53rd SYMPOSIUM OF VERTEBRATE PALAEONTOLOGY AND COMPARATIVE ANATOMY

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ABSTRACTS

EDITED BY PAUL M. BARRETT

PREFACE

On behalf of the organising committee, welcome to the 53rd Symposium of Vertebrate Palaeontology and Comparative Anatomy, hosted by the Natural History Museum. The organisers envisage a lively and enjoyable meeting and hope that you also have time to enjoy the Museum exhibitions and surrounding attractions of London while you are here. This meeting marks a welcome return of SVPCA to the Museum, which last acted as the host institution in 1987.

The meeting logo was designed by Stig Walsh and commemorates an important event in the NHM calendar: the 100th anniversary of the presentation of our superb cast of *Diplodocus carnegii*. This cast, donated by Andrew Carnegie on 12th May 1905, dominates the Central Hall and is the first exhibit that most visitors to the Museum see, often leading to a lasting impression. We are fortunate this year, as the symposium dinner will be held in the Central Hall under the watchful gaze of 'Dippy'. A small display marking the anniversary can be found on the First Floor.

This volume is arranged into three sections: abstracts for oral presentations (pp.3- 27); abstracts for posters (where offered, pp. 28-38); and poster titles where no abstract was offered (p. 39). Within each section presentations/posters are arranged alphabetically by first author. In some cases, abstracts have been lightly edited to conform to a 'house-style' and to correct obvious spelling and/or grammatical errors. This version of the abstract volume differs slightly from the printed version distributed at the meeting, reflecting last minute changes to the programme.

Paul M. Barrett

ABSTRACTS OF ORAL PRESENTATIONS

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The virtual *Eusthenopteron*: inside the head of a Devonian lobe-fin with CT

Computerised Tomography (CT) is a powerful tool for visualising the internal structure of objects in three dimensions using serial X-ray "slices", and has in recent years found increasing use in the study of fossils. Compared to a grinding series it is incomparably quicker, non-destructive, and allows “weightless” computer reconstruction of the objects in virtual space.

In collaboration with the University of Texas and Parc de Miguasha, we are reconstructing the skull of the Devonian sarcopterygian *Eusthenopteron* from a CT scan series. The aim is to complement Jarvik’s (1980) landmark study of the skull of this fish by using a different technique and a much larger individual. Our results largely confirm Jarvik’s interpretation, with the exception of a few differences such as a more posteriorly positioned external nostril, differently proportioned nasal capsules and a large fontanelle in the roof of the otoccipital. However, we find that the palatoquadrate, hyomandibular and braincase have been subtly disarticulated from each other in Jarvik’s reconstructions, in ways that obscure the precise functional relationships between these structures. This is probably due to their having been modelled individually in wax, and only then repositioned into (approximate) life positions with the help of metal armatures. Our CT-based skull model thus allows us to take a fresh look at the cranial mechanics of *Eusthenopteron*, and to more accurately infer the position of unpreserved but important structures such as the spiracular cleft.

Jarvik, E. 1980. *Basic structure and evolution of vertebrates, Volume 1.* Academic Press, London.

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Biomechanics, evolution and ecomorphology of Late Devonian arthrodires from the Gogo Formation of western Australia

Arthrodires (and placoderms in general) show a great deal of morphological diversity by the Late Devonian. Much of this diversity is seen in the skull and jaws, indicating a variety of possible feeding niches, from durophagous bottom dwellers to piscivorous cruisers. Current phylogenies place the Placodermi as sister-group to all other gnathostomes. The organization and function of placoderm feeding systems is vital to understanding early jaw evolution. The goal of this study is to understand the relationship of Late Devonian arthrodire skull diversity to ecology and feeding ability.

Functionally relevant morphological and mechanical data were collected from nine placoderms from the Gogo Formation, western Australia. These skulls were analyzed using a dynamic computer model based on linkage mechanics that calculates skull kinetics and mechanical feeding metrics in fossil vertebrates. This model has previously produced original results for a North American species, *Dunkleosteus terreli*. Here it is used to compare several arthrodire species to each other and to modern groups. Results reveal a range of kinematic transfer coefficients (KT) and mechanical advantage values. Arthrodire KT values (3.2-3.4) are generally higher then a subset of modern labrid oral linkages (0.45-1.5), but near the high end of the range of hyoid linkages (0.07-4.7), indicating that they may have utilized suction. The high range of mechanical advantage measurements (0.1-0.68) indicates a great deal of diversity in feeding ability. Such results lend strong support to the possibility of obtaining quantified

hypotheses of ecological diversity within a phylogenetically remote, and long extinct basal gnathostome taxon.

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Lizard teeth and the role of shape, wear and corrosion in inferring diet and habitat

Lizard teeth share many structural and ontogenetic features with other vertebrates. The primitive condition is pleurodonty, where the teeth are attached to the inner surfaces of the jaw bones and are regularly replaced. Teeth develop from crown to root, and enamel has a complexly sculptured surface while it is being laid down that is occasionally retained. Much of the internal tissue of the tooth is resorbed before it is shed. Acrodonty, where teeth are firmly attached to the crest of the jaws and replacement is greatly reduced, has evolved at least twice.

Crown shapes vary and sometimes show a strong correlation with particular dietary components, so they can potentially be used to infer them. For example, plant eaters and forms that eat hard prey both often have characteristic tooth morphologies. Patterns of wear are also informative about diet and sometimes habitat as well. In herbivores, phytoliths and other abrasive plant components may produce characteristic scratching, and excavations at the bases of their teeth may result from dental caries, perhaps promoted by sugars in the diet. Ant-feeders sometimes show pitting of the enamel surface, probably caused by the formic acid their prey contains. Some wear patterns can be mimicked by simple experimental procedures.

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Island monophyly and the tenrecs of Madagascar

All of the four major radiations of terrestrial mammals on Madagascar (primates, carnivorans, rodents and insectivorans) are very diverse yet, with few exceptions, DNA sequence data support monophyly of the island representatives of each order. Malagasy insectivorans are composed primarily of the Tenrecidae, a diverse group consisting of ca. 20 species in 8 genera. Based in part on a new technique for extracting information from museum specimens, and on a morphological dataset that samples fossils, this presentation addresses whether or not the pattern of island monophyly best describes the radiation of Malagasy tenrecs relative to their African mainland relatives. A case has been made using morphological data that semi-aquatic Malagasy and mainland African tenrecs form a clade with each other to the exclusion of other tenrecs. This relationship is not supported by sequence data, or by a combined morphology-DNA dataset. Also addressed is the quality and quantity of the morphological data necessary to have confidence in phylogenetic hypotheses of fossil tenrecs.

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Faunal turnover of Neogene mammals from Pakistan

Neogene Siwalik deposits of northern Pakistan span much of the Neogene and document local and global environmental changes in fluvial sediments and vertebrate faunas. Fieldwork since 1975 has documented over 1000 fossil localities and 50,000 fossil specimens. While fossils represent a broad range of terrestrial and freshwater vertebrates, mammalian remains dominate the record. Episodes of immigration signify changing intercontinental connections. Late Miocene changes in vegetation and

mammalian faunas indicate climatic change toward greater seasonal aridity, documented by stable carbon isotopes in palaeosols and mammalian enamel.

This setting is ideal for testing models of biotic turnover. For the late Miocene interval of climatic change, changes in mammalian faunas (appearances, disappearances, and ecophenotypic and evolutionary changes within lineages) were analyzed in relation to two models of turnover. The first model emphasizes habitat fidelity and environmental sorting of species according to their habitat preferences. This model predicts a replacement of resident species with immigrant species adapted to more arid vegetation. The second model emphasizes demographic properties: species with larger populations and geographical ranges should persist longer and *vice versa*. This model predicts persistence of dominant resident species through the interval of vegetation change and dietary accommodation to arid vegetation. Evolutionary changes in dietary adaptations are also expected.

We evaluated these models with data about biostratigraphic ranges, stable-isotopic composition and microwear of mammalian teeth, and relative abundance of 40 species from the Siwalik sequence between 10.7 and 5.7 Ma. While some predictions of both models are upheld, the model of environmental sorting is a better fit to the Siwalik record.

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Small ornithischian dinosaurs from the Middle Jurassic of China: a re-appraisal

Three genera of small ornithischian dinosaurs have been described from the Lower Shaximiao Formation (Middle Jurassic: ?Bajocian) of Dashanpu, Sichuan Province, People's Republic of China: *Yandusaurus multidens*, *Xiaosaurus dashanpensis* and *Agilisaurus louderbacki*. The taxonomy of these animals is extremely confused: numerous conflicting opinions exist regarding the validity of each species and the possible synonymies that might exist between them and other ornithischian taxa from China and elsewhere. Re-examination of the relevant material demonstrates that all three of the small ornithischians from Dashanpu represent valid taxa, each of which can be adequately diagnosed. In addition, these species can be distinguished from each other by many craniodental and postcranial character states. We show that '*Yandusaurus*' *multidens* is not congeneric with either *Y. hongheensis* or any other taxon, and therefore propose a new generic name for the reception of the species *multidens*. Consideration of the character states present in '*Yandusaurus*' *multidens*, *Agilisaurus* and *Xiaosaurus* shows that these taxa are not primitive euornithopods ('hypsilophodontids'), as had been suggested by most previous authors, but represent more basal ornithischians. '*Yandusaurus*' *multidens* and *Agilisaurus* can be regarded as Genasaura *incertae sedis*, whereas *Xiaosaurus* can only be recognised as Ornithischia *incertae sedis* on the basis of current data.

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The first comprehensive family-level supertree of extant placental mammals

Supertrees represent a relatively new and controversial method of phylogenetic reconstruction. By combining existing phylogenetic tree topologies ('source trees'), which can be based on any type of data, the supertree approach allows the creation of accurate, fully comprehensive phylogenies of large clades of organisms both quickly and efficiently. However, recent studies have highlighted the vulnerability of supertrees to the inclusion of poor quality or duplicated data, and some have questioned the utility of the

supertree approach as a whole (Gatesy *et al*., 2002). We show that application of an explicit protocol for source tree collection (specifically intended to exclude poor source trees; Bininda-Emonds *et al*., 2004) can result in supertrees that accurately reflect current phylogenetic evidence. We have used this protocol and a novel variant of Matrix Representation with Parsimony (MRP) to produce a family-level supertree of placental mammals, based on 725 source trees from 430 references. This phylogeny is the first to include all 113 extant families, as well as two recently extinct families – Nesophontidae and Plesiorycteropodidae – whose relationships remain obscure. The supertree is highly congruent with recent phylogenetic analyses, but is considerably more comprehensive. In agreement with most current evidence (Springer *et al*., 2004), the orders Lipotyphla and Artiodactyla are recovered as non-monophyletic, and extant placentals comprise four superorders, the origins of which may be connected with tectonic plate movements. Morphological convergence between these superorders is rife. Preliminary work suggests that other supertree methods support a largely identical topology. We suggest that the supertree topology presented here is suitable for use in studies that require a comprehensive higher-level placental phylogeny.

Bininda-Emonds, O.R.P., Jones, K.E., Price, S.A., Cardillo, M., Grenyer, R., & Purvis, A. 2004. Garbage in, garbage out: data issues in supertree construction. Pp. 267-280 in *Phylogenetic supertrees: combining information to reveal the tree of life*, O.R.P. Bininda-Emonds (ed.). Kluwer Academic, Dordrecht.

Gatesy, J., Matthee, C., DeSalle, R. & Hayashi, C. 2002. Resolution of a supertree/supermatrix paradox. *Systematic Biology* 51: 652-664.

Springer, M. S., Stanhope, M.J., Madsen, O. & de Jong, W.W. 2004. Molecules consolidate the placental mammal tree. *Trends in Ecology & Evolution* 19: 430-438.

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The discovery pattern of dinosaurs ... and how many more species are to be found?

Dinosaurs have been named since 1824, and the rate of naming of new taxa followed a sigmoid curve until 1980. After that point there has been an explosive growth of new names. Synonymy rates, however, are enormous. Compared to 'normal' synonymy rates of about 20%, at least half of named dinosaurian species are synonyms, and there is no sign that this rate of erroneous (?over-enthusiastic) naming has slowed. A new modelling approach uses such historical data to estimate the total number of valid dinosaurian species preserved in the rocks (which may or may not correspond to the total number that ever lived).

