging to two different taxa but catalogued together as AMNH 7535. These specimens, together with *Kaatedocus*, may form a morphological sequence between *Diplodocus* and the popular conception of '*Barosaurus*'; but YPM 429 seems distinct from them all. This complex situation emphasises that the diversity of Morrison Formation sauropods is still far from being resolved. New taxa continue to be named, more await description, and even well-known taxa conceal cryptic diversity.

Ageleodus: widespread mid-Palaeozoic sharks known only from teeth

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Ageleodus pectinatus was first described by Agassiz (1838) from the Burdiehouse limestone (mid-Viséan, *Taphrognathus transatlanticus* Conodont Zone) of Scotland but is better known from copious specimens in the Westphalian Coal Measures of Europe and North America, usually placed in the same species. *Ageleodus* was first found in the Southern Hemisphere from Tournaisian and Visean bonebeds from central Queensland (Eastern Gondwana). This chondrichthyan of uncertain phylogeny is known only from isolated dental elements that are mostly accepted as teeth from a basal elasmobranch; Lebedev proposed an alternative hypothesis in 1996 when he interpreted them as specialized branchial denticles. *Ageleodus* is comparatively common in fluvial (lacustrine/lagoonal) and possible marginal marine sediments of late Famennian of Pennsylvania, Tournaisian of New Brunswick and Nova Scotia, Russia, Tournaisian? to Westphalian age in Britain, Westphalian of Belgium, the Netherlands and Nova Scotia, as well as in Devonian-Carboniferous boundary beds in Victoria, Australia. Their occurrence in Late Devonian and basal Carboniferous rocks in central Russia, the Catskills, and Mansfield (Vic) provides evidence of the past Palaeotethyan distribution and possible origin of this shark genus.

DGM 1475-R, a fragment of three-dimensionally preserved pterosaur wing membrane from the Santana Formation of Brazil

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A portion of phosphatised soft tissue preserved in association with several bone fragments of a medium-sized pterosaur (DGM 1475-R) was described by Martill and Unwin in 1989 as remnants of three-dimensionally preserved wing-membrane. The true identity of the specimen was thrown into doubt by Kellner's reinterpretation of the soft tissues, in 1996, as a portion of integument associated with the thorax, and remains unresolved. Restudy of DGM 1475-R shows that the soft tissues are adjacent to and enclose the humerus shaft, and continue anteriorly (as the propatagium) and posteriorly (as the cheiropatagium) to this bone as a single, approximately one millimetre thick, multi-layer sheet bounded dorsally and ventrally by epidermis. These observations, the presence of aktinofibrillae and the absence of 'hairs', demonstrate that the soft tissues represent part of the wing-membrane. DGM 1475-R confirms the complexity of pterosaur flight patagia, which consisted of an epidermis, a spongy layer (possibly pneumatic, or part of the vascular system), aktinofibrillae, muscle fascicles and blood vessels. Some of these have been identified in specimens from the Solnhofen Limestone and other pterosaur lagerstätte, but DGM 14675-R is unique in revealing the three-dimensional structure and relationships of these tissues. Critically, the specimen resolves controversies concerning the aktinofibrillae, showing that they were composite, internal, rather than external, structures, and probably composed of collagen. DGM 1475-R also

supports the idea of structural and functional heterogeneity in pterosaur wing membranes with greater extensibility in proximal regions adjacent to the body while distal portions of the patagia were relatively stiff.

Updating the Maastrichtian dinosaur record of the Southern Pyrenees (SW Europe)

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Southwestern Europe is potentially one of the best areas worldwide to assess the composition of non-avian dinosaur faunas just before their demise. The Late Cretaceous geologic formations from NE Spain and SE France (within the ancient Ibero-Armorican island) have yielded a large amount of dinosaur fossils. Some authors proposed that a late Campanian-early Maastrichtian fauna dominated by *Rhabdodon* and titanosaur sauropods were replaced in the late Maastrichtian by a new assemblage dominated by hadrosauroid ornithopods. The multidisciplinary analyses conducted in new and classic fossil localities of the southern Pyrenees provided significant advances on the chronostratigraphy of the Maastrichtian dinosaurs. The updated biochronostratigraphic framework shows that in the early Maastrichtian the overall dinosaur record is scarce for almost all the groups (theropods, ankylosaurs and ornithopods), except for the titanosaur sauropods that are abundantly represented by eggs and tracks. The late Maastrichtian features a high abundance of hadrosauroids alongside a significant diversity of titanosaur sauropods, and an unexpected occurrence of nodosaurid ankylosaurs at early times. From the new assessment we note that the scarcity of bone remains of non-avian dinosaurs in the early Maastrichtian might be caused by ecological, sedimentary and/or sampling biases, as observed in other regions. Interestingly, the unusual occurrence of nodosaurid ankylosaurs in the early late Maastrichtian together with similar evidence reported in France suggests that the faunal turnover took place gradually after the hadrosauroids reached the island, probably at about the early Maastrichtian-late Maastrichtian boundary.

Postural stability during locomotion: the effects of object tracking and dual tasking

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The evolution of the fovea centralis, alongside smooth pursuit (SP) eye movements, resulted in the ability of primates to resolve moving objects in the visual field. SP is of major adaptive importance, playing an important role in reducing the challenges of object tracking in the dense environments inhabited by our woodland dwelling ancestors. It is consequently through SP that modern humans are able to maintain visual acuity in complex and visually 'cluttered' environments such as busy city centres. However, the requirements of SP must also be integrated with those of postural stability, and sensory inputs and functions prioritised according to immediate need due to the demand on processing. Although well understood individually, the effects that gaze control may consequently have on postural control are yet to be fully established. Therefore, this project assessed how object tracking using SP in varying levels of visual clutter impacts

on foot pressure variability during locomotion in young healthy individuals. It also aimed to determine if the addition of a secondary cognitive task during SP further exacerbated any effects. The results demonstrate the presence of an optimal level of visual clutter at which foot pressure variability is lowest, and hence stability is greatest. Foot pressure variability was seen to increase in the presence of a secondary cognitive task, and hence it appears that posture acquiesces to visual and cognitive requirements. This work therefore has implications in the design of the built environment, particularly with respect to vulnerable users such as the elderly and infirm.

A giant, skeletally immature individual of *Apatosaurus* from the Morrison Formation of Oklahoma

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USAA collection of *Apatosaurus* fossils from the Morrison Formation of the Oklahoma panhandle represents several individuals, including at least one of exceptional size. Elements from the largest individual include cervical, dorsal, and caudal vertebrae, ribs, a partial scapulocoracoid, distal femur, fibula, and pedal elements. These elements are all 11–30% larger (linearly) than the equivalent bones from CM 3018, the mounted *Apatosaurus* at the Carnegie Museum. Surprisingly, the giant Oklahoma *Apatosaurus* was not skeletally mature when it died. A dorsal vertebra, OMNH 1329, has a visible neurocentral fusion line – these are all remodelled away in CM 3018. More compellingly, a very large cervical rib, OMNH 1368, is unfused. This is consistent with fusion patterns in other neosauropods, in which neurocentral fusion precedes fusion of the cervical ribs. In *Diplodocus* and *Giraffatitan*, the largest individuals with unfused cervical ribs are less than 80% the linear size (and therefore only half the mass) of the largest known individuals. Despite its immense size, the Oklahoma giant probably was not done growing, and does not represent the upper size limit for *Apatosaurus*. Linear measurements of the Oklahoma *Apatosaurus* imply a body mass roughly twice that of CM 3018. The latter specimen has been estimated to mass 18-40 tons. The Oklahoma giant may have massed 36-80 tons, potentially exceeding *Supersaurus* and *Brachiosaurus* and rivalling the largest titanosaurs.

