

Abstracts of Presentations



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SPPC Papers

The rather naive idea of forming a museum on the Jurassic Coast

Steve Etches

The problems involved in setting up a charitable trust, obtaining funding and finding a suitable site to try and ensure the long term security of a specialised collection.

Fake Rock, Real Sand: The making of the exhibition 'Sahara - living desert'

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In 2006, the State Museum of Natural History in Braunschweig, Germany, hosted a special exhibition on the Sahara desert, focussed on the animals and plants and their adaptations to the environmental challenges of the desert climate, the change from a green desert in former times to today's ocean of sand, plus an additional component on how human beings are able to live there.

The way that the impression of a desert was achieved by using styrofoam, tile mortar and real Sahara sand to build an artificial rock face and a sand dune area is described.

Images of the finished exhibition are also shown.

The Good, The Bad and The Ugly: Preparation from the Wild West

Cindy Howells

National Museum of Wales

Fossils on sale at trade shows offer a unique opportunity to view differing styles and standards of preparation. The Tucson Show in Arizona is considered to be the largest such 'gem' show in the world, and the variety and quality of specimens is unsurpassed. Equally, it is a market for replicas, and in some cases, fakes. The talk will illustrate a small selection of the best and worst that can be seen by a visitor to this show.

The virtual and physical preparation of the Collard Plesiosaur

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The 'Collard Plesiosaur', found in 2003 in Bridgwater Bay on the Somerset coast, has been described as '*probably the best preserved and most scientifically valuable fossil plesiosaur to have been found in the UK for at least 150 years, possibly ever*' (Richard Forrest, SPPC/SVPCA 2005). The skeleton is almost complete and variably-mineralised.

The skeleton (possibly a juvenile Rhomaleosaur) was preserved in Lower Liassic Kilve Shales - a fine-grained, thinly laminated rock containing little or no cement. Held together by compression, this lithology is notoriously susceptible to fluctuations in humidity, severely compromising the integrity of specimens once dry.

The priorities for the project were to arrest shale delamination caused by environmental fluctuations and to prepare the specimen for research. The specimen appeared to be well fossilised in a homogeneous, un-cemented matrix, offering excellent potential for X-radiography. Therefore before preparation commenced the specimen was X-rayed and CT-scanned with stunning results, despite some of the limb bones not being well mineralised. This virtual preparation helped to inform the subsequent physical preparation of the material.

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Investigations were undertaken to select the most suitable tools, materials and techniques to conserve and prepare the specimen. Attempts to consolidate matrix samples with the methacrylate co-polymer Paraloid B72 were generally unsuccessful – the shale layers distorted and delaminated. However, B72 was successfully applied to the sides of the specimen blocks providing a humidity seal.

Mechanical preparation commenced with the removal of underburden, greatly reducing the specimen's weight. The use of a scalpel proved to be the most appropriate technique for developing its surface and exposing the skeleton, removing one paper-thin layer of shale at a time.

Parsons, D. 2002. A new sea dragon: from discovery to display. *Ecology in Somerset* 2002:191-198.

Palaeontological preservation with 21st Century documentation: using photogrammetry to produce highly detailed 3D image models

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Photogrammetry has long been considered an excellent means for capturing three-dimensional data about a subject. In the past photogrammetry was not widely used in palaeontology due to the need for expensive metric cameras, analytical equipment, and technical expertise. However, dramatic technological advancements have resulted in a simplification of the process for capturing overlapping stereoscopic photographs. Affordable, quality digital cameras, high performance laptops, and cost effective software allow for the production of 3D data both in the field and lab. The 3D surface data (x, y, z points) are generated from photographs, thus image textures can be registered to the surface with the quality, reliability, and authenticity necessary for scientific use and visualization. The resulting 3D image models can be utilized in a variety of softwares where vertical exaggeration and scale can be manipulated to enhance features difficult to see or measure in the field (Matthews *et al.*, 2006). This strengthens the accuracy of measurements (e.g., length, width, depth) by overcoming the biases of topography, accessibility, and lighting (Breithaupt *et al.*, 2004). In addition, more rigorous morphometric comparisons can be conducted from a multidimensional digital data set. These 3D image models will not degrade during handling, transportation, or repeated analysis and can be used to generate solid model prototypes, and for virtual cataloguing on the web. Taking stereoscopic photographs today not only preserves the specimens into the future, but it can also be used to travel back in time, as monoscopic historical photographs can be incorporated into present projects for analysis.

Breithaupt, B. H., Matthews, N. A. and Noble, T. A. 2004, An integrated approach to three-dimensional data collection at dinosaur tracksites in the Rocky Mountain West, *Ichnos*, 11, 11-26.

Matthews, N. A., Noble, T. A. and Breithaupt, B. H 2006. The application of photogrammetry, remote sensing, and geographic information systems (GIS) to fossil resource management, *in*: Lucas, S.G., Spielmann, J.A., Hester, M.H., Kenworthy, J.P., and Santucci V.L., (eds.), *America's Antiquities: 100 years of managing fossils on Federal lands, Proceedings of the 7th Federal Fossil Resources Conference, New Mexico Museum of Natural History and Science, Bulletin*, 34, p. 119-131.

Emergency remedial conservation of homeless mammoth material

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Through a peculiar series of events I managed to find myself with a box of mammoth material falling apart in my lab. The box contained numerous tooth and tusk fragments, wrapped in newspaper and placed into separate plastic sandwich bags. As a result, the material was in dire need of conservation work. The most effective form of remedial conservation was decided to be a mixture of Paraloid B72 as an adhesive and glass beads as a polymer filler in order to stabilise the material and to prevent further deterioration. I report here on the numerous problems faced throughout the work, and the overall outcome and level of success achieved.

Larkin, N. and Makridou, E. 1999. Comparing gap-fillers used in conserving sub-fossil material. *The Geological Curator* 7 (2), 81-90.

SVPCA Papers

The specialized dentition of derived notosuchians (Crurotarsi: Mesoeucrocodylia)

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Dentition has been used to infer diet in fossil crocodylomorphs (e.g. Clark *et al.*, 1989; Wu *et al.*, 1995). Caniniform teeth are likely to be well represented in predators, while complex molariform teeth can be associated with omnivory-herbivory. Notosuchians are fossil mesoeucrocodyles, including species with multicusped teeth without carinae, interpreted as omnivores-herbivores (e.g. Wu *et al.*, 1995; Buckley *et al.*, 2000). Baurusuchid notosuchians are hyperpredators, showing a theropodomorph dentition with ziphodont carinae (Riff & Kellner, 2001). *Notosuchus*, *Mariliasuchus* and *Sphagesaurus* are derived notosuchians from the Upper Cretaceous of South America, for which the diet is still poorly understood. Pol (2003) indicated that *Sphagesaurus* shows an unexpected feeding behaviour for a crocodylomorph, including tooth-tooth occlusion, fore-aft jaw movements and alternate unilateral jaw occlusion. *Notosuchus* and *Mariliasuchus* have elongated articular condyles, supporting fore-aft jaw movements. *Notosuchus*, *Mariliasuchus* and *Sphagesaurus* also show the predominance of single crowned molariforms, with oblique orientation. Only one pair of premaxillary hypertrophied caniniforms is present, without lateral compression/acute apex. Carinae are present at middle and posterior teeth only. MEV study of *Mariliasuchus* teeth shows that carinae are composed by true denticles that do not match the ziphodont pattern in morphology or distribution (Andrade & Bertini, 2005). Despite the absence of multicusped teeth, *Notosuchus*, *Mariliasuchus* and *Sphagesaurus* do not fit into a predator profile and could rather be understood as omnivorous/herbivorous species. The morphology of rostrum, supratemporal fenestra and mandible supports this hypothesis. Robustness of teeth and skull elements indicates these were durophagous foragers.

Andrade, M. B. and Bertini, R. J. 2005. Morphology of the dental carinae in *Mariliasuchus amarali* (Metasuchia) and the pattern variation among fossil Crocodylomorpha. In: Congresso Latino-Americano de Paleontologia de Vertebrados, 2. *Boletim*. Rio de Janeiro, Museu Nacional/UFRJ: 25-26.

Buckley, G. A., Brochu, C. A., Krause, D. W. and Pol, D. 2000. A pug-nosed crocodyliform from the Late Cretaceous of Madagascar. *Nature*, 405(6765): 91-94.

Clark, J. M., Jacobs, L. L. and Downs, W. R. 1989. Mammal-like dentition in a Mesozoic crocodylian. *Science*, 240(6): 1064-1066.

Pol, D. 2003. New remains of *Sphagesaurus* (Crocodylomorpha: Mesoeucrocodylia) from the Upper Cretaceous of Brazil. *Journal of Vertebrate Paleontology*, 23(4): 817-831.

Riff, D. and Kellner, A. W. A. 2001. On the dentition of *Baurusuchus pachecoi* (Crocodyliformes, Metasuchia) from the Upper Cretaceous of Brazil. *Boletim do Museu Nacional – Série Geologia*, 59: 1-15.

Wu, X-C., Sues, H-D and Sun, A. 1995. A plant-eating crocodyliform reptile from the Cretaceous of China. *Nature*, 376(6542): 678-680.

Mesozoic dinosaur diversity: taxic, phylogenetic and sampling approaches

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Patterns of species-diversity provide important macroevolutionary information. Previous work on non-avian dinosaur diversity has been used to investigate the K/T extinction, effects

of sea level on preservation, clade-clade competition and possible coevolutionary scenarios (e.g. Wang & Dodson, 2006). Most of these studies simply counted taxa to estimate standing diversity (taxic approach), while several incorporated information on ghost lineages (phylogenetic approach) or used rarefaction techniques (one potential sampling approach).

Studies on marine invertebrates have shown that the rock record (outcrop area, number of localities *etc.*) has a strong influence on diversity patterns (e.g. Smith, 2001), but similar corrections have not been applied to terrestrial clades. We compiled diversity curves for dinosaurs as a whole (including Mesozoic birds) and various component clades. Taxic diversity curves were obtained for species and genera: these were corrected using ghost lineages obtained from phylogenetic analyses. Statistical tests (Pearson's and Spearman's correlations) revealed strong positive relationships between the species/genus curves and the taxic/phylogenetic curves. This indicates that the same signals were being sampled in each case. A model of expected species-richness was then constructed for each clade using the number of dinosaur bearing formations (DBFs) present in each time interval as a proxy for outcrop area. Comparisons between the models and the diversity curves indicate that apparent patterns in ornithischian and theropod diversity can be explained largely as a result of changes in the number of DBFs. Conversely, sauropodomorph diversity bears little resemblance to that expected from the model, suggesting that at least some features of this curve result from genuine evolutionary signals.

Smith, A. B. 2001. Large-scale heterogeneity of the fossil record: implications for Phanerozoic diversity studies. *Philosophical Transactions of the Royal Society of London, Series B*, 356, 351-367.

Wang, S. C. and Dodson, P. 2006. Estimating the diversity of dinosaurs. *Proceedings of the National Academy of Sciences of the United States of America*, 103(37), 13601-13605.

Craniodental and postcranial morphology of a primitive hyracoid (Mammalia, Paenungulata) from the early Priabonian (late Eocene) of Egypt

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Recently discovered late Eocene fossil-bearing sites in the Birket Qarun Formation in the Fayum Depression, Egypt, have produced a primitive new hyracoid represented by a relatively well preserved cranium, postcranial bones, mandibular fragments and numerous isolated teeth. The sites are approximately 37 million years old, 3 million years older than the next oldest hyracoid-yielding locality in the Fayum. Despite extensive sampling and the recovery of a diverse mammal fauna (Seiffert *et al.*, 2003; Seiffert *et al.*, 2005) the hyracoid material from the Birket Qarun Formation can only be assigned to a single new genus and species. It shares some primitive features with older hyracoids from Algeria (e.g., small body size, brachyodont and bunodont molars and simple premolars). The cranium is comparable to other small Palaeogene hyracoids except that the orbit is positioned above the premolars (rather than above the molars) as in early sirenians, proboscideans and living and extinct procaviids. The mandible has a coronoid canal but there is no evidence of an internal mandibular fenestra. Postcranial material shows that the new hyracoid was not cursorially adapted, unlike some larger, younger hyracoids. The Fayum has yielded the most numerous and diverse collection of hyracoids known (Meyer, 1978; Rasmussen and Simons, 1988). Climate change and competition with other herbivorous mammals has had dramatic effects on hyracoid diversity and the discovery of the oldest known Fayum hyracoid is of great importance for understanding the adaptations of the group's most basal members.

Meyer, G.E. 1978. Hyracoidea. Pp. 284-314 in V.J. Maglio and H.B.S. Cooke (eds) *Evolution of African Mammals*. Harvard University Press, Cambridge.

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- Rasmussen, D.T. and Simons, E.L. 1988. New Oligocene hyracoids from Egypt. *Journal of Vertebrate Paleontology*, 8: 67-83.
- Seiffert, E.R., Simons, E.L. and Attia, Y. 2003. Fossil evidence for an ancient divergence of lorises and galagos. *Nature*, 422: 421-424.
- Seiffert, E.R., Simons, E.L., Clyde, W.C., Rossie, J.B., Attia, Y., Bown, T.M., Chatrath, P. and Mathison, M. 2005. Basal anthropoids from Egypt and the antiquity of Africa's higher primate radiation. *Science*, 310: 300-304.

Basal tyrannosauroids: a new theropod dinosaur from the Kimmeridge Clay (Late Jurassic: Tithonian) of Dorset, UK representing a large-bodied species of the North American genus *Stokesosaurus*

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Tyrannosauridae is a derived clade of carnivorous theropod dinosaurs, known from the Late Cretaceous of North America and Asia, some members of which attained colossal size (Holtz, 2004). However, Late Jurassic tyrannosauroids (members of the larger group containing Tyrannosauridae) which have potential to shed light on the origins of this group, are poorly-known. A partial postcranial skeleton from the Late Jurassic (Tithonian) of Dorset, England is one of only two Jurassic tyrannosauroids known from associated remains and represents a new species of the North American theropod genus *Stokesosaurus* (Madsen, 1974). The specimen provides additional anatomical evidence in support of the tyrannosauroid affiliation of *Stokesosaurus*: a distinct median vertical ridge on the lateral surface of the ilium, a pronounced shelf medial to the preacetabular notch, a prominent ischial tubercle, and a tibia that is elongate relative to the femur. With an estimated mass of 350kg, the new specimen is substantially larger than other known Jurassic and Early Cretaceous tyrannosauroids (Rauhut, 2003; Xu *et al.*, 2004, 2006), and provides evidence for a basal radiation of small to medium-sized tyrannosauroids in Asia, North America and Europe during the Late Jurassic. The occurrence of *Stokesosaurus* in the UK supports the hypothesis of a palaeobiogeographic link between North America and Europe during the Late Jurassic.

- Holtz, T.R., Jr. 2004. Tyrannosauroides. p.21-24 In: Weishampel, D.B., Dodson, P. and Osmólska, H. (Eds.), *The Dinosauria*. Second Edition. University of California Press, Berkeley.
- Madsen, J.H., Jr. 1974. A new theropod dinosaur from the Upper Jurassic of Utah. *Journal of Paleontology*, 48, 27-31.
- Rauhut, O.W.M. 2003. A tyrannosauroid dinosaur from the Upper Jurassic of Portugal. *Palaeontology*, 46, 903-910.
- Xu, X., Norell, M. A., Kuang, X., Wang, X., Zhao, Q. and Jia, C. 2004. Basal tyrannosauroids from China and evidence for protofeathers in tyrannosauroids. *Nature*, 431, 680-684.
- Xu, X., Clark, J.M., Forster, C.A., Norell, M.A., Erickson, G.M., Eberth, D.A., Jia, C. and Q. Zhao, Q. 2006. A basal tyrannosauroid dinosaur from the Late Jurassic of China. *Nature*, 439, 715-718.

