SVPCA TALKS

A Devonian tetrapod-like fish from China reveals parallelism in stem tetrapod evolution

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The fossils assigned to the tetrapod stem group document the evolution of terrestrial vertebrates from lobe-finned fishes. During the past 15 years the phylogenetic structure of this stem group has remained remarkably stable, even when accommodating major new discoveries such as the elpistostegid *Tiktaalik*. Here we present a large tetrapodomorph fish from the Late Devonian of China that disrupts this stability. This new taxon, provisionally named *Hongyu*, comes from the Famennian Zhongning Formation of Qingtongxia, Ningxia, north-central China. It is the first Devonian sarcopterygian fish to be described from the North China Block, a craton complex that at this time formed a small continent located near the equator. *Hongyu* is represented by a single specimen comprising a partial skull, gill skeleton, shoulder girdle and anterior vertebral column. It combines characteristics of rhizodont fishes with derived elpistostegid-like and tetrapod-like characters such as a plate-like scapulocoracoid, a cleithrum without a ventral lamina, and a hyomandibula that ends distally at the opercular facet. A ventrally flattened lower jaw with an extremely large and robust retroarticular process suggests a benthic "fish trap" lifestyle similar to that proposed for the aberrant Triassic temnospondyl *Gerrothorax*. Phylogenetic analyses incorporating *Hongyu* suggest two very different topologies for the tetrapod stem group: either rhizodonts clade with *Hongyu* and elpistostegids + tetrapods, or - at the cost of one extra step - rhizodonts + *Hongyu* are widely separated from elpistostegids + tetrapods. It appears that evolutionary parallelism, ecological diversity and biogeographical provinciality in the tetrapod stem group may all have been underestimated.

Bridging the divide between studies of extant and extinct diversity

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Palaeontologists and so-called neontologists often come to jarringly different conclusions about the evolutionary history of the same classes of organisms. For example, palaeontological evidence for Cope's rule is widespread - with arguably the best evidence emerging from the mammalian fossil record. Contrary to this, all attempts to find a signature of Cope's rule using extant data have failed. We show that this discrepancy occurs as a result of the ubiquitous assumption that evolution occurs as a homogenous process, inherent in all studies exploring Cope's rule within extant taxa. Rates of body size evolution fluctuate widely through time and between groups; this means that a homogeneous approach is incomplete at best, and at worst a source of potential bias in the studies of historical body size change. We take a novel phylogenetic approach to detecting trends that relaxes the assumption of uniform rates. Our results demonstrate that adaptive evolution towards larger body size is widespread and common in mammalian evolution. This adaptive view of Cope's rule brings inferences from extant data in line with patterns we observe within the fossil record. Our characterization of the evolutionary processes leading to extant mammalian diversity allows us to reconstruct ancestral sizes which bear a striking resemblance to fossil data. In fact, when we account for the observed adaptive evolution in our reconstructions, body sizes are statistically much closer to paleontological estimates. This contrasts with recent suggestions that ancestral state reconstructions using extant data may be inaccurate.

Functional maintenance and variation in cranial length of the mouse masticatory system

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The craniomandibular skeleton is a dynamic and complex structure, housing vital tissues and performing multiple critical functions. This region is however subject to considerable morphological change during development, as well as environmentally and mutationally induced individual variance. The capacity of this region to maintain appropriate functional performance despite these challenges is not fully understood. In this study the mechanical implications of variation in craniofacial length are investigated by means of a sample consisting of three strains of *Mus musculus*; a wild-type strain and two mutant strains. Both mutations selectively affect chondrocranial growth, and thus the influence of both is restricted to the cranium. The *pten* mutant phenotype is characterised by an elongated cranium, while the brachymorph is shortened. This sample allows exploration of a potential plastic response of the masticatory lever system when cranial length and the out-lever are varied. Mechanical advantage was calculated as a ratio of muscle in-lever and jaw out-lever for key masticatory muscles. Jaw out-lever length was found to be significantly different in all three strains, yet little difference in mechanical advantage for any muscles was found between strains. This maintenance of mechanical advantage is attributed to plastic adaptation in regions influencing muscle in-lever length, the latter which were found to be significantly different in the three strains. These results show the potential of the craniomandibular complex to plastically adapt to

maintain functionality when variation occurs in one region, and thus these results have significant implications for the evolvability of the craniomandibular complex.