Pterosaur overlords of Transylvania: short-necked giant azhdarchids in Late Cretaceous Romania

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Azhdarchid pterosaurs are well known for their frequent attainment of gigantic wingspans (sometimes over 10m), but are also characterised by a distinctive anatomical bauplan which is thought to be fairly uniform across the group. This comprises elongate

jaws, long limbs and short wing fingers, as well as hypertrophied cervical vertebrae, which are perhaps their most defining features. We present evidence of unprecedented morphological diversity in giant azhdarchids with EME 315, a large and robust seventh cervical vertebra from the Maastrichtian Sebeş Formation of Transylvania. The specimen corresponds in size, histology and proportions with the 10 m wingspan Transylvanian azhdarchid, *Hatzegopteryx thambema*, and likely represents a member of this genus or an extremely close relative. Despite its size, EME 315 is proportionally short and likely represents a cervical III-VII length of only 1.39 m. This is comparable to the neck lengths of much smaller azhdarchids and considerably shorter than our estimated cervical III-VII length for *Arambourgiania philadelphiae* (2.3m), another giant azhdarchid known from cervical remains. We therefore propose that long necks are not common to all azhdarchids. The robust and short-necked azhdarchid bauplan may reflect adaptation to predating relatively large animals, assuming that, as suggested for other azhdarchids, these Transylvanian pterosaurs foraged terrestrially. Because Transylvanian azhdarchids dwarf contemporary terrestrial predators by some margin, it is possible that they were apex predators in Maastrichtian Transylvania. This suggestion conflicts somewhat with hypotheses that Late Cretaceous pterosaurs were ecologically constrained and declining into extinction during the Maastrichtian.

A fresh look at the genus *Ichthyosaurus*: species characteristics, phylogeny and evolutionary drivers

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The Lower Jurassic parvipelvian ichthyosaur genus *Ichthyosaurus* is known from hundreds of specimens, the majority from the Lower Lias (Blue Lias) of southern England. Recent non-phylogenetic taxonomic reviews have recognised three or four *Ichthyosaurus* species but diagnoses have relied on variable and overlapping characters: vertebral counts; skeletal proportions; and body lengths. Despite the removal of these specimens from *Ichthyosaurus*, considerable variation persists and the monophyly of this genus needs to be tested: characters regarded as diagnostic for this taxon (such as an ulnare larger than the intermedium) are frequently ambiguous or not present in referred specimens, and our revised dataset failed to recover *Ichthyosaurus* as a clade. Two species traditionally placed within *Ichthyosaurus* group together in our new species-based analysis of thunnosaur ichthyosaurs, alongside *Leptonectes tenuirostris, Leptonectes moorei* and *Stenopterygius megacephalus*, demonstrating that the genus needs redefinition and reanalysis. Our work is aimed at: (1) resolving species-level phylogeny of *Ichthyosaurus*; (2) reinterpreting the phylogenetic relationships of traditional *Ichthyosaurus* 'species' relative to other parvipelvians; (3) better understanding the stratigraphic distribution of known specimens, and; (4) linking specimen distribution in time and space to changes in sea level, temperature and sedimentation rates in the Lias. Initial specimen-based analyses show no significant clustering of specimens with other members of putative species and some clades do not correspond with any presently recognised species of *Ichthyosaurus*. Our aim is to understand the systematics and evolution of *Ichthyosaurus* and thus elucidate tempo, mode and drivers of ichthyosaur evolution in Early Jurassic seas.

An unusual macrophagous metriorhynchid from the Late Jurassic of England

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Metriorhynchids were the crocodylomorph equivalent of cetaceans, living in marine environments during the Middle Jurassic to the Early Cretaceous. From the Kimmeridge Clay Formation of England, numerous species of metriorhynchids are known, particularly macrophagous taxa. We present evidence of a new genus and species from the Kimmeridge Clay Formation of England. This new taxon has numerous apomorphies, including: an elongated prenarial premaxilla; very long premaxillary posterior processes; premaxilla contributes to the anterior border of the first maxillary alveoli; very anteroposteriorly short mandibular symphysis (shortest of any known metriorhynchid); no evidence of a splenial contribution to the symphysis; anteroposteriorly elongated glenoid fossa on the articular; high dorsal vertebrae count (highest of any known metriorhynchid). The superficial enamel ornamentation of the tooth crowns is also unique, being largely smooth with intermittent short, discontinuous, apicobasal ridges. Some tooth crowns have extensive macrowear on the mesial and distal margins, and damaged/broken apices are common. The carinal macrowear, when present, is more extreme than that observed on *Dakosaurus maximus* teeth, although the new taxon does not have the extensive apical spalling seen in *Dakosaurus*. Under SEM, the macrowear surfaces have parallel apicobasal striations, which in extant mammals reflect tooth-tooth contact. As such, this is the second metriorhynchid with evidence for tooth-tooth occlusion (the other being *Dakosaurus maximus*). Phylogenetic analysis finds the new taxon to be a member of Geosaurini (the subclade of macrophagous metriorhynchids which includes *Dakosaurus*, *Plesiosuchus*, *Geosaurus* and *Torvoneustes*). This taxon highlights the diversity of geosaurins in the Late Jurassic open-shelf seas.

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New scale taxa from the Upper Ordovician of North America shed light on the early evolution of the chondrichthyan integumentary skeleton

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Fossil and molecular clock data have established the origin of cartilaginous fish (Class Chondrichthyes) in the Ordovician Period. Some of the oldest fossil chondrichthyans (*sensu lato*) are represented by scale taxa from the Darriwilian Stairway Sandstone (Northern Territory, Australia) and the Sandbian Harding Sandstone (Colorado). Two scale species from the latter unit (referred to in the literature as 'scale morphology A' and 'new genus F'), have been investigated by means of X-ray microtomography, SEM and Nomarski DIC microscopy. 'Scale morphology A' possesses a poly-odontocomplex crown with a characteristically large primordial odontode, and is composed solely of tubular dentine. Multiple odontocomplexes are also present in 'new genus F', in which tubular crown dentine is supported by yet to be identified second tissue type. Additional data suggest that these two taxa share a combination of characteristics (presence of scale symmetry and linear odontocomplex architecture; absence of enamel, cancellous bone and hard tissue resorption) previously documented to occur only in chondrichthyan scales. The study contributes to a growing body of evidence that is suggestive of significant diversification of tissue types (bone, tubular and atubular dentine) and morphogenetic patterns (odontocomplex and non-odontocomplex type of scale crown growth) already taking place in the chondrichthyan integumentary skeleton during the Ordovician.

Rates of dinosaur limb evolution provide evidence for exceptional radiation in Mesozoic birds

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Birds are the most diverse living tetrapod group and are a model of large-scale adaptive radiation. Neontological studies suggest a radiation within the avian crown group, long after the origin of flight. However, deep time patterns of bird evolution remain obscure because only limited fossil data have been considered. We analyse cladogenesis and limb evolution on the entire tree of Mesozoic theropods, documenting the dinosaur–bird transition and immediate origins of powered flight. Mesozoic birds inherited constraints on forelimb evolution from non-flying ancestors, and species diversification rates did not accelerate in the earliest flying taxa. However, Early Cretaceous short-tailed birds exhibit both phenotypic release of the hindlimb and increased diversification rates, unparalleled in magnitude at any other time in the first 155 Myr of theropod evolution. Thus, a Cretaceous adaptive radiation of stem-group birds was enabled by restructuring of the terrestrial locomotor module, which represents a key innovation. Our results suggest two phases of radiation in Avialae with the Cretaceous diversification overwritten by extinctions of stem-group birds at the Cretaceous–Palaeogene boundary, and subsequent diversification of the crown group. Our findings illustrate the importance of fossil data for understanding the macroevolutionary processes generating modern biodiversity.