Mass extinction of tetrapods at the Permo-Triassic boundary in Russia

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The Permo-Triassic (PT) mass extinction had as profound an effect on tetrapod diversity as on life in the sea. Studies on the PT sequences in South Africa and Russia have revealed some detail of the magnitude and pattern of ecosystem destruction and recovery, but these studies are dogged with major problems. The dating is disputed: according to current geological time scales, the Russian Tatarian, formerly the terminal stage of the Permian, has been moved down to the Middle Permian (Guadalupian, Capitanian). If this is true, the Vyatskian (upper Tatarian) fauna of Russia and the equivalent Dicynodon Assemblage Zone of the Karoo must lie well below the PT boundary. Our fieldwork in Russia in 2006 included studies of palaeomagnetism and stable isotopes (measured from carbonate palaeosols) through the entire PT succession, and these more or less confirm the classic view. Quantitative studies of the Russian faunas shows the catastrophic collapse of tetrapod ecosystems at the PT boundary, and that they had not recovered to a fully stable condition 20 Myr later at the end of the Middle Triassic (Benton *et al.*, 2004). Sedimentological studies of the Russian sections confirm major climate and environmental changes at the PT boundary: global warming, removal of plants and soils, change in fluvial regime from meandering to braided streams, and a negative carbon isotope shift. These confirm the generally accepted model of extinction following a concatenation of processes triggered by repeated eruption of the Siberian traps.

Benton, M. J., Tverdokhlebov, V. P. and Surkov, M. V. 2004. Ecosystem remodelling among vertebrates at the Permian-Triassic boundary in Russia. *Nature*, 432, 97–100.

The pectoral fin of the near-tetrapod *Panderichthys rhombolepis*

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The elpistostegids *Tiktaalik* and *Panderichthys*, members of the tetrapod stem group, are the closest known relatives of limbed vertebrates. The pectoral fin skeleton of *Tiktaalik* contains small distal bones that have been interpreted as digit precursors. This agrees well with the condition in some less crownward stem tetrapods such as the rhizodont fish *Sauripterus*, and with developmental and molecular evidence that digit precursors are present in the lungfish *Neoceratodus* and the primitive actinopterygian *Polyodon*. However, *Panderichthys* has been described as lacking digit precursors. Here we present the first x-ray CT study of the pectoral fin of *Panderichthys*, based on an unflattened specimen in which the right pectoral fin is complete and buried in matrix beneath the body. The distal "ulnare" of previous reconstructions proves to be a compound structure comprising a real, small, ulnare and an array of distal radials comparable to those of *Tiktaalik* or *Sauripterus*. Other elements compare reasonably well with the published descriptions, though the humerus is considerably more three-dimensional than previously thought. Overall, the pectoral fin skeleton of *Panderichthys* compares closely with that of *Tiktaalik*, except that the latter has a longer axis. Digit precursors appear to be present throughout the "fish" part of the tetrapod stem group as well as in more distantly related osteichthyans. Interestingly, the fin skeleton of

Tiktaalik appears autapomorphic with respect to the extended axis. The shorter skeleton of *Panderichthys*, in which the ulnare is the last axial element, may be a better representative of the ancestral condition for limbs.

Growing up in the Middle Jurassic: ichnological evidence for family groups of theropods in Wyoming; comparison of footprints and growth rates of emus and dinosaurs

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Evidence for gregarious, family-level behaviours in theropod dinosaurs, although rare, can be found in the ichnological record. Compelling evidence for theropod family groups can be seen at Middle Jurassic (Bathonian) sites in Wyoming (Adams and Breithaupt, 2003; Breithaupt *et al.*, 2004; 2006a) and Scotland (Clark *et al.*, 2005). In Wyoming, extensive research at the Red Gulch Dinosaur Tracksite and other areas within the Sundance Vertebrate Ichnofaunal Province has documented the presence of thousands of tridactyl pes impressions of the ichnotaxon *Carmelopodus* in the Lower Sundance Formation. These tracks are arranged into hundreds of trackways interpreted as having been made by a gregarious, monotaxonomic population of yearling to adult, primitive, tetanuran theropods. To better understand the ontogenetic and behavioural implications of these ichnites, the tracks of extant emus (*Dromaius novaehollandiae*) have been studied. As emus make theropod-like, tridactyl footprints, are gregarious, have precocial young, and exhibit parental care, they are excellent modern analogues for studying growth and community dynamics of small- to medium-sized carnivorous dinosaurs, as well as track formation (Milan, 2006; Breithaupt *et al.*, 2006b). By collecting ichnological data from emus of various ages, growth curves for footprints can be developed and compared to previously established growth rates for dinosaurs (Erickson *et al.*, 2001). By integrating these curves, the approximate ages of theropods represented only by their footprints can be inferred. In addition, the observations of emu activities and the associated tracks provide valuable information to the understanding of the behaviours preserved in the ichnological record of bipedal dinosaurs.

- Adams, T. L. and Breithaupt, B. H. 2003. Middle Jurassic dinosaurs of northern Wyoming: evidence from the Yellow Brick Road Dinosaur Tracksite, Bighorn Basin, Wyoming, Wyoming State Geological Survey, Wyoming Geo-notes, 78, 39-46.
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- Breithaupt, B. H., Southwell, E. H., Adams, T. L. and Matthews, N. A. 2006a. Myths, fables, and theropod community dynamics of the Sundance Vertebrate Ichnofaunal Province, in Barrett, P.M. and Evans, S.E. (eds.), 9th International Symposium on Mesozoic Terrestrial Ecosystems and Biota, Natural History Museum, London, UK, 1-4.
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- Erickson, G. M. Curry-Rogers, K., and Yerby, S. 2001. Dinosaur growth patterns and rapid avian growth rates, *Nature*, 412, 429-433.
- Milan, J. 2006. Variations in the morphology of emu (*Dromaius novaehollandiae*) tracks, reflecting differences in walking pattern and substrate consistency: ichnotaxonomical implications, *Palaeontology*, 49, 405-420.

Redescription of *Neovenator salerii* (Dinosauria: Theropoda) and its implications for theropod evolution and phylogeny

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Neovenator salerii (Dinosauria: Theropoda) is the most complete large theropod known from Europe but has only briefly been described in the literature (Hutt *et al.*, 1996; Naish *et al.*, 2001). Here we present a redescription of the holotype and referred specimens from the Early Cretaceous Wessex Formation (Wealden Group) of the Isle of Wight, which together comprise approximately 70% of the skeleton. *Neovenator* is shown to possess numerous autapomorphies, including an enlarged maxillary fenestra, a peg-and-socket accessory articulation between the premaxilla and maxilla, and curved flanges emerging from the zygapophyses of posterior dorsal vertebrae. *Neovenator* clearly belongs to Allosauroidea, a clade of basal tetanuran theropods that includes *Allosaurus*, *Sinraptor*, and the Carcharodontosauridae, a subgroup that contains some of the largest known theropods. Phylogenetic analysis finds *Neovenator* as the basal-most member of Carcharodontosauridae, a position supported by numerous synapomorphies, including camellate cervical vertebrae, details of the pleurocoels in cervical and dorsal vertebrae, a hypertrophied pubic boot, an anteriorly-expanded ischial boot, a dorsally-inclined femoral head, and a hypertrophied medial malleolus of the tibia. This placement suggests that basal carcharodontosaurids were components of European faunas before becoming restricted to Gondwana later in their evolution. Additionally, character acquisition patterns indicate that large body size and the highly apomorphic skull of derived carcharodontosaurids evolved after changes to the axial and appendicular skeleton. These changes include an increase in axial pneumaticity and alterations in limb articulation, which clearly were not a direct response to the large body size of derived carcharodontosaurids as demonstrated by their presence in the much smaller *Neovenator*.

Hutt, S., Martill, D. M. and Barker, M. J. 1996. The first European allosaurid dinosaur (Lower Cretaceous, Wealden Group, England). *Neues Jahrbuch für Geologie und Paläontologie, Monatshefte* 1996, 635-644.

Naish, D., Hutt, S. and Martill, D. M. 2001. Saurischian dinosaurs 2: theropods, in Martill, D. M. and Naish, D., (eds.), *Dinosaurs of the Isle of Wight*. Palaeontological Association Field Guides to Fossils, 10, p. 242-309.

The ceratopsian dinosaur *Psittacosaurus* in Southeast Asia : a review of old and new finds

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The early ceratopsian dinosaur *Psittacosaurus* is widespread in the Early Cretaceous of central and northern Asia, from Siberia to Mongolia and northern China. Its occurrence in Southeast Asia was first reported in 1989, when the discovery of an upper and a lower jaw in the Khok Kruat Formation (Aptian) of northeastern Thailand was announced. That material was described as a new species of *Psittacosaurus*, *P. sattayaraki*, in 1992. Although doubts

about this generic identification have been expressed, the Thai specimens show distinctive characters of *Psittacosaurus* (Buffetaut and Suteethorn, 2002). More material, confirming the occurrence of *Psittacosaurus* in the Khok Kruat Formation, has recently been found in Thailand, and the genus is also present in a formation of equivalent age in Laos. In northern and central Asia, *Psittacosaurus* is often very abundant in formations ranging in age from Hauterivian to Albian (Lucas, 2006; Averianov *et al.*, 2006). It seems to be less frequent in Southeast Asia, and not to be present there before the Aptian. This different pattern of stratigraphic distribution may be the result of a period of relative isolation of Southeast Asian terrestrial vertebrate faunas during part of the Early Cretaceous, which is suggested by various lines of faunal evidence (including the apparent lack of ornithischians in the ?Hauterivian-Barremian Sao Khua Formation). *Psittacosaurus* may have reached Southeast Asia, together with other ornithischians (including early hadrosauroids), only at the end of this period of isolation, the causes of which remain uncertain.

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- Buffetaut, E. and Suteethorn, V. 2002. Remarks on *Psittacosaurus sattayarakii* Buffetaut and Suteethorn 1992. A ceratopsian dinosaur from the Lower Cretaceous of Thailand. *Oryctos*, 4, 71-73.
- Lucas, S. 2006. The *Psittacosaurus* biochron, Early Cretaceous of Asia. *Cretaceous Research*, 27, 189-198.

Palaeoenvironmental controls on the distribution of Cretaceous herbivorous dinosaurs

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Most attempts to assess palaeoenvironmental preferences for dinosaurs have assessed distribution within a single formation. Here we use a global relational database of Cretaceous herbivorous dinosaur occurrences to test hypotheses of broad environmental preferences at the level of supraspecific clades. This database is part of a broader project on Cretaceous dinosaur and plant distribution; currently it contains geographic, taxonomic, geological and palaeoenvironmental data for c.8500 dinosaur and plant occurrences at 1750 localities. The current analyses utilised a query containing the dinosaur occurrences (1790) and associated environment and taxonomic information. The detailed environmental data was simplified into broad depositional categories of marine (6% of localities), coastal (12%), terrestrial (75%) and unknown/ambiguous (7%). Chi-squared tests were used to test specific hypotheses of associations.

A significant positive association was found between Nodosauridae and marine depositional environments ($p=0.005$); by contrast, their sister-clade Ankylosauridae are positively associated with terrestrial environments ($p=0.05$). The overrepresentation of nodosaurid specimens in marine environments suggests that they occupied a broader environmental range, including coastal areas, than did ankylosaurids (Coombs and Deméré, 1996). Hadrosaurids are overrepresented relative to other herbivores in marine environments ($p=0.001$), consistent with suggestions that they preferred coastal plain environments. However, existing evidence does not support the hypothesis that hadrosaurine hadrosaurs were more abundant in marine sediments than lambeosaurines (Horner, 1979). Both ceratopsians and pachycephalosaurs show positive associations ($p=0.005$) with terrestrial environments, supporting interpretations of inland environmental preferences. Our results provide quantitative support for previous qualitative hypotheses of palaeoenvironmental preferences, emphasising the potential of large databases in broad palaeoecological analyses.

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- Horner, J. R. 1979. Upper Cretaceous dinosaurs from the Bearpaw Shale (marine) of south-central Montana with a checklist of Upper Cretaceous dinosaur remains from marine sediments in North America. *Journal of Paleontology* 53: 566-578.

The contribution of placoderms to our understanding of the ontogeny and evolution of early gnathostomes

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Placoderms, as the outgroup to remaining gnathostomes, are critical to our understanding of the polarity of character state transitions within basal chondrichthyans and osteichthyans. For example, they document the polarity of pectoral fin characters, thus the plesiomorphic state consists of a single proximal element with a narrow attachment to the girdle. The evolution of extant conditions represents the breakup and/or variable loss within this proximal element.

Development of the gnathostome neurocranium includes the origin and fusion of the occiput and trabeculae to the primitive vertebrate braincase, evidenced by the anterior fissure among placoderms and the otic-occipital fissure in chondrichthyans and teleostomes. Placoderms retain plesiomorphic short trabeculae with the palatoquadrate articulating with the parachordals.

Fusion among anterior vertebrae to form a synarcual in placoderms mimics the anatomical transformations associated with misexpression of segment-related genes in mice and humans. Thus, one group's maladaptive misexpression may be the source of an adaptive change in other taxa where a synarcual is found.

Goodrich suggested a paired and neural crest origin for basibranchial elements of the visceral skeleton. This is confirmed in *Cowralepis mclachlani* (Phyllolepida, Placodermi) where these elements are paired throughout ontogeny and possess significant attachment sites for hypobranchial musculature (documenting their neural crest origin).

Renewed interest in placoderms is providing important evidence to establish character polarity for a number of anatomical systems. It also documents the presence in adults of characters that are now only glimpsed as transitory features in ontogeny thus a peramorphic shift among extant taxa relative to the gnathostome primitive condition.

New discoveries from Bearsden: reassessing the early record of post-Devonian fishes

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The Mississippian (Serpukhovian) Bearsden fauna (Glasgow, Scotland) is known for the exceptional preservation of its fossil sharks. The equivalent horizon was known from sites in

Ayrshire and Lanarkshire in the late 1800's, but it was not until Stan Wood's discoveries (Wood, 1982) that reports highlighted the quality of chondrichthyans from the Manse Burn Formation, as well as the diversity of actinopterygian fishes and fossil crustaceans. In general terms, the Bearsden biota resembles that of the slightly younger Bear Gulch fauna of Montana, USA (Lund and Poplin, 1999). However, while Bear Gulch fossil fishes tend to be less well preserved than their Scottish counterparts, in terms of taxonomic and morphological diversity, they far exceed their Bearsden equivalents.

The fossil record of marine fishes from the Upper Carboniferous and Permian is poor (Sepkoski, 2002), and the Bear Gulch fauna has gained significance as a marker for early representatives of clades known otherwise only from much more recent deposits (Hurley et al., 2007). This raises questions about sampling error: whether fish diversity at other relevant localities has been misinterpreted or overlooked. Here, we report new discoveries of fishes from lateral equivalents of the Bearsden locality. Discovered and prepared by Patrick Gavin, these fossils show that the range of Bearsden fishes overlaps that of the Bear Gulch fauna to an extent much greater than previously suspected, including groups until now known only from North America. These new discoveries support the suggestion that Carboniferous fish diversity is significantly under-determined.

- Hurley, I. A., Lockridge Mueller, R., Dunn, K. A., Schmidt, E. J., Friedman, M., Ho, R. K., Prince, V. E., Yang, Z., Thomas, M. G., and Coates, M. I. 2007. A new time-scale for ray-finned fish evolution. *Proceedings of the Royal Society, series B* 274: 489-498.
- Lund, R. and Poplin, C. 1999. Fish Diversity of the Bear Gulch Limestone, Namurian, Lower Carboniferous of Montana, USA. *GEOBIOS*, 32, 285-295.
- Wood, S. P. 1982. New basal Namurian (Upper Carboniferous) fishes and crustaceans found near Glasgow. *Nature* 297: 574-577.
- Sepkoski Jr, J. J. 2002. A compendium of fossil marine animal genera. *Bulletin of American Paleontology* 363, 1-560.