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A new genus and species of primitive wombat from the Riversleigh World Heritage Property in northwestern Queensland, Australia

This paper describes a new genus and species of primitive wombat from the Riversleigh World Heritage Property in northwestern Queensland. This taxon is found at two sites within the World Heritage Property, both of which are estimated to be early or middle Miocene in age. The description of this new taxon is based on two partial maxillae as well as isolated incisors and molars, and represents the smallest described wombat to-date.

Previously, the early evolutionary record of wombats prior to the late Miocene was known from a single described tooth of *Rhizophascolonus crowcrofti* from the Oligo-Miocene of central Australia. This

new taxon is therefore critical to an understanding of the early evolution of this family. The dentition displays the primitive condition of rooted molars and premolars with much of the cusp detail retained in at least the early stages of wear. Details of the dentition of this taxon along with that of the late Miocene to Recent taxon *Warendja*, suggest a trend towards the modification of a two-phase power stroke to that of a single transverse movement of the jaw in modern wombats.

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Ontogeny and homology of the clavus of the Ocean Sunfishes (Molidae, Teleostei)

The Ocean Sunfishes, family Molidae, include the most massive and some of the most bizarre of the teleost fishes. The most conspicuous character of the Ocean Sunfishes is the punctuation of the body by a deep, abbreviated, caudal fin-like structure extending vertically between the posterior ends of the dorsal and anal fins, termed the clavus by Fraser Brunner. Homology of the clavus has been a matter of debate since the first studies on molid anatomy in the early 1800's. Two hypotheses have been proposed: i) it is a highly modified caudal fin; ii) it is formed by highly modified elements of the dorsal and anal fins. To resolve this homology issue, we studied the ontogeny of the molid vertebral column and median fins and compared it to that of a less morphologically derived gymnodont, a member of the family Tetraodontidae. We show that in molids the chorda never flexes during development, that the claval rays form from the posterior ends of the dorsal and anal fins toward the middle thus closing the gap inward, and that elements of the molid clavus have an identical development and composition as the proximal-middle and distal radials of the regular dorsal and anal fins. We thus conclude that the molid clavus is unequivocally formed by modified elements of the dorsal and anal fin and that the caudal fin has been lost in molids.

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The dinosaur assemblage from the Khok Kruat Formation of Thailand: continuity and change in the Early Cretaceous of Southeast Asia

Recent discoveries in northeastern Thailand are providing a better picture of the dinosaur assemblage from the Khok Kruat Formation (dated as Aptian on the basis of sharks and palynomorphs). Some elements are reminiscent of the better-known fauna from the older Sao Khua Formation; they include a *Phuwiangosaurus*-like sauropod and a spinosaur (probably *Siamosaurus*). Broad-toothed sauropods, which are known from the Sao Khua Formation, have not been found in the Khok Kruat Formation. Dinosaurs present in the Khok Kruat Formation but so far absent from the Sao Khua Formation include *Psittacosaurus* and an advanced iguanodontian reminiscent of *Altirhinus*. The Khok Kruat assemblage, which also occurs in Laos, may be the result of a dispersal event introducing into Southeast Asia faunal elements that apparently were not present there during earlier stages of the Cretaceous.

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The phylogeny and evolutionary history of the ornithischian dinosaurs

Ornithischia is a hugely diverse, abundant, and important clade of dinosaurs. Yet a full understanding of ornithischian evolution is hampered by an absence of rigorously tested global phylogenies for the clade. In order to reassess prevailing views of ornithischian phylogeny and evolution a 'total-evidence' approach was taken. Nine higher-level and 42 species-level taxa were selected, representing all known valid ornithischians. The validity of all previously utilised characters was assessed, and direct examination of taxa allowed the identification of further characters. Data was analysed using a range of techniques including safe taxonomic reduction, reduced consensus methods and various measures of support.

The general structure of ornithischian phylogeny is supported; however, positions of certain taxa differ significantly from previous analyses. Heterodontosauridae forms the sister group to Genasaura and may represent the basalmost ornithischians known, a position concordant with stratigraphy. Strong evidence supports hypsilophodontid paraphyly, with some Middle Jurassic taxa (*Agilisaurus* and '*Yandusaurus*' *multidens*) appearing as sister-taxa to Cerapoda (Marginocephalia + Ornithopoda).

Far greater congruence with stratigraphy is present than in previous phylogenetic hypotheses, suggesting that the early ornithischian record may be better than generally believed. New time-constraints are placed on evolutionary events. For example, previous hypotheses require a Late Triassic date for the Ornithopoda-Marginocephalia split; this phylogeny predicts a Middle - Late Jurassic date for the same event, obviating the need for an extensive marginocephalian ghost-range. This analysis highlights both the necessity of rigorously testing the ornithischian tree and the areas in which efforts should be concentrated.

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Sabertooth characters in the clouded leopard

The extant clouded leopard (*Neofelis nebulosa*) has long been regarded as an unusual, small (~ 15-25 kg) pantherine and has caused problems in analyses of functional skull morphology and phylogeny. Little is known of its ecology in the wild. Although famous for its hypertrophied canines, it is, nonetheless, universally regarded as an unusual conical-toothed pantherine, with no morphological affinity to extinct sabertoothed machairodontines. However, a whole suite of characters accompany the evolution of a sabertooth morphology, and these have appeared convergently at least five times in the Tertiary in widely different groups, such as borhyaenid marsupials, creodonts, nimravids and felids. No previous studies have analysed these features in the clouded leopard and they have also been assumed to be absent in all extant felids. However, the clouded leopard is found to possess a whole suite of skull features, formerly assumed to be present exclusively in sabertooth predators, including the marked anterior angulation of the facial region, narrowed zygomatic arches, lowered jaw joint and differences in the muscle mechanics of the posterior jaw adductors. The clouded leopard differs from any extant form and may constitute a third extant felid ecomorph (the others being the cheetah, *Acinonyx jubatus*, and a general pantherine ecomorph). Data on its ecology in the wild are urgently required and scholars studying sabertooth functional morphology should pay closer attention to the clouded leopard, rather than the large pantherines.

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Gladbachus adentatus Heidtke & Kratschmer: an awkward addition to the set of early jawed fishes

Gladbachus adentatus, from the Middle Devonian of southern Germany (Bergisch Gladbach), is probably the most complete of only four early-to-mid Devonian sharks known from body fossils. The single specimen consists of the dorsoventrally flattened forequarters of a reasonably well articulated fish, including the braincase, jaws, hyoid and gill arches, and anterior vertebral column. Large areas of squamation are intact, but the paired and median fins are largely absent. The challenge of this material is whether it really represents a chondrichthyan, because many of the classic, defining, specialisations of the group are missing: fin spines, simple placoid scales, replacement tooth series, and calcified cartilage with a diagnostic, prismatic structure. Consequently, support for a relationship to crown-group chondrichthyans is weak, but remains consistent with a stem-group position. If this is correct, then *Gladbachus* delivers a new glimpse of diversity preceding the root of holocephalan (chimaeroid) and elasmobranch lineages, differing sharply from that of standard models for primitive chondrichthyans, such as '*Ctenacanthus*' and *Cladoselache*. The full consequences of this have yet to be explored, but it is already apparent that these new data are incompatible with current scenarios of chondrichthyan jaw evolution, and recently postulated similarities between early chondrichthyan and osteichthyan neurocrania.

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Clash of the titan(osaur)s – investigating sauropod phylogeny

Ever larger sauropod phylogenies have been produced, bringing with them the promise of better resolution and support. However, despite increases in numbers of taxa and characters, and datasets being merged to varying degrees, there is still much topological conflict. There are a number of possible reasons for such conflict, including; choice and interpretation of characters; choice of taxa; interpretation of homoplasy; amount of missing data; various forms of error. A comparison of the two most taxonomically complete sauropod phylogenies (Wilson, 2002; Upchurch *et al.*, 2004) revealed that all of these problems are present to varying degrees.

The way in which, and the degree to which, each of the causes of conflict influences phylogeny topology is largely unknown. The goal of this study was to use the debate over sauropod relationships as a case study in the comparison of differing morphological phylogenetic analyses. The principle aims were: quantification of the degree of congruence and conflict between the two phylogenies; assessment of the causes of topological conflict and discussion of how such problems may be resolved; and evaluation of the strategies available to the morphological phylogeneticist for data analysis and conflict investigation, leading to methodological recommendations.

Results show that each of the phylogenetic hypotheses examined has topological areas that are well supported and others that are poorly supported. A new phylogenetic hypothesis for the relationships of sauropod dinosaurs is presented. Although the taxonomic focus is on the phylogeny of the Sauropoda, many of the issues detailed are of wider concern in morphological phylogenetics.

Wilson, J.A. 2002. Sauropod dinosaur phylogeny: critique and cladistic analysis. *Zoological Journal of the Linnean Society* **136**: 217-276.

Upchurch, P., Barrett, P. M. & Dodson, P. 2004. Sauropoda. Pp. 259-322 in *The Dinosauria, Second Edition*, D.B. Weishampel, P. Dodson & H. Osmólska (eds.). University of California Press, Berkeley.

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Structure of the mammalian orbit: correlations with masticatory musculature

The mammalian orbit, or eye-socket, is a highly plastic region of the skull. It comprises between seven and nine bones, all of which vary widely in their contribution to this region between the different mammalian orders and families. Yet, despite this plasticity, relatively little research has concentrated on the orbital region. It is hypothesised that the structure of the mammalian orbit is principally influenced by the forces generated by the jaw-closing musculature. In order to quantify the orbit, fourteen linear, angular and area measurements were taken from 84 species of placental mammals using a Microscribe-3D digitiser. The results were then analysed using Principal Components Analysis. The results of the multivariate analysis on untransformed data showed a clear division of the mammalian taxa into temporalis-dominant forms and masseter-dominant forms. This correlation between orbital structure and masticatory musculature was reinforced by the results from the data transformed with respect to skull length, which showed a separation of the taxa into the three specialised feeding types as proposed by Turnbull (1970): i.e., 'carnivore-shear', 'ungulate-grinding' and 'rodent-gnawing'. Moreover, within the rodents, there was a clear distinction between species in which the masseter is highly developed and those in which the temporalis has more prominence. These results give a strong indication that, although orbital structure is in part determined by the relative size and orientation of the orbits, the forces generated by the muscles of mastication also have a large effect.

Turnbull, W.D. 1970. Mammalian masticatory apparatus. *Fieldiana (Geology)* **18**:147-356.

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New vertebrate records from the Late Cretaceous of Kazakhstan

For the last three summers, we have undertaken exploratory fieldwork in the Aral Sea region of northeastern Kazakhstan searching for dinosaurs and other fossil vertebrates. This region of Central Asia remains largely unexplored, although limited details of the geology and palaeontology of the lower Syr-Dar'ya Uplift are available.

In addition to skeletal remains, we have mapped and recovered abundant vertebrate microfossils from a series of horizons within the Late Cretaceous (Turonian–Campanian) Bostobynskaya Formation (Bostobynskaya Svita). Microfossil remains display taphonomic characteristics consistent with their deposition within floodplain-hosted assemblages and allow us to make initial estimates of the Bostobynskaya faunal composition. Teeth collected from these horizons confirm the presence of theropods, hadrosaurs and sauropods in the formation, consistent with previous suggestions of the dinosaur fauna. Compositional analysis of microfossil collections show that the material is characterised by low weathering and abrasion states, a high diversity of small fossils that represent aquatic, semi-aquatic and terrestrial taxa, and an abundance of resistant bioclasts, such as teeth. The sedimentology of the Bostobynskaya Formation is dominated by crevasse-splay and floodplain facies. New records from these sites document an important Late Cretaceous vertebrate fauna in an equally important and much understudied part of Central Asia.

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Olseniidae – a new ungulate family from Central Asia

A new ungulate mammal family Olseniidae is proposed. The definition of this family is based on fossil material, which was excavated during two field campaigns of the Martin-Luther-University to the Eocene Toru Ajgyr locality, Kyrgyzstan in 1997 and 1998. A nearly complete foot was discovered, which corresponds to an astragalus of *Olsenia mira* from the Eocene Shara Murun locality, northern China. The new Kyrgyz form cf. *Olsenia* sp. is an early ungulate that combines characteristics of mesonychids, perissodactyls and artiodactyls: tetradactyl and paraxonic foot; terminal phalanges claw-like, but not fissured; astragalus with shallow proximal caput and without distal trochlea. This unique character set fills a gap in the fossil record and gives insights into ungulate phylogeny, which is still not completely understood.