A historical perspective on the completeness of the fossil record of pelycosaurian-grade synapsids

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While it is well known that the fossil record is incomplete, it is still debated exactly to what extent is the current record adequate for inferring macroevolutionary patterns? Is the fossil record improving? And are there still many more discoveries to be made? Here, the fossil record of the pelycosaurian-grade synapsids is examined from a historical perspective. A collector's curve is generated in order to assess the history of discovery, and a polynomial model is fitted to assess whether the rate of discovery is slowing. The relative completeness index (RCI) is applied to a supertree in order to examine how complete the known fossil record is currently. To assess whether it has improved over time, this is repeated for supertrees representing each past year as far back as 1878, created by pruning taxa unknown before each year. Finally, a current taxic diversity curve is compared to pruned diversity curves representing the taxa known each decade as far back as 1853. Discovery of pelycosaurs has slowed in recent years, implying that the number of species is approaching the asymptote of the maximum 'knowable record'. Still, the RCI indicates that there are substantial gaps in the record, although the score has improved since 1913. The current diversity curve correlates strongly with diversity curves representing knowledge as far back as 1913, indicating that the curve is afflicted by the same biases.

Multi-matrix analysis of new Late Jurassic feathered theropods from China supports troodontid-avialan clade

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The evolution of birds has been one of the most long-standing and intractable problems in vertebrate palaeontology and evolutionary biology. Following mainstream acceptance of theropod dinosaurs as the direct ancestor of birds, determining which group of dinosaurs is most closely related to birds has been a matter of intense research and speculation. The current phylogenetic model, formulated almost 30 years ago and widely supported since, states that the theropod clades Dromaeosauridae and Troodontidae form a sister clade with Avialae, which contains extant birds and their ancestors, including the iconic *Archaeopteryx*. All three groups are united within the more inclusive clade Paraves. The discovery of small-bodied theropods from the Upper Jurassic Tiaojishan Formation in China, most of which have been interpreted to be troodontids but have superficial resemblances to basal avialans, has caused controversy over the last few years by proposing radically different hypotheses regarding paravian phylogeny. By incorporating three new undescribed Tiaojishan theropods into three comprehensive but competing phylogenetic matrices and optimizing the analyses to test competing models of paravian phylogeny, evidence is presented that provides an increased level of support for the hypothesis that troodontid theropods are the closest dinosaurian relatives of birds. This research confirms the existence and increases the number of troodontid-grade avialans more primitive than *Archaeopteryx*, all of which are endemic to the region that now forms part of northern China, and has consequences for understanding the development of flight and its subsequent loss within paravian lineages.

Not only a chameleon: new details about the pectoral girdle of *Megalancosaurus*

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Megalancosaurus is a late Triassic (Norian) small archosauromorph about 30 cm long, that lived in Northern Italy. Because of its specialized features, such as prehensile tail, hands and feet; rigid trunk, tall and narrow scapula and ilium, and slender limbs, that recall extant chameleons, *Megalancosaurus* has been considered as an arboreal reptile. A detailed reinvestigation of specimens with the pectoral girdle and forelimbs well preserved led to a more detailed reconstruction of these structures, suggesting new hypotheses about their function. Chameleons walk by fore and aft movements of the limbs that are kept nearly under the body, a useful kind of locomotion on narrow supports. In the pectoral girdle the clavicles are absent and the sternum is reduced, allowing a swinging of the two halves of scapulocoracoid to obtain a longer stride. In *Megalancosaurus* the pectoral girdle is very stiff, with fused clavicles and wide sternal plates fused to the coracoids. The structure of the pectoral girdle suggests that the prehensile forelimbs had other uses than only grasping twigs. The furcula, like the clavicles and sternum, reinforced the pectoral girdle for a strong pectoral musculature that allowed the arms to grasp items firmly and keep them in a ventromedial position. With the hooked tail and prehensile hindlimbs, *Megalancosaurus* was probably able to assume a tripodal position, using the forelimbs for grasping and keeping prey in a mantis-like fashion.

Towards a redescription of *Pentlandia macroptera* Traquair 1889

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The mid-Devonian dipnoan *Pentlandia macroptera* was erected by Traquair well over a century ago but is still very poorly understood. Previous descriptions have described only in the briefest detail how this genus differs from other contemporary dipnoan taxa. More recent studies alluding to *P. macroptera* have gone into some detail about elements of the post-cranial skeleton but a detailed reconstruction of the cranium has not been attempted. This is, in part, due to the poor preservation of the skull. Still, attempts to place this taxon phylogenetically have been made but all from a limited number of specimens. As such the phylogenetic position of *P. macroptera* is equivocal. New observations indicate that *P. macroptera* is polymorphic and may possess a D bone. The palatal region is described for the first time revealing dentition on the pterygoids and observations of the cheek and ventral aspect of the cranium indicate that the arrangement of gular plates is of the advanced type for dipnoans. Details of the structure of the pectoral girdle are presented with observations of the anocleithrum and cranial ribs, previously unknown in *P. macroptera*. Whereas the caudal tail fin appears to vary in shape from straight to rounded to convex, this phenomenon is attributed to taphonomic effects. This wealth of new data now allows the phylogenetic position of *P. macroptera* to be resolved to a higher degree thus improving the phylogeny of the diverse mid-Devonian dipnoans.

Dental development of the stem osteichthyan *Andreolepis hedei* revealed by three-dimensional synchrotron virtual palaeohistology

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Andreolepis hedei from the Late Silurian of Gotland, Sweden has traditionally been placed in actinopterygian based on isolated dermal elements. The recent discovery of fragments of osteichthyan-like marginal dermal jawbones, which lack the typical shedding tooth organisation of crown osteichthyans, has suggested it is actually a stem osteichthyan. The marginal denticles have recently been interpreted both as true teeth and as tooth-shaped dermal tubercles; a detailed understanding of their organisation and growth pattern is crucial for resolving the origin of the osteichthyan dentition. Here we reconstruct the three-dimensional histological architecture of the marginal jawbone from a propagation phase contrast synchrotron microtomography scan with sub-micron resolution. The overall morphology is the result of the intercalation of at least four successive generations of non-shedding odontodes. The first-generation odontodes are arranged in regular rows, and obliquely conical towards the biting margin. They were probably functional 'teeth', since they often have the tip chipped off by biting action. The second-generation odontodes maintain tooth-like near the biting margin, but become low-relief on the facial lamina. Younger generations of larger and flatter tubercular odontodes partially or fully overgrew the elder ones of well-defined shape. The buried odontodes show evidence of partial resorption from above, instead of from the root below, leading to vascular loops from the pulp cavities of the overlying odontodes making new connections to those of the preceding odontodes. The developmental model of *Andreolepis* dentition is in striking contrast to that of most osteichthyans.