Processes and flanges: the evolution of the plesiosaur braincase and posterior palate

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The aquatic adaptations of plesiosaurs have resulted in two obstacles to unravelling their evolutionary history: morphological “simplification” and a high degree of homoplasy. The braincase can be thought of as being “isolated” from the animal’s constraining aquatic medium to a certain extent, and, while not immune from these obstacles, it provides an important morphological dataset of flanges and processes which deserves attention.

Material examined includes a specimen from the Early Jurassic (Pliensbachian) of Gloucestershire, England, representing a new taxon, and specimens of the early Jurassic taxa *Thalassiodracon hawkinsii*, *Rhomaleosaurus megacephalus* and *Occitanosaurus tournemiensis*. The Pliensbachian specimen shows an anterior process of the basioccipital projecting between the conjoined pterygoids and the posterior processes of the parasphenoid on the midline. This apparently novel structure can also be recognised in other early plesiosaurs such as *R. megacephalus* and *T. hawkinsii*, where it was previously thought to be formed by the basisphenoid (O’Keefe, 2001).

The nature of the variable contact of various pterygoid flanges with one another and the basicranium has also been investigated. This has been found to differ from the published accounts in *T. hawkinsii* and *O. tournemirensis*. A review of this area of the plesiosaurian skull shows that the pterygoid flanges underplate the basicranium in different ways in different taxa. This necessitates a reassessment of the way that these structures are coded in phylogenetic analyses, and a revised scheme is proposed.

- O’Keefe, F.R. 2001. A cladistic analysis and taxonomic revision of the Plesiosauria (Reptilia: Sauropterygia). *Acta Zoologica Fennica*, 213, 1-63.

3D imaging of enigmatic tiny eggs with embryos from the Lower Cretaceous of Thailand using phase contrast X-ray synchrotron microtomography

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Recently, very small eggs containing embryos have been discovered in the Early Cretaceous Sao Khua Formation of northeastern Thailand. So far, the systematic position of these eggs could only be inferred from eggshell characters. Their surface ornamentation is typical of non-avian saurischian dinosaurs (Buffetaut *et al.*, 2005), while the three-layered prismatic microstructure is currently known only in extant and fossil bird eggs. Due to the size of these eggs (about the size of a goldfinch's) and to the nature of the hard calcitic matrix that fills the crushed shell, manual or chemical excavation is not possible. In order to study these important specimens without destroying them, we used X-ray propagation phase contrast microtomography at the European Synchrotron Radiation Facility (Grenoble). This revealed the embryos in three dimensions with a very high accuracy that would not have been possible using classical absorption microtomography. A nearly complete embryo has now been segmented with a voxel size of 16 microns permitting the identification of most of the bones. Three other eggs have been scanned and seem to show different stages of bone development. A higher resolution segmentation is under way with a 5 microns voxel size revealing structures that were invisible on the first datasets. The 3D processing of these scans will allow a complete anatomical study of these tiny skeletons in order to determine their position in the context of the dinosaur-bird transition.

Buffetaut, E., Grellet-Tinner, G., Suteethorn, V., Cuny, G., Tong, H., Kosir, A., Cavin, L., Chitsing, S., Griffiths, P.J., Tabouelle, J. and Le Loeuff, J. 2005 – Minute theropod eggs and embryo from the Lower Cretaceous of Thailand and the dinosaur-bird transition. *Naturwissenschaften*, 92: 477-482.

All at sea: Late Jurassic Testudines from Europe

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Most Late Jurassic testudines from Europe (Platychelidae, Notoemydidae, Eurysternidae and Plesiochelyidae) are purported to have been marine forms occupying a neritic habitat; an assumption which appears to be mostly based on indications of the depositional environment and general morphology of the shell of these taxa. Few studies of the functional morphology of these families have been conducted to prove or disprove this assumption. Despite the exceptional preservation of fossils from formations such as the Solnhofen Limestone Formation, Germany, and the Reuchenette Formation, Switzerland, this type of morphological study is hampered both by taphonomic features peculiar to testudines and inadequate preservation of the limbs and skulls.

The inaccuracy of using both commonly-used indicators of shell form and depositional environment has been noted by several workers (Joyce and Gauthier 2003). Indicators with a more direct correlation to habitat preference include the presence of lachrymal glands and the relative proportions of the forelimb. Data regarding the forelimb proportions of the Eurysternidae and their palaeoecological implications is presented here for the first time. New work during the course of this study has also examined the links between humeral-femoral indices and aquatic capabilities for the first time in Late Jurassic testudines.

Joyce, W. and Gauthier, J. A. 2003. Palaeoecology of Triassic stem turtles sheds new light on turtle origins. *Proceedings of the Royal Society of London*, B .2004. 271, 1–5.

New insights on the Upper Cretaceous pachycormid '*Protosphyraena*' *gladius* (Actinopterygii: Teleostei) from North America

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'*Protosphyraena*' *gladius* is an enigmatic pachycormid from the Late Cretaceous of North America, where it is known from the Coniacian-Campanian Niobrara chalks and the Campanian Pierre Shale and Selma Formations. Described remains of this species consist exclusively of pectoral fins, which can exceed one metre in length. Features of these fins link '*P.*' *gladius* to pachycormids (Lambers, 1992), but provide no evidence linking it to other species of '*Protosphyraena*'. Newly prepared material of '*P.*' *gladius* reveals details of the skull roof, neurocranium, jaws, hyoid and branchial arches, operculogular series, and shoulder girdle. These remains indicate that '*P.*' *gladius* cannot be placed within '*Protosphyraena*'. Unlike that genus, '*P.*' *gladius* is edentulous and lacks anterior extension of the rostrodermethmoid into a prominent rostrum. While '*P.*' *gladius* is not closely related to '*Protosphyraena*', it is very similar to two Jurassic pachycormids: *Asthenocormus* and *Leedsichthys* (Lambers, 1992). These two taxa appear to have been ram filter-feeders, and one of them—*Leedsichthys*—reached enormous sizes (Liston & Noè, 2004). '*P.*' *gladius* also displays features consistent with filter feeding, and extends the range of this large-bodied pachycormid clade from the Late Jurassic to the Late Cretaceous. This range extension also fills a conspicuous ecological gap: no large-bodied filter feeders were known previously from the Cretaceous. The apparent extinction of this group of pachycormids at or near the end of the Cretaceous is also intriguing, because it occurs shortly before the earliest records of large-bodied, ram filter-feeding chondrichthyans (rhincodontids, cetorhinids, mobulids) in the earliest Paleogene (Shimada, 2007).

Lambers, P. 1992. On the ichthyofauna of the Solnhofen lithographic limestone (Upper Jurassic, Germany). Unpublished PhD thesis, Rijksuniversiteit Groningen. 336 pp.

Liston J.J. and Noè L.F. 2004. The tail of the Jurassic fish *Leedsichthys problematicus* (Osteichthyes: Actinopterygii) collected by Alfred Nicholson Leeds - an example of the importance of historical records in palaeontology. *Archives of Natural History* 31: 236-252.

Shimada, K. 2007. Mesozoic origin for the megamouth shark (Lamniformes: Megachasmidae). *Journal of Vertebrate Paleontology* 27: 512-516.

Developmental modularity and the marsupial-placental dichotomy

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The contrasting evolutionary histories of marsupials and placentals have been debated for decades. The speciose placental mammals have radiated into diverse niches, while marsupials are limited in taxonomic, ecological, and morphological diversity. This disparity has been attributed to the different reproductive modes of these clades. Marsupials give birth to altricial young with only well-developed forelimbs, to crawl to the teat, and oral apparatus to suckle. They experience most of their growth outside of the womb. Placentals develop mainly *in utero*, and young are relatively precocial at birth.

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These differences in reproductive patterns have been tied to clear differences in sequence heterochrony between marsupials and placentals (Sánchez-Villagra, 2002; Smith, 2006). It has also been hypothesized that coordinated shifts in developmental timing occur among functionally- or developmentally-related structures, such as the forelimbs and oral apparatus in marsupials (Goswami, 2007). Here, we use new developmental sequence data for 11 marsupial and 14 placental species to assess the integration of developmental timing in the cranial and postcranial elements across mammals. Results demonstrate that marsupials and placentals differ markedly in the integration of developmental timing. Marsupials show significant modularity in the development of the postcranial skeleton, with independent forelimb and hindlimb developmental modules, while placentals show significant integration of the entire appendicular skeleton. There are few significant developmental modules in cranium, although placentals show greater integration in the facial region than marsupials. These differences in developmental modularity may relate to differences in morphological diversity between these clades and across the skeleton.

- Goswami, A. 2007. Modularity and sequence heterochrony in the mammalian skull. *Evolution and Development* 9(3): 291-299.
- Sánchez-Villagra, M.R. 2002. Comparative patterns of postcranial ontogeny in therian mammals: an analysis of relative timing of ossification events. *Journal of Experimental Zoology* 294:264-273.
- Smith K.K. 2006. Craniofacial development in marsupial mammals: Developmental origins of evolutionary change. *Developmental Dynamics* 235:1181-1193.

Comparative ontogenetic analysis of extant rhinos and *Teleoceras major*, a North American rhino

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Exceptional preservation of the North American Miocene rhino species *Teleoceras major* at Ashfall Fossil Beds, Nebraska, allows for an ontogenetic comparison with the extant rhinos. The skull ontogenies of the extant rhinos *Ceratotherium simum* (white rhino), *Diceros bicornis* (black rhino), *Rhinoceros unicornis* (Indian rhino), and *Dicerorhinus sumatrensis* (Sumatran rhino) were obtained and compared with *Teleoceras major*. Eighteen developmental age classes ranging from infants to old adults were distinguished for each species using posterior mandibular dental eruption and wear patterns, similar to those developed by Hitchins (1978).

Teleoceras shares several adult characters with the extant rhinos, such as a strong mandibular angle (*Diceros*, *Rhinoceros*), a deep mandibular body (*Ceratotherium*), and a high zygomatic arch (*Rhinoceros*). *Teleoceras* displays ontogenetic patterns not present in extant rhinos. For example, a strong mandibular angle and a robust zygomatic arch develop earlier in *Teleoceras major* than in *Rhinoceros* and *Diceros*. In addition, the mandibular body in juvenile *Teleoceras* is slender and tapers anteriorly as in adult *Rhinoceros* and *Dicerorhinus*, yet it develops into a deep body that is characteristic of *Ceratotherium* at all age classes. Despite these differences, some developmental patterns are consistent, such as the transition of the lower second incisor into tusk-form at Age Class 8 in *Teleoceras*, *Rhinoceros*, and *Dicerorhinus*. A geometric morphometric analysis of ontogenetic shape change further compares developmental patterns.

- Hitchins, P. M. 1978. Age determinism of the black rhinoceros (*Diceros bicornis* Linn.) in Zululand. *South African Journal of Wildlife Research* 8: 71-80.

A nearly complete elasmosaur from the Late Cretaceous Bearpaw Formation of Alberta, Canada

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In May 2007 the partial remains of a large marine reptile were uncovered by excavating equipment at the open pit ammonite mine operated by Korite International approximately 20km south of Lethbridge in southeastern Alberta. This mine is situated in sediments that were deposited in the short-lived, epeiric Bearpaw Sea that covered much of west-central North America in the Late Cretaceous (Tsujita and Westermann, 1998). For three weeks in June of 2007 a crew of 6 from the Tyrrell Museum uncovered and removed the nearly complete remains of an 8m long elasmosaur. The specimen is located in a weakly bedded black shale which yields abundant ammonites of the genus *Placentiaceras* sp. at particular horizons (Tsujita and Westermann, 1998). The skeleton lies approximately 2m below a 20cm thick altered volcanic ash layer that forms a unique marker bed in the mine, and should provide a minimum radiometric age for the specimen. At present the entire axial skeleton, pelvic and pectoral girdles, and the proximal halves of all the limbs, and a large quantity of gastroliths have been recovered. The anterior-most cervicals have been identified, but there is no indication of a skull as yet. A complete, mid-section cervical vertebrae has an overall height of 30cm and a centrum length of 14cm. The largest gastrolith seen so far has a diameter of 15cm, but stones as small as 2cm are also present. Two teeth of the shark genus *Squalicorax* sp. have been recovered in association with the bones, but no tooth-marked bone has been observed so far.

Tsujita, C. J. and Westermann, G. E. G. 1998. Ammonoid habitats and habits in the Western Interior Seaway: a case study from the Upper Cretaceous Bearpaw Formation of southern Alberta, Canada. *Palaeogeography, palaeoclimatology, palaeoecology* 144: 135-160.

Cope's Rule in Mesozoic archosaurs

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Cope's Rule (Cope, 1896) suggests that as an evolutionary lineage ages, the species tend towards larger size. Although it has been largely ignored or criticised since its inception, recent studies have suggested that indeed it may be common and based on sound principles (Kingsolver and Pfennig, 2004; Hone and Benton, 2005).

Analyses of Mesozoic archosaurs (birds, pterosaurs and dinosaurs – Hone *et al.*, 2005; Hone and Benton, 2007) suggest that Cope's Rule was in operation in all three lineages and that each produced increasingly large forms over their evolutionary history. Despite the functional limits of flight on morphology (and especially large size) both birds and pterosaurs were able to produce increasingly large individuals during the Mesozoic. In the former this is especially interesting as birds are expected to have been small during their early evolution. However the Ornithuromorpha actually show counter selection for small size in an otherwise growing clade, which may have facilitated their survival at the KT boundary.

Cope, E.D. 1896. *The primary factors of organic evolution*. Open Court Publ. Co., New York, USA 492 pp.

Hone, D.W.E., and Benton, M.J. 2005. The evolution of large size: how does Cope's Rule work? *Trends Ecol. Evol.* 20: 4-6.

Hone, D.W.E., Keeseey, T.M., Pisaini, D. and Purvis, A. 2005. Macroevolutionary trends in the Dinosauria: Cope's rule. *J. Evol. Biol.* 18: 587-595.

Hone, D.W.E., and Benton, M.J. 2007. Cope's Rule in the Pterosauria, and differing perceptions of Cope's Rule and different taxonomic levels. *J. Evol. Biol.* 20: 1164-1170.

Kingsolver, J.G. and Pfennig, D.W. 2004. Individual-level selection as a cause of Cope's Rule of phyletic size increase. *Evolution*. 58: 1608-1612.

A new primate clade from the European Eocene

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Adapis ulmensis was described by Schmidt-Kittler (1971) from the German Late Eocene fissure filling of Ehrenstein 1, based on two cheek teeth. Subsequently, it was transferred to the genus *Protoadapis* when additional isolated cheek teeth were found at nearby fissure fill sites. *Adapis* and *Protoadapis* are members of the extinct primate family Adapidae, which is characterised by a nearly complete placental dental formula, with large canines and small incisors. New dentally comprehensive material of *P. ulmensis* from the Late Eocene Solent Group of the Isle of Wight shows the presence of enlarged first incisors and reduction of the anterior premolars. These dental characteristics indicate that '*P. ulmensis*' is a member of the extinct primate family Omomyidae (subfamily Microchoerinae), not Adapidae. '*P. ulmensis*' closely resembles late Middle Eocene *Nannopithecus quaylei*, a microchoerine from the English site of Creechbarrow. A slightly more distant relationship exists with early Middle Eocene *Nannopithecus raabi* and *N. humilidens* from the German site of Geiseltal. These species together represent a distinct clade that warrants the status of new genus. This clade spans at least 10 million years of the Eocene in Europe and probably diverged from other microchoerine clades as early as the Early Eocene.

Schmidt-Kittler, N. 1971. Eine unteroligozäne Primatenfauna von Ehrenstein bei Ulm. *Mitteilungen der bayerischen Staatssammlung für Paläontologie und historische Geologie*, 11, 171-204.