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An Early Cretaceous lizard assemblage from Japan

Asia boasts the greatest known diversity of Late Cretaceous lizards, but tracing the history of this radiation has been complicated by a paucity of earlier data. New work on Barremian-Albian localities in China, Mongolia and Central Asia is filling the gaps, but many questions remain. The Early Cretaceous (Valanginian-Hauterivian) Tetori Group of central Japan has yielded a diverse assemblage of small vertebrates including fish, amphibians, reptiles, birds and mammals. The most prolific locality is that of Kaseki-Kabe, Hakusan City, Ishikawa Prefecture. It has produced at least six lizard taxa, with several associated specimens. The largest and most common is a long-bodied swimmer with anguimorph affinities. The second is a specialised herbivore with teeth resembling those of the living *Iguana*. New material of *Sakurasaurus*, originally described from Gifu Prefecture, adds important new data. A new phylogenetic analysis suggests a relationship with the Chinese (Yixian Formation) lizard *Yabeinosaurus*. The remaining Kuwajima lizards include two new scincomorphs and a very fragmentary possible gekkotan. Rectangular osteoderms closely similar to those of the Jurassic/ Cretaceous scincoid paramacellodids are common in the Kuwajima rocks and probably pertain to one of the scincomorphs, but they have yet to be found in association.

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The flying beams – what biomechanics tells us about pterosaur evolution

Investigation of the biomechanics of organismic structures yields important information for understanding evolutionary processes. In the present study, pterosaur skulls were analysed using a combined approach via finite element analysis, static investigations and application of classical beam theory. Comparison of the biomechanical behaviour of the different skull constructions present in pterosaurs results in major evolutionary transformations: elongation of rostra; inclination of the occipital region; variation in tooth morphology; reduction of the dentition and replacement of teeth by a keratinous hook or rhamphotheca; fusion of nares and antorbital fenestra; and the development of bony and soft-tissue crests. These transformational processes are discussed for their biomechanical effects biting. They are

interpreted in the light of greater feeding efficiency and reduction of bony mass combined with an increased stability against bending, shear and torsional loads. As a consequence, certain feeding options are assigned to the different skull constructions, and previous hypotheses (e.g., skimming) can be verified.

Using the principle of economisation, these processes help to define evolutionary pathways that can be used for comparison and verification of recent hypothesis of pterosaur phylogenetic systematics.

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Kuehneotherium: unexpected taxonomic diversity in the Early Jurassic fissure fills of South Wales

Kuehneotherium is one of the oldest of the "symmetrodontans", a grouping of primitive mammals characterized by the possession of a reversed-triangle molar pattern. In spite of its importance to early mammalian phylogeny, *Kuehneotherium* has proved difficult to interpret, due to the fragmentary nature of the material.

A reconstruction of the dentition is now given and the phylogenetic position of *Kuehneotherium* is re-examined. A number of features are also described which suggest that diphyodonty had been only recently established.

The Early Jurassic fissure fills of South Wales reveal previously unexpected taxonomic diversity in the kuehneotheriids, including two new species of *Kuehneotherium*. There are also a number of interesting teeth with plesiomorphic characters and the relationship of this kuehneotheriid with *Kuehneotherium* is discussed.

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Morphological integration, modularity, and the evolution of the mammalian skull

Associations among functionally or ontogenetically-related traits may be a major influence on morphological evolution. The study of morphological integration, via quantitative analyses of trait correlations, allows for investigation of broad patterns of trait associations, with data that are comparable to developmental and quantitative genetic studies. I present analyses of cranial integration for 108 species of extant and fossil mammals, including monotremes, marsupials and placentals. 3D data were gathered for 59 landmarks to assess cranial modularity and the relationship of integration to several influences on cranial morphology: phylogeny, diet, encephalisation and heterochrony.

All large clades display a strong correlation between similarity of integration and phylogeny, while diet's influence on integration is generally restricted to less-inclusive clades. Cranial modularity is conserved across therian mammals, with six discrete groups of traits. The anterior oral/nasal, molar and basicranial groups are strongly integrated, while the orbit and zygomatic/pterygoid groups are weakly integrated, probably reflecting differences in developmental complexity. The integration of the cranial vault is variable across taxa, but it is not significantly correlated with encephalisation. Monotremes display only two modules (anterior oral/nasal and basicranium), with little correlation among other landmarks, demonstrating that cranial modularity has been modified during mammalian evolution.

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Progress in the morphology and systematics of rauisuchian archosaurian reptiles

Rauisuchia is a large group of Triassic crocodilian-line archosaurian reptiles. Rauisuchian systematics is highly confused and contentious, so that it is a matter of debate whether the group is mono-, para- or polyphyletic. The unsatisfactory state of rauisuchian systematics is rooted in inadequate low-level taxonomy, and a lack of detailed morphological documentation. Recent work has made progress in describing new taxa, revising previous material, and cautiously proposing precise phylogenetic hypotheses. A summary of recent and ongoing morphological and phylogenetic work is presented, with particular attention paid to *Arizonasaurus* and *Batrachotomus*, and new data on crocodilian-line archosaur braincase anatomy. This recent work indicates that rauisuchians are polyphyletic, and that early crocodilian-line archosaurs were more diverse than previously recognised.

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Reconstructions of the cranial musculature in Liassic elasmosauroids

Reconstructions of the cranial musculature of extinct animals are a means of learning more about the characteristic feeding adaptations of individual species. Through comparison with modern taxa the feeding behaviour can be deduced, which largely increases our understanding of their way of life. Muscle reconstructions of extinct animals like plesiosaurs, who do not have a living relative or analogy, are more difficult, but still help towards creating more complete reconstructions of these animals and how they were adapted to their environment. So far, only the cranial musculature of some pliosauroid species have been reconstructed. In this talk, the first reconstruction of a plesiosauroid, namely the German *Seeleyosaurus guilelmiimperatoris* from the Toarcian Posidonian shale is presented. Based on skull reconstructions and preserved muscle scars the different cranial muscles are reconstructed and the operational mode of the jaw is explained. The differences and similarities to the pliosauroids and the implications for feeding adaptations are discussed.

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The affinities of the insectivorous mammal *Butselia*

Butselia biveri was first described on isolated molars from the Belgian early Oligocene site of Hoogbutsel. The monotypic genus was subsequently discovered in similar-aged strata in the Isle of Wight, UK. Quinet & Misonne (1965) placed *Butselia* in its own family in Gill's (1885) insectivoran suborder Zalambdodonta (tenrecs and golden moles), because its molars are semi-zalambdodont. Butler (1972) instead allied it with *Plesiosorex* (extinct lipotyphlan family Plesiosoricidae). Apart from European *Butselia*, all other pre-late Oligocene family members are Asian, the earliest, according to McKenna & Bell's (1997) classification, being *Ernosorex* and *Pakilestes* from the early to middle Eocene. The occurrences of *Butselia* then slightly post-dated an important faunal turnover, the 'Grande Coupure', when many taxa from Asia had dispersed into Europe. Therefore, stratigraphical position was consistent with an Asian origin for *Butselia* as a plesiosoricid.

Two new finds impact on the relationships of *Butselia*. One is a tooth of the genus in Isle of Wight strata predating the 'Grande Coupure', suggesting European not Asian roots. The other is an isolated

astragalus judged to belong to *Butselia*. This astragalus is unlike any lipotyphlan and, whereas plesiosoricid postcranials are unknown, it suggests either that the Plesiosoricidae are not lipotyphlans or that *Butselia* is not a plesiosoricid.

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Geometric morphometric analysis of the skull in Rhynchocephalia (Diapsida: Lepidosauria)

Rhynchocephalians were globally distributed during the early Mesozoic, but the living *Sphenodon* (the Tuatara) is restricted to New Zealand off-shore islands. Traditionally, Rhynchocephalia were considered morphologically uniform, but new research has revealed two independent aquatic radiations, differences in body proportions, novel cranial architecture, and a wide range of tooth morphologies. Basal taxa undergo a transition from simple pleurodont teeth towards larger acrodont teeth, probably representing a shift in primary jaw function from prey capture toward prey reduction. Derived taxa possessed more complex teeth, powerful bites, and sophisticated shearing mechanisms: orthal (e.g., *Clevosaurus*) or propalinal (e.g., *Sphenodon*). This diversity in feeding apparatus prompted the idea that lepidosaurian skulls exhibit a trend towards accessing larger food items: squamates use skull kinesis whereas rhynchocephalians reduced food items using harder bites. Rhynchocephalian skull shape was analysed using geometric morphometrics. This identifies associated shape differences in landmark constellations. Changes in cranial structure can subsequently be illustrated using thin plate spline deformation grids. Outgroup comparison demonstrates that rhynchocephalian clades exhibit differences in skull proportions and jaw joint position. Modifications in both of these features are closely associated with increased biting performance, indicating that acquisition of tougher food items was of major importance to rhynchocephalian skull evolution.

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Early Cretaceous high-latitude marine reptile assemblages from Australia

The Lower Cretaceous (Aptian-Albian) southern high-latitude deposits of Australia have yielded a diverse range of marine reptile fossils. Identifiable taxa include the ubiquitous Cretaceous ichthyosaur *Platypterygius*, and at least five distinct kinds of plesiosaur – a new *Leptocleidus*-like pliosauroid, the large pliosaurid *Kronosaurus*, indeterminate elasmosaurids, polycotylids, and a new genus and species of cryptocleidoid. Notably, the polycotylid material is amongst the oldest from anywhere in the world and might suggest a Southern Hemisphere origin for the group. The fossils are derived primarily from the lower Aptian to lower Albian Bulldog Shale and Wallumbilla Formation. These units are famous for producing opal and represent shallow epicontinental marine environments. Isolated plesiosaur (indeterminate pliosauroid) remains have also been recovered from high-latitude non-marine strata of the Wonthaggi, Eumeralla and Griman Creek formations. These deposits are early Aptian to middle Albian in age and

comprise fluviatile/estuarine sediments laid down in inland rift valleys and coastal flood plains near the Cretaceous southern polar circle. Estimates of palaeolatitude place most of southern Australia at around 60 to 85° South during the late Early Cretaceous. Sedimentary structures (including glacial erratics, glendonites, cryoturbated terrestrial sediments and growth-banded wood), fossils, isotope data and climatic modelling indicate highly seasonal cool-cold conditions (possibly with winter freezing). This contrasts markedly with climate regimes typically tolerated by modern aquatic reptiles, but suggests that some Mesozoic forms might have possessed adaptations (e.g., elevated metabolic levels and/or annual migration) to cope with low average water temperatures.

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Tooth root form and dietary specialisation in carnivores

Research into dietary adaptations of teeth has largely focused on crown structure but little is known about subocclusal morphology. Here I present a study on tooth root morphology and size in selected carnivore species with distinct diets and feeding behaviour. I explore the hypothesis that root attachment area is closely linked to dietary specialisation. The maxillary and mandibular dentitions of six species (*Canis familiaris*, *Panthera pardus*, *Crocuta crocuta*, *Ursus americanus*, *Ailuropoda melanoleuca* and *Phoca vitulina*) were scanned using computed tomography and reconstructed using three-dimensional image processing. The results showed that the magnitude of root surface area in all species strongly depends on the feeding behaviour and occlusal forces irrespective of feeding category. Species which engage in the mastication of tough foods such as the herbivorous giant panda *Ailuropoda melanoleuca* and the osteophagous spotted hyaena *Crocuta crocuta* exhibit postcanine roots with the relatively largest surface area when corrected for craniofacial size. In contrast, those species that feed on a soft diet like the common seal *Phoca vitulina* bear small roots with less attachment area. Moreover, the size and the distribution of root surface area along the tooth row seem to be strongly related to other structures of the masticatory apparatus such as temporomandibular joint morphology. Further investigation of tooth root morphology may offer a valuable contribution to the reconstruction of feeding behaviour and diets of other related extant and extinct taxa.