Bone histology and osteology of small-sized hadrosaurs from the Late Maastrichtian of the south-central Pyrenees (Spain)

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The continental deposits of the Pyrenean region have provided abundant hadrosaur material from the latest Cretaceous. In Huesca province (north-eastern Spain), at least four different hadrosaur taxa have been identified, ranging from specimens of 7-8 m in length (*Arenysaurus ardevoli*) down to small-sized hadrosaurs (ca. 3 m in length). The latter are represented by a number of diminutive bones recovered from the alluvial sediments of the Late Maastrichtian Conqués Formation near the village of Serraduy (Huesca province). The remains consist of small vertebrae and long bones, found in a relatively reduced area. We assume they probably belong to a single population. The vertebral material exhibits morphological features of mature individuals (vertebral centra with fused neural arches, fused partial sacrum). Two appendicular bones (an almost complete small right humerus and a distal part of a small femur) were sampled for histological examination. The humerus, although it is apparently well preserved, is

highly damaged internally, and haematitic deposits obliterate most of the cortical bone. Nevertheless, the histological structure of the preserved part of the cortex is typical of an adult, not fully grown individual. The histology of the femur is better preserved, and also exhibits the microstructural features of adult individuals. Even though none of the analysed bones belongs to fully-grown individuals, the histological and osteological analysis suggests that the small hadrosaur bones represent presumably dwarf adult hadrosaurs approaching their final body size. They are undoubtedly not the juvenile forms of the larger hadrosaur taxa described in other localities of the region.

Cranial characters and early holocephalan evolution: insights from *Deltoptychius*

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Exceptionally little is known about the relationships of early holocephalans generally, and the origins of modern holocephalan morphology, in particular. The Carboniferous holocephalan *Deltoptychius* can help to inform this question. *Deltoptychius* was discovered by Stan Wood in the early 1980s at the Bearsden fossil fish site (Serpukhovian, 326-318 Ma), but was not worked on until recently. Here we document the cranial morphology of *Deltoptychius* using 3D models generated from a computed tomography (CT) scan. Notably, parts of the braincase are preserved, even in this flattened specimen, which provide new information on the primitive conditions of early holocephalans. By comparing *Deltoptychius* to other early chondrichthyans, such as *Pucapampella*, *Chondrenchelys*, and *Helodus*, as well as the extant holocephalan *Callorhinchus*, we can begin to trace cranial character evolution within this enigmatic group. Numerous derived features, shared with extant holocephalans, are present in the skull of *Deltoptychius*, including an anterior shift in the jaw articulation, small otic capsules, the presence of tooth plates, a fused palate and neurocranium, a fused mandibular symphysis, and a pre-orbital jaw muscle insertion. However, the braincase is unexpectedly primitive in certain respects: the path of the jugular vein is ventral to, and nested under, the otic capsules, and there appears to be a persistent otico-occipital fissure. *Deltoptychius* is unique in this juxtaposition of primitive and derived characters, and compiling character information from *Deltoptychius* and other newly discovered fossil holocephalans is contributing to new hypotheses of early holocephalan relationships.

3D digital endocast of the European lambeosaurine *Arenysaurus ardevoli*

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Arenysaurus ardevoli is known from a rich hadrosaurid fauna from the Iberian Peninsula. Its braincase is the only one discovered of an European lambeosaurine. Recently, the

cranial material was scanned using industrial computed tomography (CT). After segmentation, using the visualization software Avizo, we obtained the three-dimensional endocast reconstruction. The braincase presents a slight taphonomic lateral deformation and the structures of the three-dimensional endocast are well preserved in the left side. It is possible to observe the incomplete olfactory bulbs, cerebrum, cerebellum, the beginning of the medulla oblongata, the hypophysis, the inner ear and almost every nerve from II to XII. The left olfactory bulb is the more complete and shows an L-shaped morphology in anterior view. As is typical in hadrosaurs the cerebrum has a globe-shape and the cerebellum and medulla oblonga are very narrow lateromedially. In the inner ear the three semicircular canals are approximately oriented in the three orthogonal planes, where the anterior semicircular canal is the highest dorsoventrally, and is longer. *Arenysaurus's* endocast has an anteroposterior length of 116.8 mm, a maximum width in the cerebrum of 41.2 mm, and an estimated volume without olfactory bulbs of 125.59 cm^3. The angle flexure between the cerebellum and cerebrum is very small (near to 10º), similar to the North American lambeosaurine adults. The braincase proportions and morphology opens for the first time the possibility to compare the European with other Cretaceous hadrosaurs to deepen knowledge of the neuroanatomical evolution of this clade.

The Steve Etches fossil collection

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The Steve Etches fossil collection contains over 2000 specimens collected over a period of 30 years from the Upper Jurassic Kimmeridge Clay Formation fossil Lagerstätte, mainly from Dorset, southern England. It is the most comprehensive collection of Kimmeridge Clay fossils ever assembled, and is superior in quality and quantity to the National collection. The collection is of immense value scientifically as all of the material is excellently curated with locality and horizon data, often to individual bed level with established ammonite zonation. Many of the fossils represent species new to science or are better preserved examples of taxa already known, thus adding markedly to our knowledge of (for instance) marine reptile anatomy and, potentially, their evolutionary relationships. It is the intention of Steve Etches to transfer ownership of the collection to a charitable trust established to maintain and enhance the collection in a purpose built museum at Kimmeridge. The trust has successfully passed round one of a Heritage Lottery fund application and been awarded £300,000 to develop the concept. Phase Two application will be submitted in October, and it is hoped that construction work on the new museum can begin in 2014, subject to sufficient funds being available.

Hydrodynamics of early fishes and the evolution of speed

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Minimising drag is of principle importance to many aquatic organisms, affecting both the efficiency and speed of their locomotion. Fishes, in their myriad forms have developed highly effective biomechanical and behavioural strategies for controlling fluid flow and

reducing overall drag, of which skin friction is a significant component. Some of the earliest fishes possessed dermal denticles (e.g., 'acanthodians' and thelodonts), which were likely directly exposed to the surrounding fluid, meaning we can test their hydrodynamic function without speculating about soft tissue adaptations. Using micro-computed tomography of fossil and modern material, three-dimensional plate models of repeating scale units were produced. The size, tessellation and orientation of the scales was standardised after examining specimens of the same or closely related taxa, which preserve intact flank integument. High-resolution rapid prototyping was then used to render detailed reconstructions of the flank surface. These physical models will then be subjected to flume tank analysis involving laser Doppler anemometry to measure fluid velocity and skin friction, and particle image velocimetry to observe flow patterns. This study aims to assess the impact of dermal denticles on skin friction, and whether they also reduce total drag by delaying boundary layer separation. We examine whether scale riblets act to reduce total drag, the possible mechanisms involved and the occurrence of this adaptation in the fossil record of fishes. Here we provide evidence that complex fluid principles were already being utilised by fishes to swim quickly and efficiently over 460 million years ago.

Tooth replacement patterns in two giant Upper Jurassic pliosaurids

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Dental morphology and patterns of tooth replacement in two recently described species of *Pliosaurus* were evaluated in detail. Both specimens had well preserved jaws, containing some teeth preserved in situ. Replacement teeth erupting from the bone mass were visualised by CT scans and appeared to show symmetrical eruption patterns across the medial axis, with similar growth stages represented on the left and right side. Different stages of tooth development could be clearly distinguished from the CT scans and the alveolarisation of replacement teeth could be reconstructed. Wave like tooth replacement rhythms were assessed from the degree of tooth eruption and fusion between functional and replacement alveoli. These differed from previously reported patterns seen in smaller Sauropterygians from the Middle to Upper Triassic. Our observations may be related to different tooth functions within the tooth rows.