Isolated bones versus articulated skeletons: the problem of parataxonomy in fossil squamates

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Squamate remains are very often constituted by only isolated bones, among which vertebrae are by far the most numerous. On the other hand, some specimens are preserved as more or less complete articulated skeletons. The descriptions and diagnoses are mainly elaborated from these specimens and therefore mostly based on skull material (Haber and Polcyn, 2005). Such preservation requires particular environmental depositional conditions and articulated fossils are consequently rare. This explains the fact that, even if they are informative phylogenetically, they cannot be used in palaeobiogeographic studies or stratigraphic correlations. On the contrary, isolated vertebrae are more frequent and may provide data for these kinds of studies. That is why their taxonomic determination is required. Unfortunately, they cannot be compared thoroughly to articulated fossils, the latter providing only incomplete information relative to the vertebral anatomy as most of the diagnostic vertebral characters are on the anterior and posterior faces that are not observable on these specimens. Several taxa are therefore only based on vertebral characters and may in fact be synonyms of other taxa described from articulated material. This results in the use of a possible parataxonomy. This problem is frequent within basal pythonomorphs like basal mosasauroids, "dolichosaurs" and "hind-limbed snakes" and will thus be illustrated within these taxa. The future discoveries of associated skull remains and disarticulated vertebrae and/or the isolation of vertebrae from articulated specimens (when possible) could reveal these synonymies and start to resolve this question.

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***Dryosaurus lettowvorbecki* – first results of a palaeobiological study**

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Dryosaurus lettowvorbecki belongs to the basal iguanodontia (Norman, 2004) and was found during the Tendaguru expedition to Tanzania from 1910 to 1912. Two bone beds in a single quarry were found to contain up to 14000 single bones of mostly disarticulated skeletons. These represent individuals from several ontogenetic growth stages (Janensch, 1914) of animals ranging from 0.7 to 5 metres in total length. During my PhD research, several different methods (including statistics, morphological comparison and histology) are applied to these bones to get a comprehensive picture of the palaeobiology of *D. lettowvorbecki*. First results confirm the dominance of two distinct age classes in the fossil record, recognized first by Heinrich (1999). The overall postcranial morphology is exceedingly similar in all represented sizes and first histological insights show high growth rates similar to large birds consisting generally of fibrolamellar bone with dense vascularisation. Additionally after further preparation and CT-scans, the well preserved juvenile skull from the collections of the Bayerische Staatssammlung in Munich reveals the preserved splenials, articulars, prearticulars and one coronoid previously unknown in this species (Janensch, 1955).

The first tentative conclusion for the palaeobiology of *D. lettowvorbecki* interprets this species as a fast running gregarious animal which filled a similar ecological niche to modern seasonally migrating small antelopes of the recent East African savannahs.

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Vertebrate palaeontology of the Kem Kem Beds, Morocco and palaeoecology of North Africa.

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The ?Cenomanian Kem-Kem beds of Morocco form part of the 'Continental Intercalaire' (Lavocat, 1954), and extend across much of North Africa. Sedimentary features indicate a very large northward-trending river network similar to contemporaneous deltaic environments from Egypt and Tunisia (Benton *et al.*, 2000; Smith *et al.*, 2001).

As part of an ongoing Irish–Moroccan research project we have sampled fossil vertebrate remains along a 120km north-south transect, at the base of large cross-bedded sandstone units. The fossils collected were then placed into a spatial and stratigraphic database, as part of a comparative analysis across the whole of North Africa. Such an analysis is very important, as many published records are based on purchased specimens, with no information on the geological context (Dal Sasso *et al.*, 2005). Many fossils also disappear in private collections – the scale of ‘fossil hunting’ in some areas became apparent during our fieldwork. The fossils found include remains of fish, crocodiles, turtles, sauropod and theropod dinosaurs, pterosaurs and birds. A range of preservation styles can be found, with contrasting bone taphonomy, surface diagenesis and articulation.

North-African dinosaur assemblages are very different from most known dinosaur sites in their faunal composition. Based on the literature, large multi-ton predators are found in greater numbers than in any other known dinosaur ecosystem. Several explanations are suggested.

This research project aims to correlate data from different areas in North Africa and to understand the wider context of the North African Late Cretaceous, biogeographically an important time in the evolution of a number of vertebrate groups (Sereno *et al.*, 1994; 1996).

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Hyomandibulae of Rhizodontids (Sarcopterygii, Stem-Tetrapoda)

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In digitated stem-tetrapods, the hyomandibular (which plays a central role in feeding and respiration) underwent a major morphological and functional transformation to become the stapes of the middle ear. The hyomandibulae of basal, fish-like, stem-tetrapods can therefore provide data on the primitive conditions preceding this important change. Unfortunately, only a few well-preserved examples are known, hampering wide-ranging comparisons – even though the best-known example (that of the tristichopterid *Eusthenopteron*; Jarvik, 1954) has been used as an exemplar of fish-like stem-tetrapod hyomandibula morphology, the conditions at the base of the tetrapod radiation remain obscure. We report here four hyomandibulae, from three separate localities, which are referable to the Rhizodontida, the most basal clade of stem-tetrapods. These specimens share a number of characteristics, and are appreciably different from the small number of hyomandibulae reported for other fish-like stem-tetrapods. While it is unclear if these characteristics represent synapomorphies or symplesiomorphies, they highlight the morphological diversity of hyomandibulae within the early evolution of the tetrapod total-group. Well-preserved muscle scarring on some of these hyomandibulae permit inferences of hyoid arch musculature in stem-tetrapods.

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Segmental identity within the vertebral column: what can fossils tell us?

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The identity of individual segments within the vertebrate axial skeleton is determined, in part, by the expression boundaries of homeotic genes. Alterations of these genes (e.g., misexpression or deletion) can alter the identity of an axial segment, mimicking either more anterior or posterior segments (anteriorization or posteriorization, respectively). The expression of *Hox* genes has been shown to be a critical factor in establishing the anterior-posterior axis. Misexpression and/or deletion of these genes in the cervical region of mice result in a variety of anatomical malformations (including anteriorization, posteriorization, fusion, or deletion – anatomical correlates to the underlying changes in gene expression). For example, experimental anterior misexpression of *Hoxd4* in the mouse vertebral column results in the occipital region of the skull resembling the anterior cervical vertebrae (Lufkin *et al.*, 1992). Deletion of *Hoxd3* has an opposite effect, with the anterior cervical vertebrae (atlas) coming to resemble parts of the occiput (Condi and Cappechi, 1993; 1994). In the 370 million year old (Late Devonian) placoderm *Cowralepis maclachlani* (Ritchie, 2005), the occipital and the fused anterior region of the vertebral column, the synarcual, have a nearly identical morphology. We suggest that misexpression/deletion of *Hoxd3* and/or *Hoxd4* occurred in *Cowralepis*. The putative presence of these *HoxD* genes suggests the presence of all four *Hox* clusters in placoderms, indicating that the gene duplication generating the four clusters (*HoxA–D*) occurred phylogenetically prior to the evolution of crown group gnathostomes, within the stem Gnathostomata. (Condi and Cappechi, 1993). Mice homozygous for a targeted disruption of *Hoxd-3* (*Hox-4.1*) exhibit anterior transformations of the first and second cervical vertebrae, the atlas and the axis. *Development* 119, 579-595.

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Skull joints in *Sphenodon* and other Rhynchocephalia (Diapsida: Lepidosauria)

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The Tuatara (*Sphenodon*) of New Zealand is the only surviving member of the Rhynchocephalia, a group of reptiles that were widespread and diverse during the Mesozoic. Differences in skull shape, jaw proportions, tooth structure and tooth arrangement suggest that this success was associated with a diversification of feeding strategies (Jones, 2006ab). One aspect of rhynchocephalian morphology that has not previously been examined from a functional perspective is the structure of the skull joints (sutures). In life these involve soft

connective tissue that influences the way in which stresses are distributed across the skull (e.g. Jaslow, 1992). Moreover, *in vivo* experiments on mammals demonstrate that suture morphology is affected by the stresses they experience (e.g. Moss 1961). Examination of *Sphenodon* skull material reveals that individual joints show a consistent morphology, but suture structure can differ dramatically between one joint and another. The overall pattern corresponds, at least in part, to the expected distribution of stresses during feeding. Fossil taxa demonstrate cranial joint morphologies not present in *Sphenodon*, and this correlates with differences in the anatomy of the feeding apparatus.

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Dietary change in a plant eating mammal across the Eocene/Oligocene transition

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The Late Eocene to Early Oligocene was a period of considerable climatic change, from greenhouse to icehouse conditions. The “Grande Coupure” (Stehlin, 1910) was a major mammalian faunal turnover which occurred in the Early Oligocene. Most of the endemic European mammal fauna became extinct and there was a large number of incoming taxa from southwest Asia. The perissodactyls were one of the groups most significantly affected by this event, which was coincident with the first major glaciation of the Cenozoic (Oi-1) (Hooker *et al.*, 2004). Two possible causes have been suggested for the Grande Coupure: climatic events (Legendre, 1989; Blondel, 1992) and competitive exclusion by the incoming mammals from Asia (Hooker, 2000). The perissodactyl *Plagiolophus minor* is the only member of the endemic European family Palaeotheriidae to survive the Grande Coupure and whose lineage continued into the middle Oligocene (Jehenne and Brunet, 1992).

Dental microwear takes the form of pits and scratches on the tooth enamel which are only visible under a microscope. It is produced by the interaction of the food and other ingested material with the teeth and can be used to determine changes in the diet and palaeoenvironment. The dental microwear of *Plagiolophus minor* from sites in Western Europe from both before (MP 18 and 20) and after the Grande Coupure (MP 21) was studied in order to assess any changes in the diet across this turnover, and hence whether there is any evidence of palaeoenvironmental change. The implications of these results will be discussed.

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A new global phylogeny of Plesiosauria (Reptilia: Sauropterygia)

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Plesiosauria was a diverse clade of predatory marine reptiles secondarily adapted to life in water, that played an important role in Mesozoic marine ecosystems. A new hypothesis of the phylogeny of Plesiosauria is presented that incorporates 64 taxa scored for 175 new and critically re-examined morphological characters, the majority of which are based on personal examination of relevant specimens, making it the largest and most comprehensive cladistic analysis of Plesiosauria to date.

The strict component consensus tree of the 18 most parsimonious trees recovered by the parsimony analysis is well resolved, and removal of only three ‘wildcard’ taxa by reduced consensus methods results in a fully resolved reduced consensus tree; however, bootstrap proportions and Bremer support indices for the majority of ingroup relationships are low. In agreement with some previous analyses (e.g. O’Keefe, 2001) but in contrast to Druckenmiller and Russell (2006), the present analysis does not support the traditional hypothesis of a simple dichotomy between taxa with long necks and small heads (‘plesiosaurs’) and those with short necks and large heads (‘pliosaurs’), which had dominated pre-cladistic taxonomy for over 100 years. Instead, the large headed, short-necked clade, Polycotylidae, is more closely related to *Plesiosaurus dolichodeirus* than to *Pliosaurus brachydeirus*. However, the recovered topology differs in many important respects from those generated by previous analyses, in particular in the relationships of the more basal taxa, which necessitates re-definition of a number of clades to produce a stable phylogenetic taxonomy.

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The vertebrate fossil collections of William Hunter

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Today William Hunter (1718-1783) may primarily be remembered for his pioneering work in obstetrics and our understanding of the lymphatic system, but his interests were wide-ranging, encompassing artworks (the first to collect Chardin), archaeological, numismatic and bibliographical items. As a key figure in the Enlightenment, he was one of the few in the mid-18th century to advocate the concept of extinction as recorded in the fossil record. Of some 400 fossil specimens, written records attest to the presence of at least 45 fossil vertebrates in his collection including fish from Monte Bolca, as well as specimens reflecting his comparative anatomical writings on the mastodon and ‘Irish elk’. Some of the missing 45 specimens from Dr. Hunter’s original collection, recently unearthed during researches for the bicentenary (1807-2007) redisplay of the Hunterian Museum, will be presented.

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And yet it does replace? Some new thoughts on the diversity and tooth replacement in the Mesozoic mammal *Morganucodon watsoni*

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Previous work has mainly focused on the reconstruction, rather than diversity of the Late Triassic/Early Jurassic mammal *Morganucodon watsoni*, one of the most primitive mammals known. Yet the dental morphology of this key species has proved difficult to interpret, due to the fragmentary nature of the material. One of the most debated questions is whether *M. watsoni* shows the typically mammalian condition of diphyodonty.

The preliminary results of an examination of this *Morganucodon* material from the fissure fill deposits of Glamorgan, South Wales will be given, with an emphasis on replacement morphology.

A morphometric investigation based on approximately 300 dentulous partial dentaries from the large collections of the University Museum of Zoology, Cambridge and the Natural History Museum was conducted. The results show that size in *Morganucodon watsoni* correlates with premolariform tooth resorption in a way that cannot be explained by simple intraspecific variation alone, potentially indicating polyphyodont tooth replacement. Two hypotheses as to what may cause the observed variation will be discussed and reference will be made to replacement patterns found in the associated *Kuehneotherium* material.

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Wading across the pond: a photogrammetric, spatial, and morphological comparison of Middle Jurassic dinosaur tracks from North America and the United Kingdom

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The Middle Jurassic is an important time in the evolutionary history of dinosaurs. Fortunately, there are a number of significant dinosaur tracksites from this time period that provide valuable information about the trackmakers, their environments, behaviours, and global distribution. A key to more fully understanding the animals of this time is consistent, detailed 3D documentation from sites worldwide. Close-range photogrammetry is an excellent method for the 3D documentation of fossil footprints. A significant benefit of utilizing photogrammetry to generate very high-quality 3D image models is that the external surface of a specimen, whether in the field or lab, can be captured to an extraordinary level with relatively inexpensive components. The resulting 3D digital data sets provide extreme flexibility for comparisons between specimens, as *in situ* tracks or trackways that are five

meters or 5000 kilometres apart can be compared, side by side, in three dimensions. In addition, sophisticated morphometric analysis can be conducted through the evaluation of slope, aspect, curvature, and other mathematical calculations. Thus, digital ichnological data from Middle Jurassic sites in Wyoming and Utah (Breithaupt *et al.*, 2004, Matthews and Breithaupt, 2006) can be compared with similar data from other localities. Digital track data for the United Kingdom, also known for significant Middle Jurassic dinosaur track localities (Clark *et al.*, 2005; Romano and Whyte, 2003), can be compared three-dimensionally and morphometrically to those from North America. This unique comparison will provide a rare glimpse of palaeoecology, palaeobiology, and the behavioural complexities of Middle Jurassic dinosaur communities.

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The large theropods *Becklespinax* and *Valdoraptor* from the Lower Cretaceous of England

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Our knowledge of Lower Cretaceous theropod diversity in the Wealden Supergroup has improved recently, thanks to the discovery of *Neovenator* and *Eotyranus*, and the reinterpretation of several small-bodied taxa, all of which are from the Barremian Wessex Formation (Hutt *et al.*, 1996, 2001; Naish *et al.*, 2001; Naish and Martill, 2007). However, taxa from the Berriasian-Valanginian Hastings Beds Group have gone largely unstudied since their initial, nineteenth century descriptions. *Becklespinax altispinax*, known from three articulated tall-spined dorsal vertebrae (BMNH R1828), was reported by Owen in 1855 and referred to *Megalosaurus*. Its taxonomy is confused and it has often gone by the name *Altispinax*. The neural spines of *Becklespinax* are unusual in that the second and third are taller than the first, and the apex of the second has overgrown the apex of the first. *Becklespinax* is comparable to spinosauroids and allosauroids in the morphology of its centra and vertebral laminae, but it has proved difficult to determine its precise affinities. A second Hastings Beds Group theropod, *Valdoraptor oweni*, is based on the left metatarsus BMNH R2559. Mt II is strongly compressed mediolaterally and bears a prominent dorsomedial ridge. The distal end of mt II diverges more strongly from the distal end of mt III than is typical for theropods. An isolated mt II exhibits the same characters and represents the only *V. oweni* specimen known in addition to the holotype. *Becklespinax* and *Valdoraptor* remain enigmatic and poorly known. They, and additional large theropod fragments from the Wealden Supergroup, show that several large theropods from the Lower Cretaceous of western Europe remain poorly documented.