Extratropical peaks in Cretaceous terrestrial vertebrate diversity: the influence of primary producers on vertebrate species distribution

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The Latitudinal Biodiversity Gradient (LBG), a poleward decline in species richness, is well documented in the modern world, but poorly understood. This pattern has been attributed to temperature, seasonality, the geographical extent of landmasses, and other causes. Previous studies have shown that palaeotemperate peaks (or shallower diversity gradients) are prevalent in greenhouse worlds. The Cretaceous, with its global greenhouse conditions and well-constrained climate history, provides an important counterpoint to the modern LBG, allowing for a detailed examination of the effects of climate change. Here, we examine the evolution and causes of the Cretaceous LBG using the most comprehensive dataset of terrestrial vertebrates, comprising more than 19,000 occurrences representing ~2500 species. Estimates of latitudinal diversity were calculated at 10º intervals using raw species counts and Shareholder Quorum subsampling. Generalized least-squared regression was used to examine the fit of variables representing the latitudinal distribution of fossil sampling, non-marine land area, temperature, and plant diversity. Species diversity shows a palaeotemperate peak at 45º in the northern hemisphere across the entire dataset using both raw and sampling-corrected diversity estimates, with the latter supporting a similar southern hemisphere peak. Multivariate modelling supports plant diversity, with an AICc weight 0.70, as the best explanation of subsampled vertebrate diversity. Plant diversity is best explained by a combination of non-marine area and sampling (AICc weight = 0.61). These results suggest that latitudinal climatic distribution did not directly cause the Cretaceous extratropical peak in terrestrial vertebrate diversity, but that primary producers controlled terrestrial vertebrate distributions.

Dinosaur body size maxima driven by global temperature

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Interactions between organismal evolution and physical climatic variation have been extensively studied in the Cenozoic fossil record, which is composed primarily of extant clades with well-constrained physiologies. These studies suggest, for example, that maximum body sizes within large-bodied mammalian orders were greatest during global cooling events, concordant with latitudinal body size patterns of living endotherms. However, the effect of climate change on evolution in extinct groups with potentially non-uniformitarian physiology and biology has received less attention. To estimate the relationship between maximum body size and global climate in dinosaurs, we used a comprehensive dataset of dinosaurian body masses estimated using the robust scaling relationship of tetrapod body mass with femoral and humeral shaft circumferences. For this study, we estimated 500 adult dinosaur masses, using phylogenetic generalised least squares models to estimate body mass in more fragmentary taxa. During an initial expansion phase beginning in the Triassic, maximum body masses increased from plesiomorphic values of 10-50 kg to possible quasi-equlibrium masses in the Late Jurassic. These exceeded 50 tonnes in sauropodomorphs, five tonnes in stegosaurian ornithischians, and three tonnes in allosauroid theropods. Subsequently, ornithischians attained their body size maximum around 15 tonnes, during globally cool intervals in the Early Cretaceous and again in the Campanian-Maastricthian. In contrast, sauropodomorphs attained their body size maximum, exceeding 50 tonnes, during globally warm intervals, in the Late Jurassic and early Late Cretaceous. Theropod maximum body size apparently increased gradually from the Late Jurassic to a maximum exceeding seven tonnes in the latest Cretaceous *Tyrannosaurus rex*. The positive association of body mass and temperature seen in sauropodomorphs is distinct from the negative association seen in ornithischians and modern endotherms. However, it resembles patterns in modern ectotherms, which are often larger at warmer latitudes. Our results indicate distinct evolutionary responses to climate change among major groups of dinosaurs, and suggests that sauropodomorph physiology was distinct from that of ornithischians, and also from that of mammals.