The osteohistology of the Lower Jurassic ichthyosaurs *Temnodontosaurus platyodon* and *Ichthyosaurus communis*

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The fish-like body plan of ichthyosaurs represents an example of secondary adaptation to the marine environment. There is a strong relationship between osteohistology and lifestyle. Two primary bone structures are present within secondarily marine tetrapods; cancellous bone is associated with advanced swimming capabilities, and increased compactness with shallow marine environments. Secondary bone structures provide evidence of growth and metabolic rates. The first detailed osteohistological data for the Lower Jurassic ichthyosaur *Temnodontosaurus platyodon* is presented and compared

with new osteohistological data for the contemporaneous *Ichthyosaurus communis*. Thin sections of isolated bones were described and analysed using osteohistological analysis software BONE PROFILER. These data have been used to infer the physiology and palaeoecology of *T. platyodon*. Data for the sub-adult *I. communis* is consistent with published observations. Cancellous bone was observed in both species and indicates an active, open-water swimming lifestyle. The presence of a fibrolamellar bone complex is consistent with high metabolic rates and sustained growth throughout life in both taxa. Damage from decompression syndrome was observed on a *T. platyodon* limb bone, indicating diving behaviour. We conclude that *T. platyodon* was an active swimmer which inhabited open marine environments similar to the thunniform *I. communis*. The presence of periods of slowed bone deposition within *T. platyodon* bone sections is a feature typically found in more basal ichthyosaurs and thought to be absent from post-Triassic forms. This research is important in improving our understanding of both the evolution of the thunniform bodyplan, and of homeothermy in ichthyosaurs.

Stick or twist: were microbial mats players in Green River preservation?

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The famous fossil fish from the late Lower Eocene Green River Formation, Wyoming are preserved in exquisite detail, but the taphonomic processes responsible remain poorly understood. Two observations are key. Circa 95% of the fish are both complete and fully articulated. Among those fish that are disarticulated, what we term 'half and half' preservation is common: the anterior part of the fish is extensively disarticulated although rarely incomplete, and the posterior half complete and fully articulated. Neither observation is adequately explained by existing models that envisage rapid burial of carcasses and disarticulation having resulted from scavenging. Further, experimental analogues indicate disarticulation would have occurred, even without current activity, unless decay was halted within a matter of days (which the absence of non-mineralised tissues indicates did not occur) or a 'binding' agent was involved. We propose that microbial mats on the floor of Fossil Lake held the various skeletal elements of the fish in place while decay progressed, inhibiting disarticulation. 'Half and half' specimens are those that did not fully adhere along their length and either curved laterally or became partially buoyant, thus only that part that was in contact with the substrate (typically the posterior) retained a high degree of skeletal fidelity.

Evolution of the Lower Jaw (mandible) of Gnathostomes

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The origin of the lower jaw is a key innovation that underpins the adaptive radiation of vertebrates. The jaw has undergone fundamental changes to its composition; starting with the earliest jawed vertebrates, where the lower jaw was primarily cartilaginous and composed of a few distinct skeletal elements, in comparison to mammals, which have heavily integrated lower jaws consisting of a single dentary bone. By using

characterizations of mandible composition across three major evolutionary transitions: 1) Earliest Jawed Vertebrates to Bony Fish, 2) Tetrapod to Amniotes, and 3) Origin of Mammals, this research is based on the functional significance of changes to jaw construction across these transitions. Three synthetic mandibular model shapes based on idealized morphology were created, one shape to represent each transition. Each of these synthetic models will be validated using empirical data against 3D software-generated models. A combination of metric tests will be applied to each model to assess the biomechanical properties of the mandible and how morphology has changed under the influence of selection for a particular function. Finite Element Analysis (FEA) will be used to determine the structural adaptation and efficiency of the mandible in various feeding modes. Preliminary results suggest that the overall shape of the mandible affects the functional performance of the lower jaw and that it may be advantageous to possess a jaw composed of one bony element as opposed to a jaw composed of several bony and cartilaginous elements due to a significant decrease in the level of stress or strain forced during feeding.

Cranial functional morphology and feeding biomechanics of an extant parrot *(Ara ararauna)* using finite element analysis

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The musculoskeletal anatomy and the associated feeding mechanisms in birds are highly derived, and a number of studies have focused on describing their anatomical characteristics and biomechanics. Psittaciform birds (parrots) are a speciose avian clade and have adapted to a large range of environmental niches, from tropical rainforest to semi-arid and temperate regions of the southern hemisphere. Parrot skulls display several interesting and specialised cranial adaptations, such as the unique pseudomasseter muscle, a suborbital bar, and a highly kinetic nasofrontal hinge. These features are hypothesised to enable parrots to crack open and feed on large nuts and other hard or tough foods. Here we employ contrast-enhanced computed tomography (CT) reconstructions of the hard and soft tissue anatomy of a Blue-and-Yellow Macaw *(Ara ararauna)* skull to test the specific contributions that these features make to parrot bite forces and feeding performance. Using iodine enhanced (Lugol's solution) scans we created detailed muscle reconstructions and employed the resulting muscle force parameters in finite element (FE) model of skull performance during feeding. Results demonstrate how the M. pseudomasseter, postorbital bar and nasofrontal hinge influence bite performance and cranial strain. Inferences to postulated convergence of muscular anatomy and function in psittacosaur dinosaurs and a comparison of bite force to body mass across vertebrate taxa are considered further.

An intriguing new vertebrate fossil from Lyme Regis

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During the SVPCA meeting in Lyme Regis in 2011 a large slab of Jurassic marine sediment (shales with beef) appearing to contain some fossilised fish bones was collected

on the Spittles slip east of the town. As the contents seemed unusual, associated material was searched for and preliminary preparation of all the pieces has revealed a curious association of bones and bone fragments so strange that so far no one has been able to positively identify the specimen(s). Ideas have ranged from chondrostean, sarcopterygian and the actinopterygian *Pachychormus*, to regurgitate and even crustacean - or a mixture of any of these. As a result it has been recorded as a category 1 specimen in the West Dorset fossil collecting code of conduct (record number 273) and the material has been donated to Lyme Regis Museum. Work is ongoing, all ideas are welcome and research partners are actively being sought.

What can we learn from the brain of ornithopod dinosaurs?

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The brain is generally lost before any fossilization, being subject to rapid decay after death. That does not actually prevent its study. In fact, we have the possibility to describe the endocranial cavity, and thus the supposed shape of the brain of extinct animals, through two techniques: endocranial casts made from yielding materials (silicone or latex rubber), and 3D reconstructions generated from the processing of CT-scan data. Thanks to these techniques, we looked at endocranial volumes of a variety of ornithopods from the Cretaceous of Europe and Asia. The presence of valleculae in some taxa and their implication for the determination of the brain size in fossil species are discussed. The access to the endocranial cavity leads to the establishment of new characters whose evolution can be observed through the lineage. The size of the pituitary body is related to the production of growth hormone and increases with the relative size of the animal. In relation with the increase in body size, the flexures of the brain are reduced in larger animals. The olfactory tracts are small in the oldest species and large in *Iguanodon* and hadrosaurids, however, the olfactory bulbs are relatively small in comparison with other dinosaurs. The most derived ornithopods present an enlarged cerebrum, a high cerebrum volume/endocast volume, and a high encephalization quotient. We interpret these last characters as a consequence of the behaviour, intraspecific relations and social life of hadrosaurid dinosaurs.