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Using sharks as indicators of trophic structure within 'mid' Cretaceous watermasses

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The Elasmobranchii were apical predators during the Cretaceous period and their presence was crucial for regulating the balance of oceanic food-webs. In the mid-Cretaceous a period of transgressive episodes caused a eustatic rise, meaning the destruction of shallow water environments as well as the deepening and thus cooling of large expanses of ocean. Therefore the effects of the mid-Cretaceous transgressive episodes upon the radiation, diversity and palaeobiogeography of the Elasmobranchii are being investigated in order to establish the effects of the transgressions upon the Cretaceous ecosystems.

This research is the first study to use organisms of high trophic level as palaeoenvironmental indicators, as sharks are virtually unique amongst vertebrates in yielding statistically large numbers of specifically identifiable remains. In order to establish the diversity and spatial variations of the elasmobranch faunas, sediment from a number of well-defined time-planes during critical intervals of the sea-level rise are being sampled.

Localities within the UK include the Anglo-Paris Basin, the North Sea Basin and the intervening shallows of the East Midlands Shelf.

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Tales from the 'Leeds Collection' – a unique palaeontological and archival resource

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The Leeds Collection of fossils vertebrates and invertebrates was amassed from the brick pits surrounding the city of Peterborough, England in the late 19th and early 20th Centuries. The collection was commenced by Charles Edward Leeds when he came under the tutelage of John Phillips whilst an undergraduate at Oxford around 1865, however the vast majority of the collection was made by Charles' younger brother Alfred Nicholson Leeds, who continued collecting until his death in 1917. During the Leeds brothers' lifetime the collection became, and remains, of international scientific importance. The significance of this remarkable collection arises from the well-studied and known provenance, the Oxford Clay Formation of Peterborough, and from the mechanisation of the brick making industry following the First World War which has considerably diminished the possibilities of repeating such a collection of fossils.

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The Leeds Collection is now dispersed between a number of institutions, most notably the Natural History Museum in London, and here in the Hunterian Museum of the University of Glasgow.

The Leeds collections' vertebrates include fish, such as the giant pachycormid *Leedsichthys problematicus* (Liston & Noè, 2004), a range of marine reptiles such as plesiosaurs, pliosaurs, crocodiles and ichthyosaurs (e.g. Andrews, 1910, 1913; Brown, 1981; Noè, 2001) and incomplete dinosaurs. However, in addition to the fossils, there is a largely untapped archive which adds significant value to the Leeds collection: the data from this archive is beginning to fill in details of, for instance, the pits in which the specimens were originally located, the materials used to unite the bones, and the prices for which the specimens were sold. The Leeds Collection, archive material, and other sources are here woven together to allow us to delve deeper into this unique palaeontological and archival resource.

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Calibrated diversity, tree topology and the mother of mass extinctions: the lesson of temnospondyls

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Three family-level cladistic analyses of temnospondyl amphibians (Milner, 1990; Yates & Warren 2000; Ruta & Bolt, 2006) are used to evaluate the impact of taxonomic rank, tree topology, and sample size on diversity profiles, rates of originations and extinctions, and faunal turnover. Temnospondyls are used as a case study for investigating family replacement across the Permo-Triassic boundary and modality of recovery in the aftermath of the end-Permian mass extinction (e.g. Benton *et al.*, 2004). Both observed and inferred values of family diversity have a negligible effect on diversity curves. However, inferred values produce a flattening of the curves throughout the Cisuralian, as well as a less conspicuous increase in family diversity from Tatarian through to Induan, than observed values do. Diversity curves based upon counts of genera and species display a clearer demarcation between peaks and troughs. When genera or species are rarefied within families, a recast profile of estimated family diversity during five time bins (Carboniferous; Cisuralian; Guadalupian-Lopingian; Early Triassic; Middle Triassic-Cretaceous) shows that Cisuralian and Early Triassic diversity values are closer to one another than they are when observed families are used. The Guadalupian-Lopingian value reflects, in part, the depauperate land vertebrate diversity from late Cisuralian to middle Guadalupian (Olson's gap). The time-calibrated origination and extinction rate trajectories plot out close to one another and show a peak in the Induan, regardless of the tree topology used to construct them. Origination and extinction trajectories appear disjunct in at least some Palaeozoic intervals, and background extinctions exert a significant role in shaping temnospondyl diversity during the lowermost Triassic.

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Scaling bite force in predatory tetrapods: bite force is proportional to body mass^{2/3}

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Here I show that bite forces of terrestrial predators scale with increasing body size at a scaling factor of 2/3. This negative allometry indicates that bite force increase is less-than-proportional to the increase in body mass. This scaling factor of 2/3 can be observed in many instances of scaling: scaling of surface area to its volume in isometric bodies is one obvious example, but more relevant is that of muscle force with body mass. Since the contractile properties of muscle are generally agreed to be constant throughout vertebrates with varying scale (Thomason *et al.* 1990), muscle force is most likely proportional to the physiological cross-sectional areas (PCSA) of muscles (length^{2.0}) and since body mass is essentially volume (length^{3.0}), muscle force is proportional to body mass^{2/3}. This coincidence in identical scaling factors between the theoretical scaling of muscle force and the observed scaling in bite force suggests that muscle force, not the lengths of moment arms, is the determining factor of the overall scaling trend in bite force with increasing body size. This has great palaeontological implications. In determining bite forces in extinct predators, PCSA of adductor muscles must be reconstructed with accuracy in order to obtain reliable values. Compared with this theoretical scaling in bite force, most bite force estimates in extinct predators are likely to be underestimates (Erickson *et al.*, 1996, Rayfield *et al.*, 2001, Mazzetta *et al.*, 2004a, 2004b). Thus, a more robust method of reconstructing musculature and estimating PCSA is needed.

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A skeletal reconstruction of *Rhomaleosaurus* and the systematics of pliosaurs

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The skull of the holotype of *Rhomaleosaurus cramptoni*, a giant pliosauroid plesiosaur from the Toarcian of Yorkshire has been prepared by the Paleontology Conservation Unit (NHM, London). This allows the first detailed examination of the osteology of this specimen since the superficial description of this species by Carte and Bailey (1863). The postcranial skeleton is also intended for preparation and once completed, the fully prepared specimen is planned to form the centrepiece of a new earth science museum in Dublin. The interpretation

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of this newly prepared skull is presented and compared with the older Hettangian form *Rhomaleosaurus megacephalus*, warranting generic separation. The new skull reconstruction is combined with postcranial data from a referred specimen (*R. thornstoni*) to provide the first complete skeletal reconstruction of this genus. Rhomaleosaurids combine a large skull with a long neck and so represent a morphotype somewhat intermediate between elasmosaurids (long neck/small head) and pliosaurids (short neck/large head). To assess the ecological significance of the rhomaleosaurid bauplan, the proportions of the neck, skull, and limb girdles of *Rhomaleosaurus* are compared with those of other plesiosaur taxa for which the ecology is better known. Finally, a phylogenetic analysis of pliosaurs was conducted to elucidate the systematic position of *Rhomaleosaurus* and to test the validity of the Rhomaleosauridae. The results of the cladistic analysis indicate that *Rhomaleosaurus* fits within a monophyletic rhomaleosaurid clade, and supports two other monophyletic clades, Pliosauridae and Leptocleididae.

Carte, A and Bailey, W. H. 1863. Description of a new species of *Plesiosaurus*, from the Lias, near Whitby, Yorkshire. *Journal of the Royal Dublin Society*, 4, 160-170.

Kinematic constraints on the reconstruction of dinosaur gaits

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Reconstructions of dinosaur locomotion may draw on multiple sources of evidence, including estimates of limb posture, joint ranges of motion, muscle lines of action and moments, inertial properties of body parts, and estimates of metabolic cost. Presuming that the skeletal and muscular systems work in concert to achieve kinematically and dynamically efficient locomotion, to what extent might the kinematics of the appendicular skeleton in isolation reveal an efficient gait? Towards that end, dimensionally and morphologically accurate skeletal models were created of dinosaurs (from a variety of sources including digitization) and joint range of motion estimated and represented.

Genetic Algorithms (GA) that ‘reward’ particular observables (e.g., forward travel) and penalize others (e.g., metabolic cost) have been used successfully to synthesize gaits (Sellers *et al.*, 2004). These applications of GA rely on physical simulation (to model muscle moments and inertial and gravitational forces). Distinct from these approaches, we use GA to evolve purely kinematic solutions, which are then compared with gaits observed with extant animals and as derived by other methods.

Sellers, W.I., Dennis, L.A., Wang, W.J., and Crompton, R.H. Evaluating alternative gait strategies using evolutionary robotics. *Journal of Anatomy* 204, 343–351, 2004.

Muscling in on placoderms

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Preservation of soft tissue is a rare phenomenon in Devonian vertebrates and although the Gogo Formation (Frasnian), Canning Basin, Western Australia is well known for the exquisite preservation of its fossil fish fauna as three-dimensional original bone in limestone nodules (Ahlberg 1989) labile tissues are uncommon. Only one arthrodire *Eastmanosteus calliaspis* Dennis-Bryan 1987 has been recovered where muscle microstructure is preserved as phosphatised tissue comprising striated muscle fibres and nerve endings, with possible

associated blood capillaries (Trinajstić *et al.*, 2007). In the abdominal region of the arthrodire *Incisoscutum ritchiei* Dennis and Miles, 1981 and along the dorsal margin of the body in *Austroptyctodus gardineri* Long 1997 muscle septa, which separate the muscle segments, are identified and the impressions of muscle fibres are observed between them (Trinajstić *et al.*, 2007).

Further collecting has yielded additional specimens in which soft tissue anatomy is revealed. The muscles connecting the head and thoracic shields are identified in a new specimen of *I. ritchiei* and remnants of the abdominal muscles show exceptional, three-dimensional preservation. In addition, the dermal covering of the tail has also been preserved. The real contribution of information from exceptional soft-tissue preservation is in filling-in the morphological gap left by skeletal fossils.

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 Dennis-Bryan, K. 1987. A new species of eastmanosteid arthrodire (Pisces: Placodermi) from Gogo, Western Australia. *Zoological Journal of the Linnean Society*, 90, 1-64.
 Dennis, K. D. and Miles, R. S. 1981. A pachyosteorhynchid arthrodire from Gogo, Western Australia. *Zoological Journal of the Linnean Society*, 73, 213-258.
 Long, J. A. 1997 Ptyctodontid fishes (Vertebrata, Placodermi) from the Late Devonian Gogo Formation, Western Australia, with a revision of the European genus *Ctenurella* Ørvig 1960. *Geodiversitas*, 19, 515-555.
 Trinajstić, K., Marshall, C., Long, J. A. and Bifield, K. 2007. Exceptional preservation of nerve and muscle tissues in Devonian placoderm fish and their phylogenetic implications. *Biology Letters*, 3, 197-200.

Further evidence for a broad forewing in pterosaurs

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Traditionally, pterosaurs have been reconstructed with a narrow forewing consisting of a propatagium that extended from the shoulder to the wrist and supported along the distal part of its leading edge by the medially-directed pteroid. Several authors have argued for a broad forewing with a propatagium that stretched from the shoulder to the base of the digits and which was manipulated by a forward-directed pteroid, but this is highly controversial and still widely doubted. Aerodynamic analyses, osteological and arthrological details support the broad forewing model, but this evidence has not proven decisive (Wilkinson *et al.*, 2006; Wilkinson, 2007).

Here we describe new material of the Upper Jurassic anurognathid *Jeholopterus ningchengensis* in both forelimbs of which the propatagium is associated with an anteriorly directed pteroid and can be clearly traced from the shoulder region to the distal end of the metacarpus. Though less well preserved, a similar arrangement is observed in the holotype of *J. ningchengensis*, *Rhamphorhynchus muensteri* (the Zittel wing) and a basal azhdarchoid (SMNK 3830 PAL). In addition, morphometric analysis of 38 species of pterosaur, representing 16 families and a size range of 0.4-7.0 metres in wingspan, reveals a strong correlation ($r^2 = 0.91$) between the length of the pteroid and the wing-metacarpal. This is consistent with a broad forewing model, in which the requirement for a leading edge profile free of sharp deflections strongly constrains pteroid length, but is less easily explained by the narrow forewing model where there is no direct anatomical or functional connection between the pteroid and the wing-metacarpal.

Wilkinson, M. T. 2007. Sailing the skies: the improbable aeronautical success of the pterosaurs. *Journal of Experimental Biology*, 210, 1663-1671.

Wilkinson, M. T., Unwin, D. M. and Ellington, C. P. 2006. High lift function of the pteroid bone and forewing of pterosaurs. *Proc. R. Soc. Lond. B Biol. Sci.*, 272, 119-126.

***Euhelopus zdankysi* and its bearing on the evolution of East Asian sauropod dinosaurs**

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Euhelopus was the first Chinese dinosaur to be named (Wiman 1929; Romer 1956). Its evolutionary relationships are controversial: some workers place it outside of Neosauropoda; others suggest *Euhelopus* is the sister group to titanosaurs. Re-examination of the holotypic and referred material in Uppsala, combined with phylogenetic analysis, demonstrates that *Euhelopus* is closely related to titanosaurs according to both the Upchurch *et al.* (2004) and Wilson (2002) cladistic data sets. Traditional and cladistic claims that *Euhelopus*, *Omeisaurus*, *Mamenchisaurus* and *Shunosaurus* form a monophyletic 'Euhelopodidae' endemic to East Asia are not supported. Recent discoveries hint at the existence of a hitherto unrecognised clade at the base of titanosaurs, including *Euhelopus* and unnamed forms based on teeth from Liaoning (Barrett & Wang, in press) and Spain (Canudo *et al.*, 2002). There may have been at least two radiations of very long-necked sauropods in East Asia, originating in the Middle Jurassic (*Omeisaurus*+*Mamenchisaurus*) and Late Jurassic/Early Cretaceous (*Euhelopus*), with the latter group perhaps also occurring in Europe. New information on *Euhelopus* and related forms yields insights into morphological change during the origin of titanosaurs. The large number of basal titanosaurs from East Asia has been interpreted to mean that this area represents their 'centre of origin' (You *et al.*, 2003). However, the titanosaur fossil record, combined with cladistic biogeographic studies, indicate that the group probably originated prior to the Middle Jurassic and acquired a virtually global distribution before Pangaeon fragmentation.

Barrett, P. M. and Wang, S.-L. in press. Basal titanosauriform (Dinosauria, Sauropoda) teeth from the Lower Cretaceous Yixian Formation of Liaoning Province, China. *Palaeoworld*.

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Wiman, C. 1929. Die Kreide-Dinosaurier aus Shantung. *Palaeontologia Sinica (ser. C)* 6: 1-67.

You, H.-L., Tang, F. and Luo, Z. 2003. A new basal titanosaur (Dinosauria: Sauropoda) from the Early Cretaceous of China. *Acta Geologica Sinica* 77(4): 422-429.

Osteological redescription, and taxonomic and phylogenetic position of '*Plesiosaurus*' *macrocephalus*, specimen NHM 49202, from the Lias of England

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The plesiosaur specimen NHM 49202 from the Lias of Lyme-Regis and kept in the National History Museum of London, includes the complete skull, palate and mandible with several associated cervical vertebrae. It is an adult plesiosaur of the species '*Plesiosaurus*' *macrocephalus*. An osteological re-examination of the skull of this specimen allows the addition of new morphological information to the original description by Andrews (1896). A

preliminary cladistic analysis was performed in order to understand the phylogenetic affinities of this specimen within Plesiosauria. The Pliosauroid affinities of the specimen indicate that this specimen does not belong to *Plesiosaurus* and its unique set of characters compared to other pliosauroids suggests that it should be assigned to a new genus. The specimen possesses plesiomorphic characters, including the lack of a median suture between both the anterior and posterior interpterygoid vacuities. These characters may help in clarifying the evolutionary history of the Pliosauroidae.