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New records of fossil birds from the Early Eocene Fur Formation, Denmark

Previous studies of the earliest Eocene (Ypresian) Fur Formation of Denmark have revealed a diverse fossil avian fauna. Among them are a number of articulated, three-dimensionally preserved skeletons, which represent some of the best and earliest fossil remains of anatomically modern birds (Neornithes). Situated immediately after the Palaeocene-Eocene extinction event, these fossils will provide important insights on the diversification and evolution of modern birds during the Palaeogene. Also, incorporation of these well-preserved fossils into phylogenetic analyses will provide an important key to the interrelationships within and between clades of modern birds. However, until now the fossil specimens remain largely unpublished.

The Fur Formation is chiefly a diatomite deposited in a subtropical sea with dysoxic to anoxic oxygen bottom conditions. This has resulted in other remarkable states of fossil preservation; fossilisation of soft tissue structures, such as imprints of the scales of the leg or carbonised imprints of feathers are not

uncommon. Among the previously unpublished fossil material from the Fur Formation is an articulated charadriiform (shorebird), which is the geologically oldest well-preserved fossil representative of the order. A preliminary cladistic analysis indicates that the specimen is closely related to modern gulls (Laridae: Larini), and it will be used to shed further light on the interrelationships and evolution of the order Charadriiformes.

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Problems of statistically recovering tetrapod extinction events (Late Permian – Early Jurassic)

There is a wealth of evidence that terrestrial vertebrates were affected by mass extinction events during the Permo-Triassic (at the end-Permian, end-Carnian and end-Triassic). However, statistically speaking, these results are sometimes hard to demonstrate. Two datasets, one of 814 genera and the other of 208 families, were compiled from the literature and each taxon assigned to categories of body size, diet, habitat and geographic range. Traditional metrics of diversity, extinction and origination failed to recover evidence of mass extinction. However, where stage-crossing taxa were considered in isolation the two major events (end-Permian and end-Triassic) become more prominent. Chi-square tests compared pre- and post-extinction faunas with the end-Permian and end-Carnian exhibiting significant ecological change. Jablonski's model of alternating macroevolutionary regimes is weakly supported, but not contradicted. Similarly, differences between events seem to support their contingency.

Further analysis of the datasets included Pearson chi-square tests of variable independence that show that the selected 'characters' are redundant due to rampant and significant association. Comparison between the datasets suggests neither the familial nor the generic level is the superior species-proxy in tetrapod evolution. Despite mostly negative ramifications for future research, potentially rewarding avenues are briefly discussed.

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The lumbar spine of *Gorilla gorilla, Pan troglodytes, Pongo pygmaeus* and *Homo sapiens sapiens* reflects differences in function rather than phylogenetic background or inter-specific differences in body weight

In this study, inter-specific patterns of differences in lumbar vertebral size and shape between *Gorilla gorilla, Pan troglodytes*, *Pongo pygmaeus* and *Homo sapiens* are explored and discussed in relation to inter-specific differences in locomotor repertories, body size and phylogenetic history. Geometric morphometric methods are employed to assess the high-dimensional complexity of the overall form of lumbar vertebrae and the lumbar spine as a whole. Results indicate that interspecific differences in vertebral size between great ape taxa have a relationship with interspecific differences in body size. However, differences in vertebral size between humans and great apes are related to interspecific differences in locomotor functions. With regards to hominoids as a whole, humans have the most different vertebral shape followed by *Pongo*, whereas the African apes are relatively similar to each other. Inter-specific differences in locomotor functions have a strong relationship with differences in vertebral shape but not with those in body size. Phylogeny does not have a strong relationship either with differences in vertebral size or shape between the hominoid taxa in the study. We conclude that in hominoids, lumbar vertebral size and shape are greatly influenced by the various highly specialized locomotor repertoires and loading patterns characteristic of each taxon. Understanding the range and patterning of morphological

variation in the extant hominoid taxa is essential in order to make valid functional and phylogenetic interpretations of fossil hominid skeletal material. Thus, these conclusions add valuable insights relevant to the interpretation of fossil hominid vertebral material in relation to locomotor functions.

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The Purbeckian crocodilians from Cherves-De-Cognac (Berriasian, southwestern France)

The site of Cherves-de-Cognac yields a diversified fauna, which includes all the groups of vertebrates: Osteichthyes, Chondrichthyes, Amphibia, Reptilia (Lepidosauromorpha, Testudines, Crocodylia, Dinosauria), Aves and Mammalia, with hundreds of macro-remains and thousands micro-remains. Crocodilians are particularly common, with four families represented by at least seven species. The medium to large-sized *Goniopholis* is the most abundant crocodilian, with 11 skulls and numerous post-cranial elements, referable to *G. simus* and *G. crassidens*. The longirostral *Pholidosaurus* is rarer, represented by two complete skulls and numerous isolated teeth, referable to *P. purbeckensis*. *Bernissartia fagesii* is very common with abundant isolated teeth. A small-toothed mandible can be attributed to a new Bernissartiidae. The Atoposauridae are common with four sub-complete specimens and numerous isolated teeth referable to *Theriosuchus pusillus*, but also with numerous and strange folded teeth, which could represent a new *Theriosuchus* species.

This crocodilian assemblage is deposited in a deltaic environment, contemporaneous to the Middle Purbeck Beds of Dorset. The quantitative study of the vertebrate assemblage shows that these crocodilians were inland dwellers, except maybe *Goniopholis*, which could have been a brackish-water dweller. This crocodilian community exploited diverse trophic resources, with the opportunistic *Goniopholis*, the ichthyophagous *Pholidosaurus*, the crushing Bernissartiidae and the dwarf "micropredator" Atoposauridae.

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Stegops, a problematic spiky-headed temnospondyl

The spiky-headed temnospondyl amphibian *Stegops divaricata* from the Middle Pennsylvanian coal of Linton, Ohio has remained neglected and enigmatic for several decades. It has been argued to be the ancestor of the Permian Zatrachydidae, also spiky-headed temnospondyls, although there are few resemblances other than the spikes. An examination of previously undescribed material of *Stegops*, along with a re-evaluation of the original specimens, permits a redescription and partial systematic assignment of it. All specimens have bony spikes on the tabular, quadratojugal and angular, but in apparent dimorphism, only some have squamosal and supratemporal spikes. A phylogenetic analysis of 52 characters in 15 temnospondyl taxa places *Stegops* within the dissorophoid clade but leaves its position uncertain within that clade. The Zatrachydidae, represented by *Acanthostomatops*, fall outside the Dissorophoidea, and the zatrachydid affinities of *Stegops* asserted by previous workers are based on homoplasious similarities in ornamentation. Internal relationships of the Dissorophoidea remain unresolved and *Stegops* shares conflicting similarities with Amphibamidae in some resolutions and with an *Ecolsonia* + Dissorophidae + Trematopidae clade in others.

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Eotyrannus: extreme makeover

Eotyrannus lengi Hutt *et al*., 2001 is a coelurosaurian theropod from the Wessex Formation (Hauterivian-Barremian: Lower Cretaceous) of the Isle of Wight. New preparation and investigation have allowed the preliminary description to be substantially updated and *E. lengi* has proved more complete than initially reported. It seems that *E. lengi* was more aberrant than suspected, and in many details is highly apomorphic. However, cladistic analysis, incorporating information from new basal tyrannosauroids including *Dilong* and *Appalachiosaurus*, supports inclusion of *E. lengi* within Tyrannosauroidea.

Unfortunately, *E. lengi*'s skull is fragmentary, but newly recognised elements include a surangular and palatine. The premaxillary teeth are U-shaped; unfused interdental plates were present; and both the dentaries and nasals reveal newly recognised - and surprising - apomorphies. Cervical centra are pleurocoelous, unlike the caudal dorsal centra, but the probable first sacral vertebra was also pleurocoelous. Several caudal vertebrae are preserved. New information on the scapulae shows that their dorsal end was expanded. Both humeri are present, as are an incomplete radius and ulna and multiple manual elements. At least some of the manual digits can be reconstructed, and a partial metacarpus and well-preserved trochleated distal carpal also provide new information on forelimb structure and function.

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The effects of captivity on the morphology of mammals

The effects of captivity on the morphology of mammals is not well understood, yet it has important implications for any study of the anatomy of exotic creatures that are only readily available as zoo-derived specimens in museum collections. This paper concentrates on skeletal remains rather than soft tissues and will briefly discuss a number of relevant examples in the literature before presenting in detail two studies of big cat morphology. The first is the effects of captivity on the crania of lions (*Panthera leo*) and leopards (*Panthera pardus*), which has shown that there are morphometric differences between wild and captive animals. The second study is on cheetah (*Acinonyx jubatus*) postcrania, where radiography has been used to examine cortical bone thickness in wild, modern captive-bred and historical wild caught and subsequently captive samples. The implications of these studies will be discussed, both in terms of the light they shed on captivity related morphological changes, but also the wider implications for the study of comparative anatomy.

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Adaptive zones and the pinniped ankle: a 3D quantitative analysis of carnivoran tarsal evolution

The order Carnivora occupies many habitats, ranging from arboreal olingos to aquatic seals. Despite their diverse locomotor styles, carnivorans are often divided into terrestrial fissipeds and aquatic pinnipeds. Individual tarsals contain information about locomotor function. Interlocking facets indicate flexibility; lengths of processes reveal mechanical advantages. Extensive data document the association of form and function, but tarsal analysis has been anecdotal because these blocky bones are difficult to quantify. Consequently, a method for 3D surface analysis was devised. A flexible tube of points – similar to a fishnet stocking – was applied to the scanned 3D surface and analyzed using standard Procrustes

methods. Unlike ordinary geometric morphometrics, the results represent the complete bone, not an abstract representation.
The terrestrial locomotion of fissipeds was found to constrain their tarsal morphology. Fissipeds occupy a broad, distinct zone of morphospace from which pinnipeds departed. Mapping of calcaneal morphology onto independent phylogenetic trees shows that phylogeny has retraced paths across the zone many times, with only the pinniped branch escaping. But, the rate of evolution was no higher in pinnipeds, indicating that their derived morphology is not due to rapid evolution, but to evolution along a different trajectory. Abandoning terrestrial locomotion allowed transformations selectively prohibited in fissipeds.

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Mammals from Cherves-de-Cognac (Charente, France, Berriasian)

In the quarry of Cherves-de-Cognac (Charente, Southwest France) forty-four marly and calcareous levels are exposed. Dated from the Berriasian (Early Cretaceous), they are partly equivalent to the English Purbeck Limestone Group and reveal an evaporitic coastal environment evolving from lagoonal to deltaic conditions of deposition. Most of the levels yield an abundant and diversified microvertebrate fauna, reaching 40,000 teeth per ton in the richest stratum. All vertebrate groups are present: osteichthyans, chondrichthyans, amphibians, reptiles (turtles, crocodilians and dinosaurs), birds and mammals. Mammals are exclusively present in one bed at a rate of 40 teeth per ton. They represent 0.15% of the dental micro-remains, 0.37% of the amniotes and 38.5% of the strictly terrestrial ones. Furthermore, they are diversified, since from the 24 vertebrate families registered, four are mammalians: Triconodontidae, Spalacotheriidae, Dryolestidae and one family of multituberculates. The quantitative study of the biodiversity of Cherves-de-Cognac shows that these mammals constitute an important part of the ecological diversity.

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Baryonyx walkeri: functional crocodile, theropod or something else?

Spinosaurid theropods such as *Baryonyx walkeri* possess a cranium unlike any other archosaur, combining an elongated crocodilian-like snout and bony palate with a narrow yet tall domed skull complete with antorbital fenestration. Here we present a study of the functional morphology of the spinosaur cranium, with specific reference to the function of broad and tubular snouted extant crocodilians.

Simple Finite Element (FE) models of a broad, flat 'platyrostral' snout and a tall, domed 'oreinirostral' snout were used to test the prediction that a secondary palate strengthens the skull whilst an antorbital fenestra weakens it. Generally this is the case during bilateral and unilateral biting, and oreinirostral snouts were almost always stronger than the platyrostral condition. To see if these predictions held true for more complex morphology, a Finite Element (FE) model of the snout of *Baryonyx walkeri* was created from CT scan information using 'Simpleware' FE-model generating software. Further FE-models of the snout of *Gavialis gangeticus* and *Alligator mississipiensis* were created as representatives of extant crocodilian taxa bearing a terminal rosette of teeth or a typical platyrostral snout respectively.