Nothosaur foraging tracks from the Middle Triassic of southwestern China

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The seas of the Mesozoic (266-66 Myr ago) were remarkable for predatory marine reptiles, but their modes of locomotion have been debated. One problem has been the absence of tracks, although there is no reason to expect that swimmers would produce tracks. We report here seabed tracks made by Mesozoic marine reptiles, produced by the paddles of nothosaurs (Reptilia, Sauropterygia) in the Middle Triassic of the Luoping localities in Yunnan, southwestern China. These show that the track-making nothosaurs used their forelimbs for propulsion, they generally rowed (both forelimbs operating in unison rather than alternately), and the forelimb entered medially, dug in as the paddle tip gained purchase, and withdrew cleanly. These inferences may provide evidence for swimming modes, or it could be argued that the locomotory modes indicated by the tracks were restricted to such contact propulsion. Such punting behaviour may have been used to flush prey from the bottom muds.

Ecomorphological and functional convergence in extant birds of prey

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Birds are one of the most diverse clades of modern vertebrates, and have historically been regarded as a classic group in which to study adaptation through evolution. Different lineages of birds often display remarkable convergence in their cranial and beak morphologies, frequently presumed to be associated with similarity in dietary niche. We tested this assumption by performing three-dimensional Geometric Morphometric analyses within a subset of extant neognathous birds, the diurnal birds of prey. Recent molecular phylogenies have classified this group as polyphyletic. There are therefore multiple examples of convergence within this subset of birds, for instance between the falcons (Falconidae) and hawks (Accipitridae), or between the Old World vultures (Accipitridae) and New World vultures (Cathartidae). Principal component analysis showed that raptorial morphology is highly conserved, with skull and beak morphologies clustering together across all clades. Despite this, shape does not appear to be a strong predictor of preferred prey items, except in birds with highly specialised diets such as carrion feeders (the Old and New World vultures). Instead, strong allometric and phylogenetic signals were detected, showing how feeding ecology alone is insufficient to explain the variety of forms seen in extant birds of prey. Finite Element models of beaks from representative species across the morphospace show how functional variation is accommodated within raptors. This is reflected predominantly as differences in resistance to bending between long- and short-beaked forms.

A re-description of *Mycterosaurus smithae*, an Early Permian eothyridid, and an examination the phylogeny of pelycosaurian-grade synapsids

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Mycterosaurus smithae, from the Early Permian of Colorado, was first described in 1965 as a second species of the genus *Mycterosaurus*. While the type species of this genus, *Mycterosaurus longiceps*, has been shown by multiple cladistic analyses to belong to the basal synapsid family Varanopidae, *Mycterosaurus smithae* has been largely ignored. Now further preparation has revealed more details of the skeleton, allowing a detailed re-examination. *Mycterosaurus smithae* lacks many of the characteristics of mycterosaurines and varanopids: it lacks a slender femur, serrated teeth and a lateral boss on the postorbital. Instead, the large supratemporal and the reduced contribution of the lacrimal to the orbital margin support its assignment to Eothyrididae, while the postcranium shares many characters with the eothyridid *Oedaleops*. *Mycterosaurus smithae* was included in an expanded version of a recently published phylogenetic analysis of pelycosaurian-grade synapsids. All most parsimonious trees found *Mycterosaurus smithae* to be the sister taxon of *Eothyris* within the Eothyrididae. The addition of postcranial material of eothyridids and the inclusion of the recently described basal caseid *Eocasea* confirms the recently disputed position of caseasaurs as the most basal synapsids. As the parsimony analysis produced low support values and a lack of resolution, further analyses were undertaken using Bayesian and

Implied Weights methods. While the results are similar, alternative positions for *Oedaleops* and *Echinerpeton* are suggested by Bayesian analysis. The fit of the different phylogenetic hypotheses to the stratigraphic record was tested using the Gap Excess Ratio, with the results of the Bayesian analysis being most consistent.