A specimen of *Ichthyosaurus* with a *Stenopterygius*-like pelvis, from Watchet, Somerset, England

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A small, practically complete ichthyosaur skeleton (NMW 93.5G.2) from the Blue Lias (Hettangian, Angulata Zone) shows an unusual combination of characters. The shapes of the scapula and humerus, and probable five-digit forefin with an anterior digital bifurcation are consistent with the identification as an *Ichthyosaurus*. The most unusual feature is the pelvis. One ilium and two small, robust bones, which we identify as fused ischia and pubes, are preserved near the two femora. *Ichthyosaurus* is characterised by a

tripartite pelvis. In *Stenopterygius*, the ischium and pubis are fused, although the ischiopubis is usually longer than the femur, which is not the case here. The fin elements are rounder than usually seen in *Ichthyosaurus*, except for BGS 956, the only referred specimen of *I. conybeari*. Notching is present in anterior elements (distal carpal in forefin, tibia and tibiale in hindfin), a character that has been used taxonomically for some ichthyosaurs. Notching occurs in *I. conybeari* and some large *I. communis* specimens from Somerset, as well as *Stenopterygius*. As NMW 93.5G.2 displays taxonomic characters seen in both *Ichthyosaurus* and *Stenopterygius*, it is possible that it may represent a new taxon related to the two genera.

Functional morphology of the incisors in subterranean rodents

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Rodents have evolved a very specialized morphology as selective pressures in a subterranean environment are very different to those above ground. This investigation specifically highlights the specialization of the digging apparatus for burrow construction, with an emphasis on blesmols (African mole-rats, Bathyergidae). The sample is divided between non-tooth-digging and tooth-digging rodents. Included is the non-tooth-digging mole-rat *Bathyergus suillus*, which primarily uses a scratch mode of digging, which involves soil being removed by forelimbs. This is in contrast to the chisel tooth-digger *Cryptomys hottentotus*, which primarily uses its incisors for burrowing. It was hypothesised that the curvature of the incisors in the sample of subterranean rodents would be significantly different between tooth-digging and non-tooth-digging species. Using geometric morphometric techniques, the curvature of the lower and upper incisors was measured in all specimens. It was discovered that the non-tooth-digging rodent species had smaller angles of curvature than the tooth-diggers with regard to the upper incisors. The exception to this result was the non-tooth digging mole-rat *Bathyergus suillus*, which had a large variation of incisor shape, ranging from non-tooth digging incisor shape to tooth digging. A separate analysis was conducted on the lower incisors of the sample specimens. It was found that the lower incisors grouped differently to upper incisors, with no clear separation between tooth-diggers and non-tooth-diggers. This may indicate that selection pressures on the upper and lower incisors are different.

Acherontiscus caledoniae - the first durophagous tetrapod and its phylogenetic implications

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The early limbless tetrapod *Acherontiscus caledoniae* is known from a single, poorly preserved, small skeleton from the late Lower Carboniferous of the Scottish Midland Valley. It was described by Carroll (1969) as an anomalous taxon, having many of the features of the group Lepospondyli but not their characteristic holospondylous vertebrae. It has embolomerous vertebrae and did not appear to be closely related to any other known early tetrapod. Recent CT scanning of the specimen has revealed considerable

detail including the previously unknown palate, mandibles and branchial skeleton. The skull resembles closely those of the Adelogyrinidae, another early Carboniferous group, but differs in that *Acherontiscus* has large crushing teeth on the jaw margin and a shagreen of large palatal denticles. It is the earliest known tetrapod adapted for durophagous feeding. There is a large branchial skeleton, similar to that of adelogyrinids. Unlike most lepospondyls, the larger marginal teeth are labyrinthodont. Phylogenetic analysis suggests that *Acherontiscus* is the primitive sister-taxon of the Adelogyrinidae and that the combined clade of dwarf animals is the sister-taxon of the Colosteidae, the whole group forming one of the earliest clades of secondarily aquatic tetrapods. Having labyrinthodont teeth and embolomerous vertebrae, *Acherontiscus* is not a lepospondyl and shows that the 'lepospondyl' characters of the Adelogyrinidae evolved convergently. The possibility should be considered that the remaining Lepospondyli are not a natural group but an aggregation of dwarf tetrapod clades sharing only a character-clique associated with size reduction.

Monotreme origins: evidence from teeth and jaws

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Living monotremes (platypus and echidnas) are archaic, egg-laying mammals known from Australia and New Guinea (the palaeocontinent of Sahul). Extinct monotremes, however, are known from the Mesozoic of Australia, Paleocene of South America and Cenozoic of Sahul. This suggests an eastern Gondwanan distribution for Monotremata, with origins deep in the Mesozoic. Living monotremes are highly specialised and essentially edentate; however, a dental trail can be followed via the dentitions of extinct monotremes. Mesozoic monotremes had deep-rooted molars with triangulated (non-tribosphenic) cusps, and a comparatively high molar count. Cenozoic platypuses (Ornithorhynchidae) had a reduced number of tri-cusped, shallow-rooted molars prior to the edentate state of living adult platypuses. Cenozoic ornithorhynchid premolars enable comparisons to premolars of other early mammals. Lower jaws of some monotremes retain a meckelian groove and facets for postdentary bones, contrary to some reports. Implications of postcranial features such as crural (ankle) spurs are discussed. Possible relationships to other early mammals are presented. The geographically isolated, polar to sub-polar palaeoenvironments of early monotremes influenced their evolution, perhaps accounting for certain specialisations within the group. Analysis of taxa contemporary with early monotremes reveals a unique mix of Triassic-Jurassic relict species (including labyrinthodont amphibians, possible stegosaurs and late-surviving cynodonts); taxa more typical of some Cretaceous faunas elsewhere (including early birds, and mammals such as dryolestoids, reported here), and endemic Australian species (including the enigmatic *Kollikodon ritchiei*, first reported as a monotreme but identified here as a non-monotreme stem mammal or near-mammal).

The Devonian antiarch (Placodermi, Vertebrata) fauna from Belgium: new data, new taxa and new palaeogeographical considerations

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Anatomical, systematic and palaeobiogeographical data on Devonian antiarchs from Belgium are reviewed, updated and completed with new elements from the field and unstudied material found in the palaeontological collections of Belgian universities and institutes. The material of *Bothriolepis lohesti* Leriche, 1931 is enriched and the species better described. An undetermined species of *Bothriolepis* is brought to light in the Famennian of Modave and two species of *Asterolepis* are described or redescribed in the Givetian of Hingeon and Mazy. A new species of *Grossilepis* is found in the Famennian tetrapod-bearing locality of Strud. It is the first occurrence of that genus after the Frasnian and on the central southern coast of the Euramerican continent. It was previously known from the Famennian of Latvia, Lithuania and Russia. During the Late Devonian, the Moscow Platform, Baltic Depression and Belgium were connected by shallow to continental basins. The occurrence of *Grossilepis* in the Famennian of Belgium may be the result of a late arrival or this genus has not yet been found in the Frasnian deposits of Belgium. A new species of *Remigolepis* is described from the Famennian of Spontin. Its occurrence in Belgium (the first assured notification of this genus in Western Europe) reinforces the strong faunal affinities between Belgium and East Greenland, where the genus has originally been described, and the hypothesis of an hydrographical link existing between both areas during the Late Devonian.

Axial skeleton elements of the metriorhynchid crocodylomorph *Maledictosuchus* riclaensis, from the Middle Callovian of the Iberian Peninsula

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Maledictosuchus riclaensis is the basal-most member of the Tribe Rhacheosaurini, a subclade of increasingly mesopelagic piscivores. The specimen comes from the Middle Jurassic (Middle Callovian) marine deposits (Chelva Formation) of Ricla (Aragón, Spain). It was preserved in dark limestone nodules. *Maledictosuchus* has been described and defined recently with an almost complete skull, beautifully preserved, and part of the lower jaw (MPZ 2001/130a). Associated with the skull there were three vertebrae, also preserved in nodules. These vertebrae (MPZ 2001/130b, c, d) have been recently prepared. They lack post-mortem distortion and deformation. MPZ 2001/130b is interpreted as cervical vertebra, with the parapophyseal process located on the centrum and not associated with the neural arch. Part of the neural spine and the left diapophysis are missing. MPZ 2001/130c is practically complete. It has been identified as dorsal vertebra from the position of the parapophyses and dyapophyses, both joined forming the transverse processes that project from the neural arch. MPZ 2001/130d is a caudal vertebra, with transverse process fused to the centrum, dorsoventrally flattened and ventrally deflected, and a tall vertically oriented neural spine. The vertebrae in metriorhynchids are not diagnostic elements, but the description of the vertebrae of *Maledictosuchus riclaensis* provides additional information on the knowledge of this rhacheosaurin and on the postcranial skeleton of metriorhynchids, which are usually poorly described. The fusion of the neurocentral sutures permits confirmation that the *Maledictosuchus riclaensis* holotype was an adult specimen as had been suggested previously.