We assess whether spinosaurids were indeed 'crocodile-mimics', in the sense they were adapted for torsional feeding behaviour with structural and functional parallels to extant crocodilian taxa. By digitally manipulating FE-models we test i) if the spinosaurid bony palate confers structural strength to the skull, and during what kind of feeding behaviour, and ii) if the antorbital fenestra weakens the snout, suggesting non-structural constraints influence archosaur cranial evolution.

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Soft tissue preservation in *Tanystropheus* (Diapsida Protorosauria): palaeobiological implications

A recently found specimen of the protorosaurian diapsid *Tanystropheus* shows fossilised skin and wide patches of black phosphatic material at the base of the tail. The latter are filled with small spherules of calcium carbonate, which may precipitate within a corpse in an alkaline environment supersaturated with carbonate, as may occur in stagnant water by decomposition of a consistent amount of proteins. This mass of flesh at the base of the tail, surely added considerable weight to the posterior part of the body, shifting the centre of mass posteriorly. Combining these new data with re-analysis of the body architecture of *Tanystropheus* and comparisons with the recently discovered Chinese protorosaurian *Dinocephalosaurus*, leads to the suggestions that: i) *Tanystropheus* was able to keep the neck raised off of the ground without tilting forward and ii) that it lacked any evident adaptation for effective aquatic locomotion. Consequently, it is feasible that *Tanystropheus* did not live permanently in water as previously suggested, but more probably moved along the shoreline, using the long neck to survey water from above to avoid being spotted by potential prey. This interpretation is also consistent with the stratigraphy and taphonomy of *Tanystropheus* remains from the Grenzbitumenzone.

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The middle ear of the early tetrapod *Kyrinion martilli*

It has generally been presumed that the stapes of early tetrapods supported the braincase against the palatoquadrate, with the notable exception of the Late Devonian *Ichthyostega*. This functional interpretation is based on the stapedial morphology of the Early Carboniferous colosteid *Greererpeton* and similar morphology in the Late Carboniferous embolomere *Pholiderpeton*.

The Late Carboniferous baphetid *Kyrinion martilli*, from the northeast of England, clearly does not have a supporting stapes. CT scanning and 3D computer reconstruction of the internal cranial anatomy of *Kyrinion* has revealed a dorsolaterally directed, somewhat laminar, stapes preserved in its original position. The stapes articulated with the parasphenoid at its proximal end and also sat in the fenestra ovalis. Its distal end did not contact the palatoquadrate complex. It is proposed that the stapes was in intimate contact with a space between the braincase and the pterygoid, which presumably contained a spiracle. This arrangement may have allowed the stapes to pass some airborne vibrations to the inner ear.

Kyrinion's middle ear provides evidence for a functional transition to the tympanum-coupled stapes believed to be present in temnospondyls; the first tetrapod group to evolve an apparatus adapted to the perception of airborne sound.

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Walking on water, digging holes, or distant relatives: what affects the shape of the pelvis in lizards?

A major taxonomic split occurred within the Squamata early in its history, dividing the clade into Scleroglossa and Iguania. One fundamental difference between them concerns locomotor ability; many

iguanians show an ability to run bipedally, whereas, with few exceptions, scleroglossans generally do not. Conversely, limb reduction or loss has occurred repeatedly in scleroglossans, a characteristic seen in no other lepidosaurs.

The pelvis is fundamental to tetrapod locomotion; it is a point of attachment for important hindlimb and axial musculature. Its shape is therefore likely to be influenced by locomotor habits. There is, however, also the question of descent: one might reasonably expect two groups sharing a recent common ancestor to share morphological and physiological similarities.

These issues have been explored through geometric morphometric analysis of the shape of the ilium. Ilia from a wide variety of lizard species were photographed, digitised, and then subjected to Principal Components Analysis. Consideration of the complete data set showed a distinct phylogenetic clustering at the family level (i.e., iliac morphology is generally conservative within a family), whilst functional effects were also observed in groups employing specialised locomotion (e.g., chameleons, and in arboreal *versus* terrestrial varanids). Clear shape changes are also revealed which mirror the trends towards limb reduction and bipedality.

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On the phylogeny of talpid moles (Mammalia)

A parsimony analysis was performed after sampling 17 recent talpid genera for 157 morphological characters, using shrews and hedgehogs as outgroups. Independent of which alternative coding for some contested dental homologies were used, the main analysis resulted in one most parsimonious tree of 473 steps. A series of features support talpid monophyly, for which *Uropsilus* is the most basal taxon. A Japanese shrew mole clade (*Urotrichus*, *Dymecodon*) is placed after *Uropsilus*, and excludes *Neurotrichus*. The monophyly of the desmans is well supported. *Scaptonyx* is sister group to a monophyletic Eurasian fossorial mole clade, while *Scaptochirus* is sister group to *Mogera*. The monophyly of Scalopini was supported, with *Scalopus*, *Scapanus* as sister groups. Based on our results and those of previous authors, it is clear that several migrations must have occurred between Eurasia and North America during the Cenozoic, and that strict fossoriality evolved at least twice independently in talpids. Evolutionary plasticity and propensity to migrate across continents is further demonstrated by preliminary examination of the talpid fossil record in a phylogenetic context.

The independent evolution of a bony tube enclosing the stapedial artery is likely to be correlated with adaptations to low frequency hearing. Another rare feature in the middle ear of several species is a bullate stapes. Different degrees of hypsodonty characterize different taxa. A lot of morphological variation in ankle characters was found, which can be used in isolation to distinguish most clades. The enlargement of prehallux and prepollex are likely epigenetically coupled.

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Neck constructions and pneumaticity in sauropods

Sauropods show a variety of different neck types, ranging from moderately long to extremely long necks. Soft-part reconstructions, biomechanical investigations and calculations of neck flexibility are used to work out constructional differences in these neck types and the biomechanical role of pneumatic spaces. Sauropod neck constructions mainly differ from each other by the proportions of cervical vertebrae and

proportions and morphology of cervical ribs, which influence the mobility of the necks.

In the neck of sauropods, a dorsal, lateral and ventral muscle mass can be reconstructed of which the ventral one was the smallest. Along with the ventral cervical muscle mass and a cranially oriented scapulocostal muscle, ventral flexion of the neck was conducted mostly by gravity. The dorsal ligament system elastically suspended the neck and guaranteed elastic recoil after lateral and ventral movements. The cervical vertebrae were surrounded and penetrated by pneumatic diverticula, which also interdigitated with neck muscles. The reconstructed arrangement of pneumatic diverticula around the cervical vertebrae, in particular hose-like pneumatic diverticula inside the gap of bifurcated neural spines, suggests that the cervical pneumatic system in sauropods could have contributed to neck bracing as pneumatically stabilizing structures.

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Interrelationships of early primates and the origin of crown Strepsirrhini

The time and place of origin of the crown strepsirrhine or "toothcombed" prosimian clade containing the Malagasy lemurs, African galagos, and Afro-Asian lorises has long been a matter of great interest to palaeoprimatologists. There is general agreement among specialists that the extinct Laurasian adapiform primates (notharctids, adapids and sivaladapids) are stem strepsirrhines, but it is not clear whether these taxa are paraphyletic with respect to crown Strepsirrhini or if they represent that clade's monophyletic sister group. Here, I present the results of a phylogenetic analysis of over 100 living and extinct primates based on 359 craniodental, postcranial and soft tissue characters, which tests various hypotheses bearing on the nature of the proposed crown strepsirrhine-adapiform relationship. Interrelationships of Laurasian adapiforms (particularly notharctids) are found to be unstable, but there is no support for the hypothesis that these taxa are paraphyletic with respect to crown Strepsirrhini. Instead, crown strepsirrhines are found to be nested within a paraphyletic group of Afro-Arabian stem strepsirrhines (e.g., *Djebelemur*, "*Anchomomys*" *milleri* and *Plesiopithecus*), some of which have evidently been misidentified as members of otherwise Eurasian radiations. These results support the hypotheses that crown Strepsirrhini arose in Afro-Arabia and that the lemuriform presence in Madagascar is due to dispersal.

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What can bone histology tell us about pterosaurs?

The study of pterosaur bone histology dates back to the middle of the 19th Century, but systematic studies only began recently. Pterosaur bones are predominantly composed of highly vascular fibrolamellar bone, indicating that pterosaurs grew rapidly. However, cranial and pedal bones contain LAGs (lines of arrested growth) that record pauses in bone deposition. Pterosaurs had determinate growth and deposited an endosteal lamella and a periosteal EFS (external fundamental system) at maturity. Pterosaurian epiphyseal growth plates contain endosteal bone and calcified cartilage. Although endosteal reworking is extensive, secondary osteons are rare. Some smaller elements contain an orthogonal plywood-like tissue, composed of alternating lamellae, which may have biomechanical significance. Not all bones are supported internally by trabeculae; in some cases endosteal ridges may provide reinforcement. Pterosaurian reproductive mineral dynamics probably did not involve the deposition of a specialised bony tissue within the lumen of the long bones. Comparative bone histology can distinguish between bones of small theropod dinosaurs and pterosaurs, but cannot reliably separate birds from pterosaurs or distinguish between pterosaur taxa.

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Sweet seventy-five and never been kissed: the Natural History Museum's Tendaguru brachiosaur

In 1930, an expedition led by Frederick Migeod excavated a large sauropod dinosaur at Tendaguru, Tanzania. This specimen, BMNH R5937, has attracted surprisingly little study: it has been the subject of only one significant publication, and none of the material has been figured. Migeod's (1931) account described the specimen as "of the *Brachiosaurus* type", but also mentioned non-brachiosaurid features including bifurcated neural spines and "wings" in the anterior dorsals. If his interpretations are reliable, other proportions are also non-brachiosaurid, e.g., humeri only two thirds as long as the scapulocoracoid. The prepared material includes two dorsal and four cervical vertebrae, two further dorsal centra and an unidentified long-bone fragment. The cervicals are proportionally longer than in *B. brancai*. Unopened jackets contain additional material including at least three more cervical vertebrae, a "wing" from a dorsal, sacrals, a scapula and an ilium. Of the prepared material, the two dorsals are the best preserved, and probably represent D8 and D9. They have several laminae not usually associated with *Brachiosaurus*, including long, parallel spinoprezygapophyseal laminae and a configuration of the divided spinopostzygapophyseal laminae in which the median branches merge into a postspinal lamina and the lateral branches join the spinodiapophyseal laminae in a compound lateral lamina. However, lamination varies greatly along the dorsal column of the *B. brancai* type specimen, so comparing BMNH R5937 with it is difficult. The more complete dorsal column of *Cetiosaurus oxoniensis* also shows significant variation between adjacent dorsals, casting doubt on the widely assumed taxonomic informativeness of vertebral laminae.

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The Jehol Biota of China and its significance for the diversity, ecology and evolutionary history of pterosaurs

In recent years Lower Cretaceous sediments of the Jehol Group in northeast China have yielded many spectacular vertebrate fossils, among them more than 100 specimens of pterosaurs. Important finds include eggs with embryos and several examples of exceptionally well preserved soft tissues, but the most striking aspect of this pterosaur assemblage is its unparalleled diversity. Representatives of two clades of basal pterosaurs (Anurognathidae and Scaphognathinae) and almost all major pterodactyloid clades (Ctenochasmatinae, Gnathosaurinae, Lonchodectidae, Tapejaridae, Azhdarchidae, Istiodactylidae, Ornithocheiridae and ?Pteranodontia) have been found in these deposits and form the most diverse pterosaur assemblage yet known. This assemblage demonstrates that pterosaurs were an important component of continental vertebrate biotas, while the widely varying size and morphologies of the 12+ species described so far hints at considerable ecological complexity within Early Cretaceous pterosaur communities. The Jehol Biota also shows that these pterosaurs lived at the same time and in the same environments as a remarkably diverse assemblage of birds. This contradicts the view that the basal radiation of birds led to the displacement of pterosaurs from many habitats and suggests that, in terms of their evolutionary history, there was little direct interaction between these two major groups of flying vertebrates.

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Chinshakiangosaurus – a cheeky Chinese sauropod?