Andrews C. W. 1896. On the Structure of the Plesiosaurian Skull. *Quarterly Journal of the Geological Society of London*, 52: 246-253.

Wise as an owl – 147 million years of avian brain evolution

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Although the term ‘birdbrain’ is commonly used as an insult indicating lack of intelligence, many living bird species display cognitive abilities equalling and even exceeding those of many mammals (Lefebvre *et al.*, 2004). The avian brain has evolved along a course parallel to that of the mammalian brain and, for most avian species, the ability to fly has apparently resulted in constraints on brain volume relative to body size (encephalisation quotient: EQ) and overall brain shape (Jerison, 1973). The endocranial cast associated with the holotype specimen of *Archaeopteryx* (147 ma) and recent micro-CT investigations of its skull, demonstrate the earliest-known bird already possessed a brain similar in EQ to living species (Domínguez *et al.*, 2004). However, recent micro-CT analysis of non-avian theropod skulls (e.g., Kundrát, 2007) has also shown that some also possessed EQs within the range of living avian species. Our recent analysis (Milner & Walsh, in press) of the brains of two Lower Eocene (55 ma) fossil birds demonstrates that avian brain shape and EQ of these taxa were almost entirely like those of living bird species.

Here we discuss the significance of brain enlargement in avian and non-avian theropods in the context of the evolution of powered flight and overall cognitive ability. We suggest that the most important neurological evolutionary trends in Jurassic to Cenozoic birds are probably mostly related to sensory integration and cognition than to flight adaptation. However, although some skeletal specialisations for flight may have affected overall brain enlargement, others, such as the development of the telencephalic wulst region (involved in integration of visual stimuli) may be related to those specialisations.

Domínguez P., Milner A. C., Ketcham R. A., Cookson M. J., and Rowe T.B. 2004. The avian nature of the brain and inner ear of *Archaeopteryx*. *Nature* 430: 666-669.

Jerison H. J. 1968. Brain evolution and *Archaeopteryx*. *Nature*, 219: 1381-1382.

Kundrát, M. 2007. Avian-like attributes of a virtual brain model of the oviraptorid theropod *Conchoraptor gracilis*. *Naturwissenschaften*, 94, 499-504.

Lefebvre L., Reader S. M. and Sol D. 2004. Brains, Innovations and Evolution in Birds and Primates *Brain, Behaviour and Evolution*, 63: 233-246.

Milner, A. C. and Walsh, S. A. In Press. Avian brain evolution: new data from Palaeogene birds (Lower Eocene) from England. *Zoological Journal of the Linnean Society*.

Brain size and insular dwarfism: a case study of the extinct dwarf hippopotamuses from Madagascar

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The effect of insular dwarfism on the brain size of island mammal species relative to that of their mainland ancestors is a matter of debate (Köhler & Moyà-Solà, 2004). Although it is generally accepted that a reduction in body size within a mammalian species is usually associated with relatively little brain size reduction, reflecting the early completion of brain development, it remains unclear whether the insular dwarfing process follows this trend. Most dwarfed island mammals are extinct and incompletely preserved, accounting for the dearth of empirical data until now. However, the exceptional preservation of the recently extinct dwarf hippopotami from the Holocene of Madagascar are an exception. Measures of cranial capacity have been taken from up to 50 well preserved crania of two dwarf subfossil hippopotami, *Hippopotamus lemerlei* and *Hippopotamus madagascariensis* and from a complete postnatal ontogenetic series of dry skulls of the probable ancestor, the extant mainland *H. amphibius*. Results from a comparative morphometric analysis of growth in the larger mainland hippopotamus and the two dwarf species are presented. A hypothesis of ontogenetic scaling is evaluated in the context of the reduction in both brain and overall skull size of these dwarf species. In light of the current controversy over brain size reduction in the putative dwarf hominin *Homo floresiensis* (Martin *et al.* 2006), studies of other mammalian analogues such as the hippos, with larger samples and ontogenetic series, are likely to be informative on mechanisms of dwarfing in mammals.

Köhler, M. and Moyà-Solà, S. 2004. Reduction of brain and sense organs in the fossil insular bovid *Myotragus*. *Brain Behaviour and Evolution* 63: 125-140.

Martin, R. D., MacLarnon, A. M., Phillips, J. L., Dussuieboux, L. Williams, P. R., and Dobyns, W. B. 2006. Comment on "The brain of LB1, *Homo floresiensis*". *Science* 312:999.

Computer simulation of feeding behaviour in marsupial and placental carnivores

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Representative marsupial and placental carnivores are commonly invoked as examples of phenotypic convergence (Wroe & Milne, 2007). However, form-function analyses of various character systems have often yielded conflicting results. Here we examine convergence in mechanical behaviour between skulls of the thylacine (*Thylacinus cynocephalus*) and dingo (*Canis lupus dingo*), and African (*Panthera leo*) and marsupial (*Thylacoleo carnifex*) lions, using newly developed 3-D finite element (FE) analysis techniques (Wroe *et al.*, in press). Our FE models incorporate multiple properties for cancellous and cortical bone. Both cranium and mandible are treated as functional units, with jaw adductor forces determined using a 'dry-skull' method (Wroe *et al.*, 2005; Christiansen & Wroe, 2007). Stress distributions in simulated behaviours reveal considerable similarity between thylacine and dingo, but also informative differences. The thylacine's mandible performs relatively poorly where only the actions of the jaw muscles (intrinsic) are considered. Stresses are comparatively high in the posterior of the thylacine's cranium under loads that simulate forces generated by the predator's cervical musculature or the prey itself (extrinsic). We conclude that the dingo is better adapted to withstand the high extrinsic loads that are likely to accompany social hunting of relatively large prey. Preliminary results suggest that compared to that of *P. leo*, the

skull of the marsupial lion is adapted to resist extremely high intrinsic and extrinsic forces, suggesting habitual predation on large animals.

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A taxonomic tale: What exactly are *Metriorhynchus* and *Geosaurus*?

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Over the course of the past 170 years various generic names have been proposed for the numerous species of metriorhynchid crocodyliforms. Of these most have been considered, at some point, a junior synonym of *Geosaurus*, *Metriorhynchus*, or *Dakosaurus* (Lydekker, 1888; Zittel, 1890). However, very little work has been done to determine their interrelationships or the monophyly of the genera attributed to this family (Muller-Töwe, 2005; Gasparini *et al.*, 2006).

In order to rectify this, a phylogenetic analysis was undertaken using 120 osteological characters and 46 taxa. Metriorhynchidae was found to be monophyletic, though *Pelagosaurus* is the sister taxon to Teleosauridae. The genera *Teleidosaurus* and *Metriorhynchus* are paraphyletic, with the European brevirostrine forms of *Metriorhynchus* being attributable to *Suchodus*, and the South American species to *Purranisaurus*. *Geosaurus* is polyphyletic, with the type species nesting with *Dakosaurus*, as does one species of *Cricosaurus*, making *Dakosaurus* a junior synonym of *Geosaurus*. However, all the other species currently within *Geosaurus* are monophyletic, with the type species of *Enaliosuchus*, *Cricosaurus*, and *Neustosaurus* nesting within this clade. As *Neustosaurus* is the oldest name, all species are transferred to that genus, with the exception of *Geosaurus gracilis*, as it lacks the hindlimb synapomorphies of *Neustosaurus*, therefore the name *Rhacheosaurus* is resurrected for this species.

Metriorhynchus, *Rhacheosaurus*, and *Neustosaurus* form a monophyletic clade that are characterised by becoming successively more marine adapted. Its sister group is a clade formed by *Suchodus*, *Purranisaurus* and *Geosaurus*, which became successively adapted to high-order carnivory.

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The *Chimaerasuchus paradoxus* paradox: a critical review of a poorly known fossil crocodile

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Chimaerasuchus paradoxus is an amazing fossil mesoeucrocodile, considered terrestrial and herbivorous, with multicusped molariforms and an elongated jaw joint that allowed proal masticatory movements. This constitutes a set of characters unexpected for crocodiles. The sole specimen (IVPP-V8274) comes from the Wulong Formation (Hubei Province, Central China), referred to the Albian (Wu *et al.*, 1995; Wu & Sues, 1996). Phylogenetic works shows *Chimaerasuchus* as sister-group to *Sphagesaurus*, and nested within Notosuchia. Other related taxa include the Gondwanic baurusuchids, notosuchids and *Comahuesuchus*, all from the Upper Cretaceous and most from South America. Cladograms from different frameworks do not support the idea of *Chimaerasuchus* as a Lower Cretaceous species. Although the spatial distribution of *Chimaerasuchus* may be explained through dispersion route(s), the biochronologically paradoxical distribution needs reevaluation. A preliminary review on the geological information from Chinese basins shows that there is little confidence in the age of the Wulong Formation (Yang *et al.*, 1979; Hao *et al.*, 1986). A critical review of the phylogenetic work compared two of the major accepted datasets (Pol & Apesteguia, 2005; Jouve *et al.*, 2006). Bootstrap and branch decay show that there is little support for the phylogenies, and *Chimaerasuchus* may represent a more basal group within Notosuchia. The lack of preservation of key morphologic structures in *Chimaerasuchus* (e.g. choanae, basicranium) may introduce further bias to the analysis. *Chimaerasuchus* may only be assigned to the Cretaceous, and is closely related to *Sphagesaurus* and derived notosuchians. The revision suggests a possible predictive biochronological function to phylogenetic analysis.

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Overview of the Leeds fossil vertebrate collection in the National Museum of Ireland

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The Alfred Leeds collection of fossil vertebrates from the Middle Jurassic Oxford Clay is world famous (Leeds, 1956). However, few people know of the Leeds collection housed in the National Museum of Ireland (Natural History), which is both historically and scientifically important. It includes several specimens that have never, or only very recently (Gandola *et al.*, 2006), received scientific attention. Of particular note are partial skeletons of a juvenile plesiosaur *Cryptoclidus eurymerus*; the ichthyosaur *Ophthalmosaurus*; the thalattosuchian crocodyliformes *Metriorhynchus superciliosus* (two skulls with associated bones) and the related *Steneosaurus edwardsi* (an exceptionally well-preserved anterior part of the skull and partial post-cranial material).

Historically, the collection is notable because it was acquired at a critical period in the history of the Leeds fossil collection, when it first began to be dispersed throughout other museums in Europe and America (Liston & Noè, 2004). It also represents one of only two large fossil vertebrate collections in the National Museum of Ireland, the second being Lee's collection of Lias reptiles. The purchase of the collection was negotiated in 1893; the fossils were purchased for the amount of £70 in the same year, representing the first transaction of Leeds material outside of the British Museum. A description of the Dublin Leeds collection is to be published shortly.

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The systematic position of *Semlikiichthys*: the carangoid hypothesis

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Semlikiichthys is a fossil genus of perciform fish from the Neogene continental deposits of Africa, known in several Mio-Pliocene sites of the Great Lake Region, and in the Pliocene of the River Nile (Greenwood & Howes, 1975; Otero & Gayet, 1999) and in the Upper Miocene of Toros-Menalla in Chad (Otero *et al.*, submitted). Initially related to genus *Lates*, it was left *incertae sedis* after the phylogenetic study of the family Latidae (Otero, 2004). At first glance, one of us (BC) noticed a striking similarity between *Semlikiichthys* and certain carangoid fishes, and proposed to compare its bony anatomy with representatives of each family of this highly derived marine fish group, including Carangidae (jacks and pompanos), Coryphaenidae (dolphinfishes or mahi-mahis) and Echeinidae (remoras), and relatives. Here we present the results of these comparisons. We focused on neurocranial characters, especially the shape of the vomer and the supraoccipital and its median crest. The observed characters are placed on a phylogenetic tree based on morphological data (Leis, 1994; O'Toole, 2002) and molecular data (Dettai & Lecointre, 2005). We discuss their homology and then the possible position of *Semlikiichthys* within these groups. We also propose a further

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path to precisely ascertaining the systematic position of *Semlikiichthys*, which will aid in understanding the history and the evolution of acanthomorph fishes notably that of the carangoid group whose position is still in debate (Dettai & Lecointre, 2005). Moreover, if a position within the Carangoidei is confirmed, this would have implications for the Miocene palaeogeography of the basins of the Nilo-Sudanese region and their colonisation by marine species.

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Categories of disarticulation of testudine skeletons

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Testudines present a novel problem in taphonomic studies. The contiguous shell effectively obscures some of the decay and disarticulation normally seen in other vertebrate carcasses, including the major internal organs, pectoral and pelvic girdles, and some proximal limb elements. A total of eight categories of disarticulation can be discerned in extant and extinct testudine skeletons. This is a greater number than distinguished in other studies of vertebrate decomposition (Martill 1985, 1986; Kemp and Unwin 1997; Kemp 2001); however this reflects the nature of the more resistant shell as a single unit. The relatively early separation of skulls and limbs (which tend to disarticulate from the extremities) from the rest of the skeleton is due to: the weight of the head, causing it to hang down from the body; the passive extension of the legs of carcasses (Weigelt, 1927); the differential properties of testudine skulls in water currents compared to the rest of the skeleton (Blob, 1995); and the preferred sites of scavenging activity on the carcass. The presence of 'sacks' of resistant integument retaining disarticulated bones in close association could cause misinterpretation of some fossil specimens, as could the role of the keratinous scutes in binding disarticulated shell bones.

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New discoveries of lambeosaurine hadrosaurids from the Tremp Basin (Maastrichtian, Southern Pyrenees): description and stratigraphic setting

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We document discovered hadrosaurid remains that demonstrate the presence of the Lambeosaurinae clade in the Maastrichtian of the southern Pyrenees. These remains come from three sites located in different stratigraphic horizons across 40 m of succession that are part of a larger 400 m sequence of Maastrichtian strata. Laterally, these sites are scattered throughout 1500 m, but can be directly correlated in the badlands of the area. Thus, all the sites correspond to approximately the same time span. The majority of the skeletal material is found scattered in fluvial sandstones.

The Serrat del Corb site has provided a nearly complete pelvis. The ischia have lambeosaurine synapomorphies such as a “booted” distal shaft and a caudodorsally recurved iliac peduncle. The Molí del Baró-1 site has yielded an ischium that also shows a caudodorsally recurved iliac peduncle. In the Euroda Nord site, an incomplete right maxilla was recovered showing a wide and long rostradorsal premaxillary shelf, characteristic of Lambeosaurinae.

The anatomical information derived from these new materials will allow comparisons with taxa from Asia and North America. These comparisons are crucial if one is to gain a more complete understanding of hadrosaurid origins, evolutionary relationships, and historical biogeography.

The palaeobiogeographic distribution of Liassic plesiosaurs

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Although their remains date from the early Hettangian or Rhaetian (Storrs & Taylor, 1996), the plesiosaurs were soon dispersed over the entire world, as Australian plesiosaurs of Toarcian age indicate (Thulborn & Warren, 1980). However, they are most abundant in Europe, which was covered by a shallow epicontinental sea during the Lower Jurassic, leaving only some small islands. Three main zones can be distinguished in this area: an English zone, a Norman-Benelux and a German zone. The best and most abundant discoveries are from the English zone, followed by the Toarcian plesiosaurs from Germany. It is remarkable that, although the distance between these zones is not great, and there are no obvious barriers, species specification, and to a slightly lesser extent also generic specification, is high. No species is found in more than one zone, and only the genus *Rhomaleosaurus* is found in both the English and the German zones. However, the faunal composition is very similar at family level. Throughout the Liassic, elasmosauroids are found in all zones, whereas plesiosauroids are less abundant in the Toarcian than in the Hettangian and Sinemurian, and cryptoclidids have not yet appeared. And although the plesiosauroid species in the English and German zone

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are not the same, they belong to similar morphotypes and/or are closely related, indicating that they occupied similar ecological niches.