Allodaposuchus remains from the Upper Cretaceous of Europe: new crocodylomorph discoveries

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During the last six years, three complete skulls of the eusuchian genus *Allodaposuchus* have been described. PSMUBB-V-438 from Oarda de Jos (Romania) was classified as *A. precedens*; MDE/CM-616 from Fox-Amphoux (France) was assigned to *Allodaposuchus* cf. *A. precedens*; and MPZ-2012/288 from Serraduy del Pon (Spain) was named *A. subjuniperus*. The late Campanian-early Maastrichtian skulls MDE/CM-616 from Fox-Amphoux (France) and the unpublished MDE/C3-1402 from Bellevue (France) could belong to a new species of *Allodaposuchus*. They show characters not shared with *A. precedens* and *A. subjuniperus*, such as the absence of anteromedial shelf on the supratemporal fenestra and a boss on the paroccipital process, or the presence of depressions on the rostrum. Another interesting eusuchian was recovered from the lower Maastrichtian of Fumanya (Spain). It is a skeleton with postcranial and fragmentary cranial remains. A preliminary study of this taxon shows similarities with *Allodaposuchus*, such as the presence of a canalis quadratosquamosoexoccipitalis. Its ilium differs from those described in the Upper Cretaceous of Europe, having a more developed anterior process. Other fragmentary cranial remains from Armuña and Villamitjana (Spain), Bellevue (France) and Iharkút (Hungary), and other eusuchians, such as *Musturzabalsuchus*, *Arenysuchus* and *Massaliasuchus* are also similar to *Allodaposuchus*. However, their fragmentary nature makes it necessary to find more complete specimens to test the true phylogenetic relationship with *Allodaposuchus*. The Upper Cretaceous of Europe shows a complex scenario with a mosaic of eusuchians with similar shapes but with enough differences to reveal several species traditionally attributed to *A. precedens*.

Puzzling new large-sized hadrosaur remains (late Maastrichtian, NE Iberian Peninsula)

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The new late Maastrichtian hadrosaur site of Costa de les Solanes (CDS) was discovered in 2012 in the Tremp Formation (south-central Pyrenees, Catalonia). The bones, preliminary attributed to a single individual of lambeosaurine, are bigger than other hadrosaur bones previously found in the late Maastrichtian of the European Archipelago. The length of CDS tibiae and femora (890 mm and 960 mm, respectively) is much longer than those recovered from the stratigraphically equivalent Basturs Poble (BP, Tremp Formation) hadrosaur bone bed (with tibiae and femora ranges between 385 mm-730 mm and 420 mm-720 mm, respectively). Firstly, CDS long bones length is observed to be

considerably bigger than those recovered at the BP site. Furthermore, CDS bones are compared with hadrosaur tibiae and femora from the Late Cretaceous of the Dinosaur Park Formation (Canada) that fall into the category of the largest adult individuals hind limbs (710 mm-1030 mm and 790 mm-1030 mm, respectively). The lambeosaurine of CDS, despite its large size, still ranges below the mean of the worldwide 'adult size-class', and opens three possible scenarios to explain the hadrosaur size ranges of the Iberoarmorican domain. 1) BP and CDS assemblages might be located in the same ontogenetic line, the CDS individual being an adult with a different environmental preference from the rest of the herd found in BP; 2) variation in length between BP and CDS long bones might imply the co-existence in the same area and time of both small and large-sized taxa; 3) this size difference might reflect a size-related sexual dimorphism within the same hadrosaur group.

New ichnological data from Galinha dinosaur tracksite (Bajocian-Bathonian, West-Central Portugal): depth analyses through laser scan

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A complete digital outcrop model of the 40,000 m^2 Galinha sauropod tracksite, located on the eastern side of the Serra Aire (Bajocian-Bathonian, West-Central Portugal), was generated in order to quantify the morphological characteristics of two of the most emblematic manus-pes sets of sauropod trackways. These have been assigned to *Polyonyx* isp. (G1) and *Polyonyx gomesi* (G5) respectively. They both display a 'speech bubble-shaped' manus track with large pollex claw. They differ from each other on the presence/absence of digit marks both in manus and pes, the orientation of the pollex (digit I of the manus), in Track Length/Track Width ratio and in the symmetry of the manus prints. Field observations show that G1 pes displayed faint digit marks while in G5 these are distinctly impressed. G1 manus impressions showed a postero-medially oriented digit I but no other digit impressions, while G5 manus impressions display a medially oriented pollex and discernible claw marks. We examine whether these differences are anatomical, implying a different trackmaker origin, or rather a function of preservation. Depth analysis based on laser scan data revealed digit impressions also in the G1 manus-pes set and a significant similarity in the orientation of digit I and claw marks in G1 and G5. The data from this three-dimensional approach implies that both trackways were produced by non-neosauropod eusauropods displaying a comparable anatomy both in manus and pes. Variations in morphology between the tracks of G1 and G5 may have been due to rheological variation at the time of track formation.

Cranial anatomy and ontogenetic development in the giant rodent *Isostylomys* (Hystricognathi, Dinomyidae) of South American Neogene.**

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The present communication describes adult and juvenile full growth fossil specimens of the caviomorph rodent family Dinomyidae Alston 1876, collected at the same location and geological formation. The remains of the adult (MNHN 2187) consist of an almost complete skull with its partially preserved jaw, representing the first mention of skull-mandible associated remains of a giant rodent of the extinct South American subfamily Eumegamyinae. The juvenile specimen (MNHN 2687) – a complete mandible and an associated right calcaneus – is the first to be recognized as such for the entire subfamily. The materials come from the coast of the Río de la Plata in southern Uruguay, exhumed from pelitic sediments assigned to the late Miocene Camacho Formation. Both materials are assigned to *Isostylomys laurillardi* Kraglievich 1926, based on the homologies observed in the configuration of the teeth, demonstrating that the dental configuration in Eumegamyinae remains unchanged during most of its growth. Current studies on the dental ontogeny of large size rodents (Hydrochoeridae and living Dinomyidae in different growth states) also casts doubt on the validity of the subfamily Gyriabrinae, which may be in fact constituted by juveniles of different taxa that belong to other subfamilies of Dinomyidae. **Contribution to the Project CSIC-211-348 (MU).

A cranial endocast of *Pliosaurus kevani* with implications for sensory capability in large pliosaurids.