Chinshakiangosaurus chunghoensis is an enigmatic and poorly understood sauropodomorph from the Lower Jurassic Fengjiahe Formation of Yunnan, China. Examination of the left dentary of *Chinshakiangosaurus* reveals that it possesses an unusual combination of 'prosauropod' and 'sauropod' character states. Cladistic analysis places *Chinshakiangosaurus* as one of the most basal sauropods known currently. Mapping of dentary and dental characters onto the most parsimonious topologies yields insights into the sequence of acquisition of a number of feeding-related characters. For example, it seems that basal sauropodomorphs (traditional prosauropod taxa) possessed a fleshy cheek that attached to the mandible along a marked ridge, and that the same structure was present in the most basal sauropods. The early sauropod skull developed a lateral plate that reinforced the bases of the tooth crowns labially, and possessed teeth with 'wrinkled' enamel and a concavity on the mesial portion of the lingual part of each crown, while retaining a fleshy cheek and a relatively weak symphysis. More advanced sauropods (eusauropods) lost the cheek, perhaps in order to increase the gape of the jaws in response to a change in feeding style that involved collection of larger quantities of poor quality foliage.

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Taphonomic study of Late Eocene rodents (Mammalia) from the Isle of Wight (UK)

Micromammalian fossils belonging to 15 taxa have been collected from the Osborne Member, Late Eocene, northwest Isle of Wight (UK), and the taphonomic history of the two most abundant species, *Isoptychus* sp. and *Thalerimys fordi*, has been studied. The two theridomyid species show similar patterns of mortality, element representation, breakage, etching and weathering and, therefore, share similar taphonomic history. The majority of the individuals belong to the vulnerable age groups (young and old) and died of biological causes. The most likely process for the accumulation of the remains is predation by a mammalian carnivore. A premolar of a mammalian carnivore, *Cynodictis* cf. *lacustris*, was found in the horizon and this animal is the most probable predator of the theridomyids. Extended fragmentation of fresh bone and puncture marks are attributed to chewing by the predator. Some of the material was exposed on the surface for some time before burial and during that period some of the specimens were chewed by the glirid *Glamys priscus*, also present in the fauna. The remains may have been subjected to trampling, as indicated by breakage of dry bones and absence of complete large bones. The theridomyid specimens have not been transported for long distances by water and, thus, the two rodents belong to the local micromammalian community.

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Evidence at hand: implications of hand proportions for function, evolution and lifestyle in extant diprotodontian marsupials

Diversity, locomotor adaptations and evolution of the marsupial postcranial skeleton are rarely analysed on a broad scale. Nevertheless, evolutionary, functional and palaeontological inferences resting on a representative sample of any clade are valuable. This study investigated intrinsic hand proportions in the diverse and speciose marsupial order of Diprotodontia. Fifty-two measurements of 90 specimens representing 50 species were taken, size-adjusted, and evaluated by Principal Components Analysis (PCA). Confidence for variable loadings was established by determining their standard error using a bootstrap method. The first principal component (PC1) distinguished between arboreal and terrestrial species, and was mainly correlated with outer finger length and median width. The second principal component separated several major diprotodontian higher-level clades. Comparison of phylogenetically independent contrasts created using a composite phylogeny showed significant differences in PC1 (arboreal *vs.* terrestrial) values between possums, koalas and the remaining Diprotodontia. This suggests that long and slim phalangeal elements and ectaxony are adaptations to arboreality, as suggested by of numerous non-phylogenetic functional studies on mammals. The best lifestyle predictors, useful even for single phalangeal elements, are ratios between most positive (phalangeal length) and most negative (phalangeal width) PC1-correlated measurements. In contrast, the commonly used ratios between proximal and intermediate phalanges did not distinguish between arboreal and terrestrial taxa. Several other potential adaptations, e.g., for burrowing or gliding, could not be tested in a phylogenetic framework due to the small sample size, but are congruent with findings across tetrapods. This study shows that in the diprotodontian hand, similarities in lifestyle result in anatomical similarities, suggesting that convergence is common.

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'Hormone markers' and the ontogeny and evolution of the human face

The relationship between attractiveness and markers of masculinity in the male face is not clearly understood, both in the context of facial growth and development and with regard to hypotheses of sexual selection. There is considerable variability reported for female preferences for male faces, but new evidence from study of facial growth suggests that "masculinity" could have been misrepresented. A comparison of male and female ontogenetic trajectories, calculated from dimensions recorded from the facial and basicranial skeleton of a native Southern African population of *Homo sapiens*, tests whether growth, uniformly across the face, complies with a model of ontogenetic scaling in men and women. This study identifies one region of the upper face (height of the nasomaxillary complex) that does not correspond to predictions based on the ontogenetic scaling of facial measures. This shortening of the male nasomaxillary region, a change associated with puberty, indicates that sex steroids can affect regions of the face differently, but not in relation to previously identified 'hormone markers'. Furthermore, this facial dimorphism is clearly evident in *Homo erectus,* and fossil crania can be sexed accordingly. The findings imply that the adolescent skeletal growth spurt, uniquely derived in humans relative to other primates, had evolved in *Homo erectus*. Male facial attractiveness and female preferences seem to have played a more important role in shaping human evolution than has been previously recognised.

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Pterosaur wing shape, and its implications for flight

The potential for gaining a deeper understanding of pterosaur locomotion - both aerial and terrestrial - has greatly increased in recent years, thanks to the discovery of several near-complete, three-dimensionally preserved fossil skeletons in the Santana Formation of Brazil, most of them belonging to the predominantly Early Cretaceous family the Ornithocheiridae. Given the usual crushed state of pterosaur fossils, these 3D specimens offer an unprecedented opportunity to study joint function. Using ten such specimens and a novel functional morphological technique, a representative ornithocheirid (*Anhanguera santanae*) was accurately reconstructed in three dimensions, and the range of movement at the various joints was determined. The analysis has revealed a number of hitherto unknown and unique aspects of pterosaur flight control, in particular the role of the pteroid bone - a slender element that articulated at the wrist - and the use of shoulder rotation. In birds and bats the forelimb is typically rotated back to increase the angle of attack of the wing for low-speed flight, and rotated forwards for high-speed flight. The opposite may have been the case in pterosaurs.

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New tridactyl dinosaur trackways from the Berriasian of Lower Saxony/Germany

In summer 2004, digging activity in a quarry near the Münchehagen tracksite, close to Hannover, revealed a large bedding surface with abundant tridactyl dinosaur tracks. To date, approximately 80 m^2 of the new tracksite has been uncovered, yielding five trackways belonging to the ichnogenus *Iguanodontipus* and two "allosaurid" theropod trackways. The new tracksite is highly significant because of i) its excellent preservation of theropod and ornithopod tracks, ii) the general scarcity of longer trackways in the Early Cretaceous of northern Germany, and iii) the unusual walking directions of the track-producers.

The trackway layer is a fine-grained mudstone with superbly preserved tracks as well as ripple marks. The iguanodontid tracks (n = 37; longest trackway: n = 18) measure 24-44□m in length and width, thus corresponding to sub-adult animals with a body length of about 5□m. Interesting features of the trackways are "gliding" structures and tracks, where the deep mud was possibly squeezed around and between the toes and hoofs, respectively, during movement. These structures together with the short pace (49-77□m; mean: 69□m) and stride length (104-156□m; mean = 134□m) might indicate that the iguanodontids walked carefully in the unstable sediment. All *Iguanodontipus* trackways run in different directions: three of them cross each other; none of them represent a straight line of walking.

One of the theropod trackways consists of five tracks, the other of two tracks. The width of the tracks is 23-27□m (mean = 24□m); the length is 28-40□m (mean = 35□m). The pace of the longer trackway is 102-113□m (mean = 107□m) and the stride is 210-220□m (mean = 216□m), indicating a relatively fast running animal. Ongoing research will clarify if these small theropod trackways represent a new ichnogenus.

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Palaeobiology and diversity of the turtle fauna from the late Miocene Urumaco Formation in Venezuela

The diverse turtle fauna from the Urumaco Formation (late Miocene) includes the world's largest extinct turtle *Stupendemys geographicus*, the first reliable reported occurrence of a trionychid in South America, a fossil matamata species, and at least two species of pelomedusoids, including *Bairdemys venezuelensis*. New fossils of *Bairdemys* show a great deal of cranial variation in features previously thought to be diagnostic for particular species. The lower jaw of *Bairdemys* has a large triturating surface, which together with the great development of a secondary palate is probably correlated with a diet consisting of hard molluscs. A large nesting site demonstrates that *B. venezuelensis* was a colonial nester, which laid its eggs in beaches and lived in a near-shore marine environment, providing the first direct evidence of the palaeoecology of this species. Several new carapaces and postcranial elements of *Stupendemys* provide new information about the palaeobiology of this species. A histological study of a new carapace (CL 3.3mts) reveals that apparently this species did not follow any outstanding way of growth to reach its gigantic size. Sharpey`s fibres are present only in the external cortex of the neural hinting at some kind of anchoring of the overlying soft tissue (probably the upper strata of the dermis) that resides just below the keratinous shields. Comparisons of postcranial anatomy with fossils attributed to *Stupendemys* from Brazil, show that at least two species of this genus inhabited in the Miocene of the neotropics. This work was supported by the National Geographic Society.

ABSTRACTS OF POSTER PRESENTATIONS

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Carnassial rotation in machairodonts

Sabre-like canines have evolved several times in mammals, not only among carnivorans, but also among other eutherians and even metatherians. The changes in skull morphology and non-canine dentition are remarkably similar in this odd mix of carnivorous mammals. These changes has been observed in arctocyonids such as *Anacodon*, creodonts such as *Apataelurus* and *Machaeorides*, nimravids, such as *Eusmilus* and *Hoplophoneus*, barbourofelines such as *Barbourofelis* and *Sansanosmilus* and in many machairodonts, e.g., *Smilodon*. Among the metatherian borhyaenids the genus *Thylacosmilus* evolved some of the most extreme sabres of all carnivores. The sabres themselves differ among genera, but two general morphotypes were present. Dirk-toothed, with long slightly and crenulated canines, and scimitar-toothed with shorter and more strongly serrated canines. Whether short or long sabres, the skull morphology changed in numerous ways. Ubiquitous changes included reduction in dentition, enlargement of the carnassials, reduction of the coronoid process and reduced width of the zygomatic arches, among others. An often overlooked feature of many sabretooths are the presence of carnassial rotation, creodonts as well as felids, in which the teeth in the lower tooth-row rotate to minimize inter-carnassial distance. The presence of attrition (thegosis) on the carnassials but not on the sabres, is undoubtedly linked to the rotation of the lower carnassials. The functional morphology of this unusual trait is discussed.

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Palaeobiology of Pietraroia fishes as inferred from phosphorus determination in coprolites

Phosphorus is an important element for many essential processes in the body of all living organisms, as it is involved in the metabolism of fat, carbohydrate and protein, and in energy metabolism. For these reasons, phosphorus is very widely distributed in both plants and animals, and thus in their foods. When a fish ingests its prey, most of the phosphorus ingested finally ends up in excrement, since the amount required by the fish is negligible as compared to the ingested amount. Here we show that, by combining a method to quantify the phosphorus in fish coprolites, using a set of equations widely used in field marine ecology and some very basic assumptions, it is possible to assess the kind of prey ingested and its maximal dimensions. Though a rough one, it is also possible to obtain an estimate for the composition of the food web at the level of fishes in the ancient seas of Pietraroja.

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Vertebrate-fossil rich plattenkalk of Pietraroia (southern Apennines, Italy): a sedimentological and taphonomical approach

Pietraroia plattenkalks are richly fossiliferous, fine-grained cherty limestones, from the Matese Mountains - southern Apennines, Italy, and are well known for the exceptional state of preservation of the fossils. Based on detailed taphonomical analyses, the fossil assemblage recognised in the Pietraroia plattenkalk represents a taphocoenosis and an obruption deposit in the sense that most (if not all) of the animals were transported to an accumulation site from other places. A likely scenario could be that the sediments were deposited in a depressed area in which gravity currents carrying animals from above, capturing both living and dead organisms, transported them into accumulation sites placed well below the original place where they lived and/or died.

First considered as shallow lagoon deposits or as intra-platform small basin-fill, the Pietraroia plattenkalk sequences, on the basis of sedimentological analyses and geometrical reconstructions, are here interpreted as deposits from a submarine channel, the "Pietraroia Channel", and that they document a major transgressive event. Transgression was associated with the development of suboxic to anoxic conditions at the seafloor that favoured fossil preservation and the deposition of coprolite-rich and bituminous layers found within the plattenkalk sequences. A peculiar palaeogeographical and palaeotopographical setting, strongly controlled by local tectonics, saw the contiguity of wide emergent areas with a relatively deep-water channelised area where fossiliferous plattenkalk sequences were deposited.