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Reassessment of the English Cretaceous ichthyosaur *Platypterygius campylodon*

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New and existing specimens of the English middle Cretaceous (Albian-Cenomanian) ichthyosaur *Platypterygius campylodon* (Carter) are described in detail. Key features including coarsely striated conical tooth crowns, quadrangular tooth roots, basioccipital with reduced extracondylar area, humerus with a well developed dorsal trochanter, and closely fitting, block-like phalanges are typical of the genus (McGowan, 1972; Maisch & Matzke, 2000). The presence of an expanded proximal humerus with rounded dorsal trochanter and only two distal facets for the radius and ulna (extrazeugopodial facet absent) is closely comparable to *Platypterygius* remains from continental Europe (Germany and Russia) and indicates a probable conspecific relationship. Despite its large size (length around 5 metres), *P. campylodon* shows adaptations for dealing with relatively small food items. The long, narrow snout would have assisted in prey capture by reducing drag as the jaws were swung sideways and snapped shut underwater. The robust dentition might imply selective feeding on hard-shelled invertebrates (e.g. ammonites) and/or active prey dismemberment, perhaps by 'shake feeding'. Large orbits suggest a primarily visual hunter. However, prominent channels on the external surfaces of the snout and mandible could have housed branches of the trigeminal and facialis nerves servicing a dermal sensory system (e.g. electroreceptors). The massive stapes appears to have lost all sound-conductive function, and alternatively forms a structural brace between the basicranium and quadrate jaw articulation.

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The Ecology, Growth and Osteology of *Leedsichthys*

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The results of a seven year project on the Jurassic suspension-feeder *Leedsichthys* are presented, with constrained estimates of its palaeoecology. Following a review of available material (Liston, 2004), archival documentation (Liston & Noe, 2004), and a subsequent revision of osteological identifications (Liston, 2005, 2006), the estimated lengths of specimens of *Leedsichthys* have been revisited. Constrained estimates of lengths have permitted the construction of a modern model of this animal, incorporating its swimming abilities and optimum feeding speeds. In parallel with this, growth ring analysis (Liston, Steel & Challands, 2005) allowed the generation of 'length-at-age' estimates, enabling comparison with growth of contemporary large suspension-feeders such as the basking shark (*Cetorhinus*) and the whale shark (*Rhincodon*). As the first 'large' (> 2 metres Standard Length) suspension-

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feeder, the growth rates of this Jurassic bony fish are within the range indicated by specimens of whale and basking sharks.

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A Palaeocene deep-water shark fauna from the Southwest Pacific

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Apart from the enigmatic cnidarian, *Waiparaconus* Buckeridge, 1983 and the remains of the early penguin, *Waimanu* Jones, Ando and Fordyce, 2006, the Palaeocene sediments of North Canterbury, New Zealand are not noted for their fossils. However, careful searching of exposures along the banks of the Waipara River has produced several hundred isolated shark teeth, dated on the basis of nannofossils as Danian to Selandian for the most part.

The fauna includes at least 15 elasmobranch genera, of which several are new records for the New Zealand fossil biota. Representatives of the living frill sharks, cow sharks, gulper sharks, dogfish, kitefin sharks, sand tigers and goblin sharks are present, including the first fossil representative of *Centroselachus*. In addition, a number of extinct genera, such as *Notidanodon*, *Sphenodus* and *Paraorthocodus*, are remnants of the Cretaceous fauna. This fauna allows insight into the shark species present in the southwest Pacific during the Paleocene and adds to the knowledge of shark faunas of this age world wide.

Comparison with extant species belonging to several of the genera present suggests that the fauna is a deep water one, typical of the outer continental shelf to upper continental slope. This conclusion is apparently at odds with the interpretation of the Waipara Greensand, from which the majority of specimens was derived, as having been deposited in a shallow marine setting under conditions of very slow sedimentation (Browne & Field, 1985) and requires further investigation.

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Environmental and geological controls on the diversity and distribution of the Sauropodomorpha

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Although research on the Sauropodomorpha is a thriving field, few studies have examined the ecological, geographic and geological factors that controlled their biodiversity and biogeography (Barrett & Upchurch, 2005). This work will examine the possible correlation between such factors as the ecological setting, spatial and temporal distribution, and taphonomy of the Sauropodomorpha, and hypotheses concerning macro-evolutionary patterns. One important hypothesis that will be tested is how their state of preservation is affected by the environment in which they lived; this should help tease apart genuine patterns from taphonomic biases. A large dataset, at the specimen level, will be collected from museum visits, field sites, existing datasets and the published literature (Upchurch *et al.*, 2004). This will then be integrated into a Geographic Information System, allowing a variety of statistical analyses to be undertaken in order to test possible correlations between parameters. This will provide insights into the evolution and palaeoecology of the Sauropodomorpha as well as enable a better understanding of the taphonomic effects that such large terrestrial vertebrates undergo. In addition, it may also be relevant to our understanding of global change both during the Mesozoic Era and today.

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A new hadrosaurian bonebed in the Maastrichtian of the southern Pyrenees: a stratigraphic and taphonomic approach

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The Basturs Poble bonebed (Maastrichtian, south Pyrenees) has yielded 508 archosaur (dinosaur and crocodile) bone remains during several field campaigns between 2001 and 2006, becoming one of the most important Upper Cretaceous sites in the Iberian Peninsula in terms of the number and preservation of the remains found. Nearly 97% of determinable cranial and postcranial remains correspond to hadrosaurs (Hadrosauridae indet.).

Among the studied hadrosaur skeletal elements there are no diagnostic characters in the cranial and postcranial bones that permit different hadrosaur species to be distinguished. On the basis of this fact, we can work with the hypothesis that the bonebed is composed of a single hadrosaur species. It is to be noted that all ontogenetic stages (e.g. maximum length of tibiae ranging between 38.5 cm and 70.1cm) are reflected in the material recovered.

This site represents a paucispecific palaeocommunity. The bones can be found in two stratigraphic horizons: the lower one corresponds to fine sandstone that shows abundant edaphic carbonate nodules and mottling, while the upper is composed by a very fine sandstone with no sedimentary structures. According to the taphonomic and sedimentological data the former is the product of an *in situ* bone accumulation in a palaeosol with no

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significant transport processes, while the accumulation in the latter comes as the result of a limited mass transport. Bone abrasion and weathering is similar for both layers. This, together with the discovery of evidence of trampling in the palaeosol, suggests that the remains were exposed in a subaerial environment after the death of the animals and the upper level is the result of an early erosion of the palaeosol.

Evolutionary biomechanics of the presacral vertebrae of sauropod dinosaurs: a new approach

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The complex structure of sauropodomorph presacral vertebrae, with their sophisticated system of bony laminae, has long been interpreted as being determined by mechanical constraints. Wilson (1999) noted that this is "... a plausible, but currently unsubstantiated argument". However, this hypothesis has never been tested empirically. In a new approach, Finite Element Structure Synthesis (FESS) will be applied to presacral vertebrae to reveal the form-function relationships, and the results will be set in a phylogenetic framework to analyse the morphofunctional evolution of these structures. FESS is an inductive analytical method using finite elements and is ideal to test the emergence of detailed structures from stresses applied to generalized models of the elements in question. This method is thus ideal to test the hypothesis at hand. In order to employ stresses on generalised models of the elements in question, it is necessary to a) reconstruct the possible posture and mobility of the presacral vertebral column, and b) to reconstruct the axial musculature and its line of action as accurately as possible, using the Extant Phylogenetic Bracket approach. In a first step, this analysis will be carried out for a basal sauropodomorph (*Plateosaurus*) and a neosauropod (*Diplodocus*) to establish the mechanical principles of vertebrate design in these taxa. Then, the significance of the results will be analysed for a wide variety of sauropodomorph dinosaurs, to establish the importance and pattern of functional aspects for the evolution of sauropodomorph presacral vertebrae.

Wilson, J.A. 1999. A nomenclature for vertebral laminae in sauropods and other saurischian dinosaurs. *Journal of Vertebrate Paleontology* 19 (4):639-653.

Affinities and morphology of a poorly known chondrichthyan from the Upper Cretaceous

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Within the Cretaceous a unique chondrichthyan appeared and disappeared leaving little more than isolated teeth as a fossil record. Although a few associated teeth and vertebrae have been recovered, they are few and incomplete.

Consequently the morphology and systematic affinities of the Ptychodontidae are unknown. Calcified cartilage found in association with teeth prove the animal to be chondrichthyan in Order, but whether they are shark or ray, or within their own unique group, is still to be determined. The teeth themselves are robust and highly ornamented, and from the few articulated specimens recovered, it has been established that *Ptychodus* possessed a crushing dentition comprising hundreds of teeth in each jaw.

In a unique study involving measurements of the dental ornamentations and morphology of the occlusal surface, a possible phylogeny has been constructed in an attempt to identify the phylogenetic relationships within the Family Ptychodontidae, plus their systematic

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affinities within the Order Chondrichthya. It is an experimental study to ascertain whether such a method can be used in this way.

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The continental vertebrate succession of the Vallcebre Syncline (Maastrichtian, southern Pyrenees)

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In the Vallcebre syncline there is a succession of strata, belonging to the Tremp Formation, up to 800 metres thick, which displays a clear evolution from transitional (with coal formation) to entirely continental environments (red beds). This section comprises the Cretaceous-Tertiary (K-T) boundary and contains an exceptional record of dinosaurs and other vertebrates, invertebrates, and plant fossils found in 400 metres of Maastrichtian succession. The age of the Vallcebre area is well constrained after the occurrence of a clear magnetostratigraphic succession that can be compared to the standard polarity scale after biochronological constraints. The vertebrate record consists of dinosaurs, crocodiles, chelonians and batoids. Dinosaur taxa include titanosaur sauropods, ?dromaeosaurid theropods and hadrosaur ornithopods. The ichnological record comprises several sites with titanosaur and hadrosaur tracks in the basalmost levels and close to the K-T boundary, respectively. An abundant egg and eggshell record has been documented throughout the lower units of the succession. Four megaloolithid oospecies have been identified including *M. siruguei* and *M. mammillare*. The whole record makes the Vallcebre area a remarkable succession to contribute to our understanding of the last European dinosaurs. Our results indicate the dominance of sauropods and hadrosaurs in the early and latest Maastrichtian environments of Vallcebre syncline, respectively. These are found both in transitional (brackish) - together with crocodiles, chelonians and batoids - and continental (fluvial) settings, the hadrosaurs and theropods being most abundant (or solely present) in fluvial environments. On the other hand, the eggshell record shows the typical southwest European succession of dinosaur oospecies.

Where are the Early Cretaceous plesiosaurs?: The first sacral vertebra of Plesiosauria (Reptilia: Sauropterygia) found in the Arcillas de Morella Formation (Aptian, Early Cretaceous) of Eastern Spain

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Plesiosaur remains are known from all over the world, but in the Early Cretaceous of Western Europe, only a few localities have been described (Yagüe *et al.*, 2003; Bardet *et al.*, 2006). Although plesiosaurs are abundant during the Upper Jurassic and Upper Cretaceous fossil record, the bones of these animals are poorly represented in the Early Cretaceous. Such sparse record has been attributed to extinction events (Haggart *et al.*, 2003) and to the inadequacy of the fossil record (Bardet, 1994, 1995; Haggart *et al.*, 2003). We agree with Bardet *op. cit.*, that the poor plesiosaur fossil record of the Early Cretaceous of Western Europe is biased by the scarcity of studies of plesiosaur material and outcrops of this age. The Arcillas de Morella Formation is a stratigraphic unit which covers this age. It is composed by marine and non-marine facies, and is mainly known for its dinosaur fauna. Most of the studies on the vertebrate fossils of these sites have dealt with this group, leaving some vertebrate fossils from other groups (such crocodiles, turtles or plesiosaurs) unpublished (Ruiz-Omeñaca and Santos-Cubedo, 1998; Weishampel *et al.*, 2004). New discoveries provide essential clues to understand the distribution of the Cretaceous Iberian plesiosaurs. Herein, we report a sacral vertebra of a plesiosaur from the Mas de Rafael site (Tudela, Spain). This specimen constitutes the first sacral vertebra of Plesiosauria (Reptilia: Sauropterygia) described in the Early Cretaceous (Aptian) from Spain and the first evidence of the group outwith the type locality of the Arcillas de Morella Formation (Morella, Spain).

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Dinosaur fossils in marine facies from ANA locality, Arcillas de Morella Formation (Aptian, Lower Cretaceous, Cinctorres, Spain)

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The ANA site was discovered in 1998, but it remained unexcavated until 2002, when a team of palaeontologists formed by members of the Institut Paleontologia Crusafont from Sabadell and the Grup Guix from Vila-real unearthed the first fossil from the locality.

Nowadays there are 371 fossils collected, including vertebrate and invertebrate species. Dinosaur bones (Theropoda and Ornithopoda) are abundant in this assemblage. The site is located within the Arcillas de Morella Formation (Aptian, Early Cretaceous). This formation crops out in the Maestrat Basin, located in the eastern part of the Iberian rift system (Iberian

Chain). Salas et al., (1995) suggested several units for the Maestrat Basin (up to 5.8 km of Mesozoic sediments) for the Lower Aptian Depositional Sequence (Lower Cretaceous Megasequence). Gàmez et al., (2003) defined five facies associations for the formation that they interpreted as non-marine, and observed at the upper part a shift towards marine environments.

In the ANA locality, we identified the ichnospecies *Teredolites clavatus* Leymerie, 1842. Ferrer and Gibert (2005) interpreted the horizon containing *Teredolites* in a nearby outcrop at the Teuleria Milian in the upper part of the Arcillas de Morella Formation as indicative of a transgressive surface (TS), therefore ANA would be located on a transgressive surface (TS) and it corresponds to marine facies. Therefore, dinosaur fossils from ANA were finally buried in a marine environment, and this would occur in other dinosaur sites within the Arcillas de Morella Formation.

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Osteology and phylogenetic position of *Anomoiodon liliensterni*, a procolophonid reptile from the Middle Triassic Bundsandstein of Germany

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Procolophonoids are small to medium sized Permo-Triassic parareptiles, and several taxa have biostratigraphic potential. The procolophonid reptile *Anomoiodon liliensterni*, from the Middle Triassic of Germany, is represented by two closely associated skeletons preserved as natural moulds in sandstone. These skeletons were described from plaster casts with little detail (Huene, 1939) and subsequently the moulds were misplaced. This was unfortunate because interest in *Anomoiodon* was renewed after suggestions that it is the senior synonym of *Kapes* (Spencer & Storrs, 2002). *Kapes* is known from the Triassic of Russia and the United Kingdom, where it has been used as an informal index taxon (Novikov & Sues, 2004; Spencer & Storrs, 2002). Fortunately, the original specimens of *Anomoiodon* resurfaced recently. New silicone rubber casts reveal the anatomy of *Anomoiodon* in more detail and allow a comprehensive comparison with *Kapes*.

The two specimens of *Anomoiodon* measure about 150 mm from snout to tail. Several cranial sutures, together with details of the dentition and the postcranial skeleton can be seen. *Anomoiodon* shares numerous features with *Kapes*, including the general shape of the skull, posteriorly increasing size and height of the marginal dentition and the shapes of the prefrontal bone, the interpterygoid vacuity and the dorsal vertebrae. *Anomoiodon* and *Kapes* form a sister-group relationship in my phylogenetic analysis of the Procolophonoidea. Thus a close relationship, or indeed synonymy, is a real consideration. In addition, re-examination of all suggested species of *Kapes* is undertaken to verify its abundance in Russia and relationship with *Anomoiodon*.

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PalArch, Netherlands scientific journal

Andre Veldmeijer and Hanneke Meijer (presented by Natasja den Ouden)

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Evidence for big sauropods and dromaeosaurid theropods from a new Maastrichtian locality in the southern Pyrenees

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Sauropod and theropod dinosaurs probably exhibit one of the scarcest fossil records in the Late Cretaceous of the Pyrenees in contrast to the great abundance of hadrosaur fossils. Recent excavations of a new Maastrichtian vertebrate locality at the Tremp Formation deposits from Vallcebre syncline (Catalonia, southern Pyrenees) bring new data about these taxa. Fossils from Peguera-1 locality include disarticulated fore and hind-limb bones of a sauropod, theropod and crocodile tooth, and eggshell fragments. They are associated with ferruginous concretions, abundant root traces and scattered bones.