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Pliosaurids were a diverse group of marine reptiles (Sauropterygia, Plesiosauria) known from Middle Jurassic to Upper Cretaceous deposits from across the world. Many of these were large-bodied predators of other marine megafauna. Previous ecological studies of this group have primarily used skull and girdle morphologies to place large pliosaurids as ambush predators, using stealth rather than any pursuit behaviour to apprehend prey. However, unlike similar work with theropod dinosaurs there is no neurological evidence to support the morphological data. Presented and described here is a virtual cranial endocast derived from micro-focus computed tomography (μCT) scanning of the skull of *Pliosaurus kevani*, a large-bodied pliosaurid from the Late Jurassic of southern England. The endocranial volume reconstructed is very small relative to skull size, similar in proportion to the brains of Mesozoic archosaurs of a similar trophic level. The cerebral hemispheres are small and poorly defined while the olfactory tract is comparatively large and well-developed, without any prominent dorsal arch between the telencephalon and the mid-brain. This study represents the first cranial endocast for Plesiosauria and contains the first data on the olfactory tract in Sauropterygia. The reconstruction indicates a suite of features intermediate between basal sauropterygians and predatory archosaurs, as well as implying that *Pliosaurus kevani* relied largely on olfaction when hunting while hearing and visual acuity were likely under-developed by comparison.

Middle Miocene elasmobranchs of Sharktooth Hill, Kern County, California, a new synthesis with comparison to the Calvert Formation, Calvert County, Maryland elasmobranch fauna

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The Sharktooth Hill Bonebed (SHB) is a relatively thin, yet remarkable deposit of mostly marine vertebrate fossils from the middle Miocene in southeastern San Joaquin Basin. The SHB, of the Round Mountain Silt Member of the Temblor Formation, formed between 16-15 Ma during the middle Miocene Climatic Optimum (MMCO) and is among the richest bonebeds known. The SHB has attracted the attention of early investigators since its discovery in the 1850s, followed by sporadic formal investigations starting in the 1920s that continue through today. However, there has been no recent synthesis of the elasmobranchs. Reported here is the elasmobranch diversity, with a revised listing of the elasmobranchs and an initial comparison to the contemporaneous, shallow marine, temperate fauna of the Calvert Formation (CF) (Chesapeake Group) of the Calvert Cliffs. Fossils from both sites consist largely of teeth, but include dermal denticles, spines, and occasionally centra. The SHB also has gill rakers. The SHB fauna is a diverse group with 19 families: Carcharhinidae, Hemigaleidae, Scyliorhinidae, Sphyrnidae, Triakidae, Lamnidae, Cetorhinidae, Odontaspididae, Myliobatidae, Dasyatidae, Mobulidae, Rhinopteridae, Squalidae, Echinorhinidae, Heterodontidae, Hexanchidae, Pristiophoridae, Rajidae, and Squatinidae. Previous lists of the fauna include taxa that are not found in the current collections investigated, or have been revised in taxonomic schemes. In comparison, the similarly aged fauna of the CF consists of 16 families (including Alopiidae and Pristidae) with all SHB families represented with the exception of: Scyliorhinidae, Triakidae, Squalidae, Heterodontidae and Pristiophoridae. The strong commonality in faunas implies that the SHB also represents a shallow marine, temperate sea.

Late records of extinct mammals, environments and climate from Late Pleistocene-Early Holocene fluvial beds (Southern Uruguay, South America)*

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The mammalian association of fluvial beds in southern Uruguay (Santa Lucía basin) is analysed and the chronologic, environmental and climatic information is studied. The persistence in the early Holocene of extinct mammals is matter of discussion in South America (SA), and many of the few localities yielding evidence are subject of scrutiny. The chronological framework is substantiated by Radiocarbon (^{14}C: 7 samples; 5 wood, 2 teeth) and Optically Stimulated Luminescence ages (OSL: 13 sandy samples), which span the last 30,000-8,000 yrs BP. OSL ages are grouped as follows: Late Pleistocene: A) 31,160+/-2,285 and 30,855+/-2,370; B) 23,785+/-2,990; C) 17,090+/-1,430 to 12,270+/-900. Early Holocene: D) 11,620+/-990 to 8,760+/-965 yrs BP. ^{14}C ages delimited the following intervals. Late Pleistocene: A) 22,450+/-400 to 21,530+/-140. Early Holocene: B) 11,150+/-120 to 10,480+/-100 yrs BP. The survival in the early Holocene

of extinct mammals is discussed. It is highlighted that a section that yields a mudstone level in the top, overlying a sandy level with 9,330+/-670 and 8,760+/-965 yrs BP and in the base a sandy level with 12.5 kyrs OSL ages. The early Holocene sandy and mudstone levels yield extinct mammals (horses, medium to large camelids, some deer and armadillos) which suggest that they could have still survived ca. 8 kyrs at these latitudes in SA. The fossil content of the Late Pleistocene beds indicates arid/semiarid environments, predominance of grassland in open areas along with lotic environments, likely related to cold climates including the last phases of Isotopic Stage 3 and the onset of Last Glacial Maximum. *Contribution to ANII/FCE-1-2009-2398(MU).

Assessment of *Troodon* clutch morphology provides new data about brooding behaviour

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Oological material recovered from Egg Mountain and other localities in the Upper Cretaceous (Campanian) Two Medicine Formation in Montana (USA) provides a wealth of information about the reproductive behaviour of the small maniraptoran theropod *Troodon formosus*. Studies of embryos, eggs, clutches, a nesting trace, and eggs associated with adult skeletal remains reveal that *Troodon* exhibited avian-like reproductive behaviour, likely including brooding. Here, we use topographic and photogrammetric techniques to assess in-clutch egg arrangement in order to produce the first 3-D representations of *Troodon* clutches and individual eggs. These techniques provide more accurate models that allow detailed assessment and description of clutch morphology, revealing significant data on the specific way of brooding. This study focuses on egg arrangement in three clutches containing 16 to 24 eggs (MOR-363, MOR-675, MOR-963) and includes their orientation and relative position in clutches and within a trace fossil nest. Results show a tight packing of sub-vertical eggs arranged in one egg level and with the blunt poles slightly pointing to the clutch centre. All clutches display the same teardrop morphology and vertical egg arrangement, which strongly suggests post-depositional manipulation of the eggs by the parents during egg laying. In addition, the teardrop configuration of *Troodon* clutches shows strong similarity to the brood patch shape documented in several extant birds. We hypothesize that the overall clutch morphology and arrangement in *Troodon* was probably constrained by the size and shape of the brooding area of the incubating parent. This type of incubation closely resembles the brooding behaviour exhibited by extant birds.

Articulated rays from the Late Cretaceous of Morocco and the affinities of the genus *Ptychotrygon*

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Articulated fossil batoids are typically known as compression fossils, such as those from the Late Cretaceous Lebanese plattenkalks. Whilst often well preserved, their detailed anatomy and structural relationships are difficult to interpret. Articulated batoids preserved in three dimensions are very rare and largely restricted to a single described species from the mid Cretaceous Santana Formation of Brazil. The Moroccan Turonian (Late Cretaceous) locality of Goulmima is well known for its ammonites, teleost fishes and marine reptiles preserved in calcareous nodules. Recently, a number of batoids have been recognised which preserve their hard part anatomy in three dimensions. A single specimen of a recently described batoid, *Tingitanius tenuimandibularus*, is the earliest known platyrhinid. Other specimens belong to schlerorhynchid sawfishes of at least two genera. Preliminary studies confirm the presence of *Micropristis* based on its dental and rostral peg morphology, with tooth morphology suggesting that this is congeneric with *Texatrygon*. Other, typically larger, specimens are very similar to *Libanopristis*, but display articulated dentitions referable to Ptychotrygon, a batoid with a global distribution, unknown affinities and described only from isolated teeth. This raises the intriguing possibility that the Lebanese specimens of *Libanopristis* may be juvenile specimens of *Ptychotrygon*.

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David Ward, The Natural History Museum (Earth Sciences)
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Mark Witton, Portsmouth University (SEES)
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