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Immortal Clay II: a first for Alfred Leeds - but is it a reptile egg?

The Alfred Leeds Collection is one of the major fossil marine reptile collections at the Natural History Museum, London. It contains at least 300 specimens collected towards the end of the 19th Century from the Middle Jurassic Oxford Clay around Peterborough. One of its more unusual treasures is BMNH R2903, the first specimen to have been described as a fossilized 'reptile egg'. 'The Sphere' declared that it predated the discovery of dinosaur eggs in Mongolia (Anonymous, 1923). Then in 1950, W.□E. Swinton featured the enigmatic fossil in an article for The Illustrated London News suggesting that it might be an amphibious dinosaur egg. As an isolated curiosity, and given the unlikelihood of a fossil egg occurring within the marine sediments of the Oxford Clay, it has been overlooked for decades and still lacks a satisfactory identification. CT scanning work undertaken by the University of Glasgow in 1995, as part of a comparative programme of scanning technologies used with fossil eggs, revealed the internal density contrasts of the object, and appeared to show a discrete mass of components within. This CT scanning work has recently been supplemented by SEM analysis of the surface of the object that indicated a laminated structure to the outer crust or 'shell'. Although the thickness and structure of the 'shell' mitigates against a dinosaurian/avian diagnosis it is still too early to exclude the possibility that it is in fact a fossilised Middle Jurassic reptile egg. Further SEM studies may yet reveal the putative egg's true identity.

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Finite Element Modelling of the cat skull

Finite Element Analysis (FEA) is a computer modelling technique, developed by mechanical engineers, which can be used to test how structures respond to imposed loads. It has recently attracted interest from biologists and palaeobiologists interested in skull and skeletal biomechanics, but the question of validation remains an issue. As a preliminary step, we have compared data obtained from a FE model of a cat skull (*Felis sylvestris catus*) with that from an earlier *in vitro* analysis of the cat skull using strain gauges.

The FE model was created with data provided by the High Resolution Computed Tomography Laboratory, University of Texas, Austin. It was then loaded and constrained to replicate the experimental set-up used by Buckland-Wright in his classic work on the cat. He recorded five major strain foci – in the anterior, middle and posterior parts of the zygomatic arch; along the canine root; and on the palatal surface adjacent to the tooth row. The same five zones were observed on the FE models with comparable strain values. Peak levels of strain were recorded in the zygomatic arch and at the anterior root of the zygomatic arch, and these findings match those of more recent *in vivo* studies of other mammals.

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A cladogram for the Deuterostomia based on molecular-biological and fossil evidence.

On the basis of molecular-biological evidence from extant animals, the basic cladogram for deuterostomes reads: (((hemichordates + echinoderms) *Xenoturbella*) chordates). Moreover there is now molecular evidence that, if the probable effects of long-distance attraction are discounted, the basic cladogram for chordates should read: (acraniates (tunicates + vertebrates)). Here, we accept these results and attempt to place the most primitive deuterostome fossils in the stem groups implied by the cladograms. In doing so, we find that a stereomic calcitic skeleton of echinoderm type, with each plate a single crystal of calcite, is not a hallmark of echinoderms as commonly believed. Rather, in the latest common ancestor of all extant deuterostomes it would have existed, but has been lost at least six times among the descendants of that animal. In this light, a calcitic skeleton in a carpoid is a symplesiomorphy - it does not indicate an echinoderm but merely a deuterostome. We further conclude that the carpoids known as ctenocystoids are stem-group hemichordates, mainly because one recently discovered ctenocystoid must on functional-morphological grounds have been a burrower comparable to an extant enteropneust, and in particular to the newly described deep-sea enteropneust *Torquarator*. The carpoids called Cincta, which probably gave rise to the ctenocystoids, are also likely members of the hemichordate stem group. The echinoderm stem group is probably represented by the basically triradial fossils known as helicoplacoids and *Tribrachidium*. Their triradiality presumably evolved, in more crownward parts of the echinoderm stem group, into the standard quinqueradiality of extant echinoderms. The most primitive (most "rootward") part of the chordate stem group was probably included in the solute carpoids, while more crownward members of the chordate stem group were the cornutes. The most primitive members of the chordate crown group were the mitrates. The most primitive known solute was attached by the end of its tail, whereas more crownward stem-group chordates, and the mitrates also, locomoted rearwards tail first.

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The Middle Jurassic vertebrate assemblage of Skye, Scotland

In the Middle Jurassic, the UK consisted of a series of islands at the western edge of the European archipelago. The vertebrate faunas of these islands include some of the earliest frogs, salamanders, albanerpetontids, turtles, lizards, choristoderes and maniraptoran dinosaurs, as well as a diversity of mammals. However, most localities yield only dissociated bones. The Kilmaluag Formation of Skye also produces rare associations. Recent fieldwork has extended the known assemblage and added a nearly complete turtle and partial salamanders. The Skye assemblage contains representatives of 12 major vertebrate clades and >20 distinct taxa including hybodont sharks; semionotiform fish; primitive caudates; a turtle; lepidosauromorphs (*Marmoretta*, lizards); choristoderans (*Cteniogenys*), crocodiles (goniopholids, atoposaurs); pterosaurs; sauropod dinosaurs; tritylodont synapsids (*Stereognathus*), and mammals (*Borealestes*, indet. docodont). This assemblage is similar to those from English localities, but appears to differ in the rarity of crocodiles, and the absence of frogs and albanerpetontids. Salamander and turtle remains are the most abundant at the site, whereas terrestrial animals (pterosaurs, dinosaurs, mammals) are relatively rare. This could imply an environmental bias in the record (probably the most likely option) and/or the operation of a taphonomic filter related to body size (the latter in the case of dinosaurs and crocodiles).

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Initiation and ordered tooth development: do fish do it differently to amniotes?

Recently, it has been suggested that stem-group gnathostomes and basal taxa of crown-group gnathostomes may each possess a unique pattern for the establishment of both tooth initiation sites and further replacement tooth production. Few studies have focussed on the early events that prime these initial odontogenic sites across the vertebrates. The initial sequential pattern that lays down the order of tooth site specification is thought to vary across the major vertebrate clades. Subsequently, the mechanism involved in producing further generations of teeth may also show fundamental differences across the vertebrates. Within the rainbow trout there are different tooth-bearing locations, each with a different temporospatial order for the initial tooth positions. Early components of the mechanisms that lay down the pattern for a spatiotemporally ordered dentition have been identified in fish. In the trout dental system individual teeth are initiated within a common epithelial odontogenic band for each toothed region, localised by the expression of *Shh* and *Pitx-2*. Gene expression is restricted to the basal epithelium of each odontogenic band. Within this band tooth buds are located and form in alternate tooth positions for each dentate region, thus initialising the primary order and that of the replacement dentition. Both gene expression data and morphological observations will be compared for osteichthyan (*Oncorhynchus mykiss*) and chondrichthyan fish (*Scyliorhinus canicula*), both for initial dental pattern and their replacement mechanisms. This forms the basis for understanding the evolution of tooth initiation order and further lifetime production in early vertebrates.

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The gorgonopsids: an investigation in phylogenetic and functional terms

The Gorgonopsia, a group of mammal-like reptiles from the Upper Permian of South Africa, is revised. This work aimed to resolve major issues in the alpha-level taxonomy of these animals, which remained unclear in several areas despite the enormous efforts of Sigogneau-Russell (1970, 1989). The 22 genera that were thought to be valid at that time have been further investigated and compared. As a result, the number of genera has been reduced and the total species number has also been modified. The mounted skeleton of ?*Aelurognathus parringtoni* was re-examined and investigated functionally and morphologically. The questionable relationships of this East African specimen are resolved: it is shown to have a close affinity with the Russian form *Sauroctonus progressus*. On this basis, it was possible to establish a sound, computer-based phylogeny for this group for the first time.

?*Aelurognathus parringtoni* was compared with the sabertoothed cat *Smilodon* in functional terms. As both taxa possess extremely elongated canines, I sought to identify other possible functional convergences in the rest of the skeleton. It was discovered that this particular gorgonopsid shows some functional similarities to *Smilodon*, but this must be considered in the light of the different evolutionary histories of each of these animals.

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Imaging the otic capsules of a pliosaur

Well-preserved pliosaurs (Reptilia: Sauropterygia) are rare, and those with high-quality braincase material are extremely uncommon. A new and undescribed genus and species of pliosaur from the Lower Cretaceous of Colombia, South America, is one of the very few pliosaur specimens which preserves the otic capsules and braincase substantially complete, articulated and largely uncrushed. The 3D cranium of this new specimen has been acid-prepared, revealing the otic capsules and details of the internal osseous labyrinth. However, the bones surrounding the osseous labyrinth are both fragile and fused, and understanding the detailed osteology and visualising the precise morphology of the semicircular canals is challenging. In order to obtain fuller information from the fossil, the otic capsules were CT scanned and the images manipulated with the software VG Studio Max in order to produce a virtual 3D ‘cast’ of the semicircular canals. The generation of this 3D computer model of the otic capsules and the osseous labyrinth of this pliosaur, displays for the first time, full details of this region of the cranium in a sauropterygian marine reptile.

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Auctioning the Past – the development of live auctions for the sale of fossils

The commercial sale of palaeontological material has emerged over recent years as one of the most controversial and fiercely contested debates in palaeontology. This paper explores a sector of the fossil market, focusing on live auctions and the emergence of a new market in fossils from the early 1990s through to 2005. The findings are based primarily on quantitative and qualitative data drawn from the major auction houses and catalogues.

Auctions play an important role in signalling the presence of a market, and can act as a socially acceptable process for determining price when there are high levels of uncertainty and ambiguity. Originally marketed as the 'collectibles of the 1990s', the auction market was built on the popular success of Michael Crichton's *Jurassic Park* and exciting new scientific discoveries. Fossils at auction have since undergone a transformation, emerging as a more stable and successful décor market in the UK. This paper describes and explores the characteristics of the current UK auction market: price trends, supply, location of material, and type of material being sold, analysing the emergence and development of a market for fossils presented as décor and *objet d'art*.

This paper also explores differences between UK auctions and the more controversial US auction market for fossils, comparing price ranges, types of material sold, and presentation. Finally, a brief mention and comparison is made to one of the online auction houses, eBay.

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A biomechanical analysis of cranial function in Dicynodontia

Dicynodonts had a derived feeding apparatus that permitted propaliny and allowed effective grinding of plant material. Changes in skull structure across Dicynodontia were previously correlated with changes in masticatory function, and hence, diet. Derived cranial features of *Lystrosaurus* were hypothesized to increase the efficiency of its masticatory system relative to a generalised, purely Permian dicynodont such as *Oudenodon*. These features possibly allowed *Lystrosaurus* to cross the Permo-Triassic boundary due to its ability to exploit new, more resistant vegetation.

This study will examine quantitatively the functional significance of cranial form of *Oudenodon* and *Lystrosaurus* using Finite Element Analysis (FEA). By determining the distribution and magnitude of cranial stress, FEA can establish if morphological differences have biomechanical significance related to changes in masticatory function. To implement FEA, several aspects of dicynodont skull anatomy must be first examined and include: i) investigating qualitative differences in skull morphology correlated with changes in masticatory function; ii) creating three-dimensional skull models; iii) examining the histology and determining the approximate material properties of dicynodont cranial bone; and iv) establishing the attachment areas of the adductor muscles. These combined parameters will allow FEA to accurately model the distribution and magnitude of stresses experienced during mastication for both genera.

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A palaeoenvironmental reconstruction of Laetoli, Tanzania using a bovid community ecomorphological survey

There has been a renewed interest in the application of ecomorphological techniques to bovid postcranial remains as a way to infer past ecological conditions at sites pertaining to hominin evolution. However, the best habitat discriminators are often complete long bones that are rarely found intact in fossil assemblages, reducing the efficiency of this method. Furthermore, only a handful of elements have been analysed in an ecomorphological context and the remainder of the postcranial skeleton has been neglected despite the relatively high occurrence of the complete recovery of some of the smaller and denser elements like the carpals and tarsals.