Sauropod humeri and femora, which usually lack epiphysis ends, have an estimated total length of 120 and 170 cm, respectively. This clearly indicates a large-sized sauropod, in agreement with hip height estimations (260-280 cm) from the nearby Fumanya titanosaur track record.

The almost thirty small and serrated theropod teeth associated with sauropod bone limbs include various morphotypes with likely dromaeosaurid affinities. Finally, the scarce eggshell fragments belong to *Megaloolithus siruguei* oospecies.

Sauropods bones and tracks from Peguera and Fumanya localities prove the occurrence of big titanosaurs in Late Cretaceous environments of Southern Europe and bring new data on sauropod diversity in southern Pyrenees basins where various species may have existed. In addition, theropod (?dromaeosaurid) teeth represent the first data of this group in the early Maastrichtian of the Vallcebre syncline.

Isolating functional degrees of freedom in limbs during locomotion

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The pattern of limb movements characteristic of a given vertebrate during locomotion is, at least in part, reflected in its osteology. The limbs, working in concert, produce an efficient (hence smooth) forward movement of the body. Candidate movements for a given limb can be formalized as trajectories within a configuration space defined by all possible combinations of joint deflection angles, to within some given angular resolution. This space can then be explored using Genetic Algorithms (GA) techniques [Holland, 1992], where a candidate movement is evaluated on how well it transports the body while minimizing angular and translational deviations during the forward path. This application focuses on the pectoral girdle and forelimbs of the sauropod *Apatosaurus*, to determine how the limb might have functioned during locomotion. The wrist, elbow, shoulder, and pectoral girdle are provided appropriate functional degrees of freedom (FDOFs) per joint (e.g., flexion/extension at the elbow; flexion/extension plus abduction/adduction and medial- and lateral-rotation at the shoulder). By selectively adding and removing specific FDOFs if it possible to isolate the relative contribution of each towards the locomotion task. This is particularly important in examining the potential mobility of the pectoral girdles, for which no strong constraint on their position and range of motion is provided by their osteology.

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Cranial evolution and feeding biomechanics in Sauropodomorpha

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Sauropodomorphs include some of the most bizarre and biomechanically unfeasible animals ever to have existed. How they fuelled their multi-tonne bodies on an apparently nutrient poor diet of fibrous plant matter challenges our understanding of both extinct and extant biological systems. As the food acquisition and processing centre, the skull and dentition have obviously been the focus of much research in relation to feeding behaviour (Barrett, 2000; Barrett & Upchurch, 2005; Sereno & Wilson, 2005). These studies have shown that rather than having relatively simple teeth and jaws as once thought, sauropodomorphs (especially sauropods) actually showed considerable diversity in cranial and dental morphology and function (Upchurch & Barrett, 2000). Previous studies focused on the shape of the skull and teeth, and characteristic tooth wear patterns produced by tooth-tooth or tooth-food contact. Although immensely valuable, until now no attempt has been made to quantify the biomechanics of the sauropodomorph skull.

This project will incorporate biomechanical analysis techniques with new data taken from CT scanned skulls (*Camarasaurus*, *Diplodocus* and *Massospondylus*), which will be used to create Finite Element models. In addition, geometric morphometrics will be employed to explore the disparity of shape of teeth and isolated cranial elements, to permit a synergy of quantitative structural and functional morphological techniques in order to characterise the craniofacial evolution and diversity of feeding behaviours within this fascinating group of dinosaurs.

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Programme

Tuesday 28th August

SPPC morning session

10:00-12:00 Tours of new Hunterian and Kelvingrove Museum vertebrate palaeontological displays

Creating the vertebrate palaeontological displays for the Kelvingrove Museum. John-Paul Sumner

12:00-13:00 Practical demonstration of historical glue-making, and implications for conservation. Leslie F. Noè

SPPC Talks

Session 2 - Chair: **Richard Forrest**

14:00-14:20 The Rather Naive Idea of Forming a Museum on the Jurassic Coast Steve Etches

14:20-14:40 Fake Rock, Real Sand: The making of the exhibition 'Sahara - living desert' Michaela Forthuber

14:40-15:00 The virtual and physical preparation of the Collard Plesiosaur Nigel R. Larkin

15:00-15:30 Coffee

Session 3 - Chair: **Leslie Noè**

15:30-15:50 Palaeontological preservation with 21st century documentation: using photogrammetry to produce highly detailed 3D image models Neffra A. Matthews and Brent H. Breithaupt

15:50-16:10 The Good, The Bad and The Ugly: Preparation from the Wild West Cindy Howells

16:10-16:30 Emergency remedial conservation of homeless mammoth material Emma-Louise Nicholls

Evening Icebreaker in Zoology Museum (including JFMF charity auction)

SVPCA Sessions

Wednesday 29th August

09:00-09:10 Welcome from Ewen Smith, Director of the Hunterian Museum

Session 1 - Chair: **Jon Jeffery**

09:10-09:30 Segmental identity within the vertebral column: what can fossils tell us? Zerina Johanson, Robert Carr and Alex Ritchie

09:30-09:50 Muscling in on Placoderms Kate Trinajstic, Carina Marshall, John Long and Kat Bifield

09:50-10:10 The contribution of placoderms to our understanding of the ontogeny and evolution of early gnathostomes Robert K. Carr, Zerina Johanson, Alex Ritchie, Hervé Lelièvre and Daniel Goujet

10:10-10:30 Using sharks as indicators of trophic structure within 'mid' Cretaceous watermasses Emma-Louise Nicholls

10:30-11:00 Coffee

Programme

	Session 2 - Chair: Marcello Ruta	
11:00-11:20	New insights on the Upper Cretaceous pachycormid ' <i>Protosphyraena gladius</i> ' (Actinopterygii: Teleostei) from North America	Matt Friedman, Kenshu Shamida and Anthony Maltese
11:20-11:40	Hyomandibulae of Rhizodontids (Sarcopterygii, Stem-Tetrapoda)	Jonathan E. Jeffery and Martin D. Brazeau
11:40-12:00	The pectoral fin of the near-tetrapod <i>Panderichthys rhombolepis</i>	Catherine A. Boisvert and Per Erik Ahlberg
12:00-12:20	Tales from the 'Leeds Collection' – a unique palaeontological and archival resource	Leslie F. Noè and Jeff J. Liston
12:20-14:00	Group photograph , then break for lunch	
	Session 3 - Chair: Matt Friedman	
14:00-14:20	Calibrated diversity, tree topology and the mother of mass extinctions: the lesson of temnospondyls	Marcello Ruta and Michael J. Benton
14:20-14:40	Isolated bones versus articulated skeletons: the problem of parataxonomy in fossil squamates	Alexandra Houssaye and Jean-Claude Rage
14:40-15:00	All at Sea: Late Jurassic Testudines from Europe	Sarah Fielding
15:00-15:20	Skull joints in <i>Sphenodon</i> and other Rhynchocephalia (Diapsida: Lepidosauria)	Marc E. H. Jones
15:20-15:40	New Discoveries from Bearsden: Reassessing the Early Record of Post-Devonian Fishes	Michael I. Coates, Patrick Gavin and Neil D. L. Clark.
15:40-16:00	Coffee	
	Session 4 - Chair: Mark Evans	
16:00-16:20	A Taxonomic Tale: What exactly are <i>Metriorhynchus</i> and <i>Geosaurus</i> ?	Mark Young
16:20-16:40	The specialized dentition of derived notosuchians (Crurotarsi: Mesoeucrocodylia)	Marco Brandalise de Andrade and Reinaldo J. Bertini
16:40-17:00	Mass extinction of tetrapods at the Permo-Triassic boundary in Russia	Michael J. Benton, Richard J. Twitchett, Tim Kearsley, Andrew J. Newell, Marcello Ruta, Mikhail V. Surkov, Graeme Taylor and Valentin P. Tverdokhlebov
17:00-17:20	A new global phylogeny of Plesiosauria (Reptilia: Sauropterygia)	Hilary Ketchum
Evening	Lord Provost's Civic Reception	

Thursday 30th August

	Session 1 - Chair: Richard Forrest	
08:30-08:50	A skeletal reconstruction of <i>Rhomaleosaurus</i> and the systematics of pliosaurs	Adam Stuart Smith
08:50-09:10	A nearly complete elasmosaur from the Late Cretaceous Bearpaw Formation of Alberta, Canada	Donald M. Henderson
09:10-09:30	Osteological redescription, and taxonomic and phylogenetic position of ' <i>Plesiosaurus macrocephalus</i> ', specimen NHM 49202, from the Lias of England	Peggy Vincent
09:30-09:50	Processes and flanges: the evolution of the plesiosaur braincase and posterior palate	Mark Evans
9:50-10:10	Coffee	

Programme

	Session 2 - Chair: Mike Coates	
10:10-10:30	Further evidence for a broad forewing in pterosaurs	David M. Unwin, Matthew Wilkinson, Lü Jungchang and Natalie Bakhurina
10:30-10:50	Cope's Rule in Mesozoic Archosaurs	David W.E. Hone
10:50-11:10	Mesozoic dinosaur diversity: taxic, phylogenetic and sampling approaches	Paul M. Barrett, Victoria Page and Alistair McGowan
11:10-11:30	Vertebrate Palaeontology of the Kem Kem Beds, Morocco and Palaeoecology of North Africa	Nizar Ibrahim, Lahssen Baider, Gareth Dyke, Nour-Eddine Jalil, Fouad Ouanaimi, Remmert Schouten and Samir Zouhri
11:30-11:50	3D imaging of enigmatic tiny eggs with embryos from the Lower Cretaceous of Thailand using phase contrast X-ray synchrotron microtomography	Vincent Fernandez Paul Tafforeau and Eric Buffetaut
11:50-13:30	Lunch	
	Session 3 - Chair: Brent Breithaupt	
13:30-13:50	Basal tyrannosauroids: a new theropod dinosaur from the Kimmeridge Clay (Late Jurassic: Tithonian) of Dorset, UK representing a large-bodied species of the North American genus <i>Stokesosaurus</i>	Roger B. J. Benson
13:50-14:10	The large theropods <i>Becklespinax</i> and <i>Valdoraptor</i> from the Lower Cretaceous of England	Darren Naish
14:10-14:30	Redescription of <i>Neovenator salerii</i> (Dinosauria: Theropoda) and its implications for theropod evolution and phylogeny	Stephen L. Brusatte, Roger B. J. Benson and Stephen Hutt
14:30-14:50	Scaling bite force in predatory tetrapods: bite force is proportional to body mass ^{2/3}	Manabu Sakamoto
14:50-15:10	<i>Dryosaurus lettowvorbecki</i> – First Results of a Paleobiological Study	Tom Hübner
15:10-15:40	Coffee	
15:40-16:30	Plenary on SVP 2009	
Evening	Whisky-tasting with Dr. Jim Hansom at the Hunterian Museum, including a short introduction to William Hunter's fossil vertebrate collection.	

Friday 31st August

	Session 1 - Chair: Darren Naish	
09:10-09:30	Wading across the pond: a photogrammetric, spatial, and morphological comparison of Middle Jurassic dinosaur tracks from North America and the United Kingdom	Neffra A. Matthews and Brent H. Breithaupt
09:30-09:50	Growing up in the Middle Jurassic: ichnological evidence for family groups of theropods in Wyoming; comparison of footprints and growth rates of emus and dinosaurs	Brent H. Breithaupt, Neffra A. Matthews and Todd L. Green
09:50-10:10	Kinematic Constraints on the Reconstruction of Dinosaur Gaits	Kent A. Stevens and Eric D. Wills,
10:10-10:30	<i>Euhelopus zdankysi</i> and its bearing on the evolution of East Asian sauropod dinosaurs	Paul Upchurch and Jeffrey A. Wilson
10:30-11:00	Coffee	

Programme

Session 2 - Chair: Jerry Hooker		
11:00-11:20	Palaeoenvironmental controls on the distribution of Cretaceous herbivorous dinosaurs	Richard J. Butler, Paul M. Barrett, Paul Kenrick and Malcolm G. Penn
11:20-11:40	The ceratopsian dinosaur <i>Psittacosaurus</i> in Southeast Asia : a review of old and new finds	Eric Buffetaut, Varavudh Suteethorn ² and Sasidhorn Khansubha
11:40-12:00	Wise as an owl – 147 million years of avian brain evolution	Stig A. Walsh and Angela C. Milner
12:00-12:20	And yet it does replace? Some new thoughts on the diversity and tooth replacement in the Mesozoic mammal <i>Morganucodon watsoni</i>	Felix Marx and Pam Gil
12:20-12:40	Developmental modularity and the marsupial-placental dichotomy	Anjali Goswami, Vera Weisbecker and Marcello R. Sánchez-Villagra
12:40-14:00	Lunch	
Session 3 - Chair: Anjali Goswami		
14:00-14:20	Computer simulation of feeding behaviour in marsupial and placental carnivores	Stephen Wroe, Philip Clausen, Colin McHenry and Karen Moreno
14:20-14:40	A new primate clade from the European Eocene	J.J. Hooker and David L. Harrison
14:40-15:00	Morphology and the Afrotheria	Robert J. Asher
15:00-15:20	Craniodental and postcranial morphology of a primitive hyracoid (Mammalia, Paenungulata) from the early Priabonian (late Eocene) of Egypt	Eugenie C. Barrow, Erik R. Seiffert and Elwyn L. Simons
Session 4 - Chair: Tom Kemp		
15:40-16:00	Dietary change in a plant eating mammal across the Eocene/Oligocene transition	Sarah C. Joomun, Jerry J. Hooker and Margaret E. Collinson
16:00-16:20	Brain size and insular dwarfism: a case study of the extinct dwarf hippopotamuses from Madagascar	Eleanor M. Weston and Adrian M. Lister
16:20-16:40	Comparative Ontogenetic Analysis of Extant Rhinos and <i>Teleoceras major</i> , a North American Rhino	Mark D. Hagge
16:40-16:50	Ten minutes on Field Trip and Annual Dinner	
Evening	Annual Symposium dinner (Arisaig)	

Saturday 1st September

Field Trip

Previous Venues

2006 - Paris (Ecole Nationale des Mines)	1979 - Oxford
2005 - London (NHM)	1978 - Reading
2004 - Leicester (Univ./New Walk Museum)	1977 - Newcastle upon Tyne
2003 - Oxford (Univ. Mus. Natural History)	1976 - London (University College)
2002 - Cambridge (Sedgwick Museum)	1975 - Edinburgh (Royal Scottish Museum)
2001 - York (Yorkshire Museum)	1974 - Manchester
2000 - Portsmouth	1973 - Leeds
1999 - Edinburgh (Nat. Mus. of Scotland)	1972 - London (BMNH/Royal Holloway)
1998 - Bournemouth	1971 - Bristol
1997 - Derby	1970 - Cambridge
1996 - London (University College)	1969 - Newcastle upon Tyne
1995 - Newcastle upon Tyne (Dental School)	1968 - Reading
1994 - Le Havre	1967 - London (Queen Elizabeth College)
1993 - Cambridge (Univ. Mus. Zoology.)	1966 - Edinburgh (Royal Scottish Museum)
1992 - Bristol	1965 - London (Royal Holloway)
1991 - Oxford	1964 - Bristol
1990 - Milton Keynes (Open University)	1963 - Cambridge
1989 - Leicester	1962 - Newcastle upon Tyne
1988 - Boulogne sur Mer	1961 - London (University College)
1987 - London (BMNH)	1960 - Oxford
1986 - Belfast (Queen's)	1959 - London (Royal Holloway)
1985 - Manchester	1958 - Bristol
1984 - London (University College)	1957 - Cambridge
1983 - Bristol	1956 - Newcastle upon Tyne
1982 - Cambridge	1955 - Oxford
1981 - Cardiff	1954 - London (University College)
1980 - Kingston upon Thames	1953 - Cambridge



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