In order to increase the amount of material available for an ecomorphological reconstruction, the majority of bovid postcranial elements were assessed for their ability to discriminate between seven habitat types in a series of discriminant function analyses. A global sample of extant bovids (n = 205), cervids (n = 14) and tragulids (n = 5) comprise this comparative dataset. The baseline of chance accuracy for the DFAs (i.e., the percentage of correct predictions that can be expected when habitat assignments are randomised) was determined. This baseline served as the cut-off point between good and bad habitat predictors. The good predictor elements from both the Upper Laetoli Beds and the Upper Ndolanya Beds at Laetoli were analysed. Summaries of the number of specimens predicted to belong to each habitat type indicate that at the time of deposition of the Laetoli Beds the area had heavy woodland-bushland cover with some lighter tree and bush cover and grass available. The results also indicate that during Ndolanya times the environment had become more open and the grassland component of the environment had increased significantly. Light woodland-bushland and an abundance of grass cover dominated the landscape, although tracts of land with denser vegetation likely existed, agreeing with earlier suggestions that the area was a semi-arid bushland.

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Catfish remains from the Eocene of Mali

The fossil catfish fauna from Palaeocene/Eocene strata in the Republic of Mali, west Africa are presented. They are compared with similar faunas from other west African localities. The implications for the timing and extent of the trans-Sahara seaway are explored.

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Revision of the short-snouted alligatoroid *Acynodon iberoccidentalis* from the Late Cretaceous of southern Europe

Excellent new specimens of the alligatoroid eusuchian *Acynodon iberoccidentalis* are described from late Campanian-early Maastrichtian localities of southern France. A complete skull and a mandible allow identification of new diagnostic characters. *Acynodon* is the only known globidontan alligatoroid

from Europe for this period. These specimens add enough new data to allow comparison with previously described North American basal globidontans such as *Brachychampsa*, *Albertochampsa* and *Stangerochampsa*. Phylogenetic affinities of *Acynodon* are examined by addition of the new identified characters to a previously published data matrix.

The relatively short snout, the heterodont dentition, presenting anterior peg-like and posterior crushing teeth, the medial expansion of a shelf on the mandible and the robustness of the posterior portion of the mandible suggest that *Acynodon* attained some degree of feeding specialization. Previous hypotheses concerning diet among basal globidontans are explored. North American globidontans showing posterior crushing and anterior piercing teeth have been viewed as generalists. The anterior peg-like teeth of *Acynodon* reinforce the hypothesis of a different diet.

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A new choristoderan reptile from the Lower Cretaceous of Japan

A new species of *Monjurosuchus*, a choristoderan reptile, is described from the Lower Cretaceous Kuwajima Formation (Tetori Group) of Japan. This is the first report of the genus from Japan and this is also the first report of the same tetrapod genus shared between the Jehol Group and Tetori Group. The new species is characterized by unique postorbital structures, such as reduction of the quadratojugal and a spiky flange on the squamosal. A phylogenetic analysis including the new animal was conducted, which also incorporated data on a poorly known long-necked choristodere from China (*Hyphalosaurus lingyanensis*) for the first time. A new phylogenetic hypothesis is proposed that differs significantly from previous studies. Choristoderans are formed mainly by two monophyletic groups. One group, Neochoristodera, includes *Champsosaurus*, *Tchoiria*, *Simoedosaurus* and *Ikechosaurus*. It is characterized by snout elongation and a relatively small orbit. The other, unnamed, group includes *Lazarussuchus*, *Monjurosuchus*, *Hyphalosaurus* and *Shokawa*. These species are recognized as a monophyletic group for the first time. The group is mainly characterized by a dorsally directed large orbit and closed lower temporal fenestrae. Members of the group remained as small animals less than 1 m in total length, but exhibited high morphological diversity, for example, giving rise to long-necked forms such as *Hyphalosaurus* and *Monjurosuchus*.

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Structural analysis of the skull of *Tyrannosaurus rex* using two-dimensional finite element method

Tyrannosaurids, such as *Tyrannosaurus rex*, have fused, robust nasals in comparison to other theropod dinosaurs. Our interest is in asking why are the nasals fused. From the results of two-dimensional Finite Element Analyses (FEA) of the skull of *T. rex* in lateral view, we interpret the fused nasals as an adaptation against high stress during feeding. We carried out two-dimensional FEA on the dorsal view of the *T. rex* skull for further examination of the mechanical function of the nasals. Two models of the fused and unfused nasals were compared when experiencing shear load along the tooth rows. The results include: i) shearing strain concentration in the nasals is significantly less and distributed over a larger area, including the frontals and parietals, if the nasals are fused; and ii) shearing stress is high at the nasals in both cases. Our analyses confirm that the fused nasals are mechanically suitable for coping with shearing strain in tearing. The shearing strain in the nasals is improved by fused nasals. The fused nasals are

observed in basal tyrannosaurids such as *Dilong paradoxus*. It is suggested that morphological change of the nasals that occurred in the tyrannosaurid lineage was related to the stress distributions created by shearing strain during tearing.

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Pelagosaurus typus Bronn, 1841 (Mesoeucrocodylia: Thalattosuchia) from the Upper Lias (Toarcian, Lower Jurassic) of England

The thalattosuchian crocodilian *Pelagosaurus typus* Bronn, 1841 from the Upper Lias of England is properly documented and described for the first time. The material under study is part of a historical collection founded by Charles Moore (1814-1881) at Strawberry Bank (Ilminster, England) in the late 1800's. The identification of pelagosaurs in England extends the range of this species across the English Channel. *Pelagosaurus* was a very small, exceedingly long-snouted, gracile crocodile whose diet probably consisted of small fish, crustaceans and possibly insects. Laterally placed eyes suggest that this species actively pursued its prey rather than sitting and waiting at the water surface. Predation on the small-bodied fish *Leptolepis* is evident due to stomach contents of a small juvenile pelagosaur that confirm this interpretation. The exact phylogenetic position of *Pelagosaurus* has been debated: however, evidence from this current study reveals that this species is most closely allied with the family Teleosauridae. Pelagosaurs possess the majority of teleosaurid apomorphies, including: four premaxillary teeth; small prefrontal; lachrymal visible in dorsal view; presence of the mandibular fenestrae; dermal armour; and a straight tail. Accordingly, *Pelagosaurus* can be seen as a primitive small-bodied teleosaurid.

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Cranial biomechanics in basal ornithischian dinosaurs

Since its discovery and initial description, *Heterodontosaurus tucki* has remained a problematic animal in terms of its cranial biomechanics during feeding. This small herbivorous dinosaur from the Early Jurassic upper Elliot Formation of South Africa features a closely packed magazine of cheek teeth with oblique occlusal surfaces that suggest *H. tucki* processed plant matter using a transverse power stroke. Because diapsid jaw musculature does not allow a side-to-side motion of the lower jaw against the upper jaw, several fundamentally different theories have been put forward to explain how *H. tucki* chewed. These include rotation or scissoring of the dentaries against the predentary, propaliny and lateral rotation of the cheek region. I am utilizing FEA (Finite Element Analysis) to approach the problem of cranial biomechanics and feeding in *H. tucki* in a way that will allow the various proposed hypotheses to be objectively tested. CT scans from the cranium of *H. tucki* have been used in the construction of a three-dimensional finite element model. Forces simulating those encountered during each of the proposed feeding mechanisms will be applied to the model and stress and strain patterns generated by different feeding strategies will then be analysed to determine which of the proposed modes of mastication best corresponds to skull morphology.

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Jaw biomechanics and bite force estimates in theropod dinosaurs

Feeding function is, perhaps, one of the most interesting aspects of the cranial skeleton and many studies have been conducted for both extant and extinct animals. The general skull morphology of theropod dinosaurs is widely consistent, but there is also a significant amount of diversity. Differences in jaw margin morphology indicate a variety of feeding applications, strategies, and behaviours. However, despite speculation, the mechanical significance of this diversity has rarely been analysed and compared. 1The hypothesis that jaw margin morphology affects bite force distribution along the jaw margin has been tested through basic mechanics with the aid of computer simulations. Jaw margins were approximated as simple mathematical equations and bite forces were calculated along their entirety, which in theory reflects the gradual changes and distributions of bite forces. Calculations showed that bite forces are transmitted most efficiently in accordance to certain jaw morphologies. There is also a general trend for the highest efficiency to be in the anterior regions of the jaws, where bite forces are naturally and unavoidably lower. This analysis showed that jaw margin morphology does affect bite force distribution and in some cases compensates for anatomical loss of bite force.

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The mutability of the earliest paired appendages

The Osteostraci (cephalaspids) are a specialised and intriguing group of agnathan fishes that are currently thought to be the sister taxon of the jawed vertebrates. Although lacking jaws, the majority of Osteostraci possess a number of gnathostome apomorphies, including paired appendages, which some authors argue to be homologous to the paired appendages of gnathostomes.

Phylogenetic analysis of the intra-relationships of this group can help us answer questions about this proposed homology. Whilst previous authors have investigated such intra-relationships, in-depth systematic studies utilising modern cladogram construction techniques such as PAUP have yet to be conducted on the group. Such studies will also shed light on the debate as to whether paired appendages evolved once and were subject to reversions or evolved many times within and outside of the group.

The Silurian thyestidiens are a key monophyletic group containing both forms with paired appendages and without. They have long courted controversy regarding their position as either the most derived or most basal osteostracans. Here, a new phylogeny of the thyestidiens is presented based on a study of British, Estonian, Russian and Scandinavian material. This phylogeny provides the basis for an analysis of the interrelationships of this group and to trace the evolution of key vertebrate innovations, crucially including paired appendages.

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First occurrence of the ichthyodectid *Cladocyclus sp.* in the Lower Cretaceous Plattenkalk of Pietraroja (southern Italy)

Among the ichthyofauna of Pietraroja, Ichthyodectiformes have been reported only from a post-

cranial partial skeleton attributed to the species *Chirocentrites* cf. *coroninii*, at the beginning of the 20th Century. Recently, the finding of a complete and articulated skull and pectoral girdle has been attributed to the family Ichthyodectidae and confirmed the fossil record of this family in the Lower Cretaceous of southern Italy. Preliminary researches on the cranial material assign it to the genus *Cladocyclus*.

The preservation of the specimen is exceptional, as it is usual with fossils coming from the Pietraroja area, as it preserves not only a fully articulated skull and pectoral girdle, but also soft tissue preservation of muscles around the ribs. Most possibly this specimen is the most complete ichthyodectid in the southern Italian fossil record. Geochemical studies seem to indicate that the specimen has been phosphatized, which may be a common process of fossilization in the Pietraroja area, although no other study in this sense has been carried out in the area. Furthermore, even the other material attributed to *Chirocentrites coroninii* is under examination, and preliminary results exclude this genus and point out that the old material may actually be attributed to the genus *Cladocyclus* as well.

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A mathematical descriptor for theropod forelimb claws: methods and implications

Theropod forelimb claws were often the main weapon during predation, therefore the understanding of their structure and use seems to be of great relevance for the study of dinosaur palaeobiology. We have examined the forelimb claws of 30 theropods from a geometric point of view and have found that the basic descriptor for all of them is represented by a 3rd degree polynome. In order to create control groups we have applied the same kind of analysis to forelimb claws of different living predatory taxa (felids and ursids), but for these samples we have found a number of different descriptors in the same family, quite different from the uniform results obtained for theropod dinosaurs. Similar results have been found for hindlimb claws of birds, which also show several different descriptors. Therefore, all the theropod forelimb claws can be described within a single family of curves, all generated from a 3rd degree polynome, which may have either functional morphological and/or ontogenetic importance.

OTHER POSTERS (NO ABSTRACTS OFFERED)

Etches, S. Kimmeridge fishes.
Jones, M.□E.□H. Skull evolution in the Rhynchocephalia (Diapsida: Lepidosauria).
Liston, J., Steel, L. & Challands, T. Lured by the rings: growth structures in *Leedsichthys*.
Maidment, S. A re-description of the postcranial skeleton of the primitive stegosaur *Huayangosaurus taibai*.
Nicholls, R. Palaeoart exhibition.
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Walsh. S., MacLeod, N. & O'Neill, M. Analysis of spheniscid tarsometatarsus and humerus morphological variability using DAISY automated digital image recognition.