Gastornis island: the peculiar composition of the Palaeocene terrestrial vertebrate faunas of Europe

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In most Cenozoic terrestrial vertebrate assemblages, the largest animals are herbivorous mammals. Exceptions are to be found on some islands, such as Madagascar and New Zealand, on which giant flightless birds (aepyornithids, dinornithiformes) were the largest tetrapods until the arrival of humans. Our research on the ecology of the Palaeogene giant bird *Gastornis* show that during the Palaeocene the continental ecosystems of Europe were unlike those of the other northern continents and exhibited a very peculiar structure, similar in many respects to that of the above-mentioned insular ecosystems. The Palaeocene mammals of Europe were generally small forms, the largest taxon being the omnivorous arctocyonid *Arctocyon primaevus*, with an estimated body mass between 18 and 44 kg. *Gastornis*, with an estimated body mass of 108-193 kg, was by far the largest terrestrial vertebrate. Geochemical and morphofunctional investigations have shown that *Gastornis* was herbivorous. It thus appears that the Palaeocene terrestrial ecosystems of Europe were dominated by giant plant-eating birds. This is unlike the situation in North America and Asia, where the largest Palaeocene vertebrates were herbivorous pantodont mammals weighing up to 600 kg. The isolation of Europe during the Palaeocene may have resulted in insular conditions under which gastornithids (and the smaller remiornithids) could flourish while mammals remained small. Conditions changed drastically at the beginning of the Eocene when new intercontinental connections brought large herbivorous mammals to Europe and allowed *Gastornis* to disperse to Asia and North America.

Biomechanical trends and functional shifts in sauropodomorph craniodental evolution

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The Sauropodomorpha included the largest known terrestrial vertebrates and were the first dinosaur group to achieve a global distribution by the Early Jurassic. Whilst basal 'prosauropods' were relatively unspecialized omnivores, the origin of Sauropoda is marked by characters hypothesized to have increased cranial robusticity associated with a shift towards bulk-feeding and obligate herbivory. Derived diplodocoid and titanosaur lineages then show convergent characters hypothesized to represent functional convergences towards a specialized diet. A combination of multivariate analysis of biomechanical characters, osteological and myological reconstruction, finite element modelling and analyses of biomechanical character evolution was used to test whether divergent sauropodomorph clades achieved herbivory in similar ways. Results demonstrate that 'prosauropod' taxa are characterized by relatively gracile and mechanically inefficient skulls and mandibles, but are also highly disparate – potentially relating to variation along the omnivory/herbivory spectrum. A functional shift towards increased cranial robusticity, mandibular efficiency and the onset of tooth occlusion is observed at the base of the Sauropoda, consistent with a shift towards bulk-feeding on coarse matter. Whilst more basal eusauropods remained adapted towards accommodating high bite forces, diplodocoids and titanosauriformes show convergent trends towards lower bite forces, more gracile jaws and shearing dentitions. Despite this overlap, the Diplodocidae remain distinct from all other taxa. Modelling of biomechanical character evolution demonstrates significant changes in rate associated with both the Diplodocoidea and Titanosauria, and some evidence for a shift at the base of the Sauropoda. Comparison with body mass demonstrates common phylogenetic trends in both, but little overlap in significant rate shifts.

Opening up the dipnoan brain: new insights from the cranial endocast of *Dipterus valenciennesi*

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Dipterus valenciennesi is an iconic fossil lungfish. Described by Sedgwick and Murchison in 1829, it was the first Middle Devonian fossil fish to be described from Scotland and is also one of the most common. Specimens are typically flattened, but rarer three-dimensionally preserved crania provide the opportunity to investigate the endocranial morphology in unprecedented detail. The quality of information gained from micro-CT scans of two specimens reveals information about the brain cavity and rostral tube system in a level of detail comparable to material from the famous Upper Devonian Gogo locality in Western Australia. The endocasts have allowed

quantitative comparison of key endocranial features such as the utricular recess, ampullae of the labyrinth system as well as the volume of nerve and vessel canals. Coupled with reconstructions of the lateral line system, these data form a key resource to commence testing hypotheses of sensory development in the Dipnoi, between fresh water and marine taxa for instance, as well as charting the evolutionary trajectory of brain form between sarcopterygian groups.

A new representative of stem-lineage Zatheria (Mammalia) from the Middle Jurassic (Bathonian) of the Isle of Skye

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The Middle Jurassic is arguably most poorly-known interval of early mammalian evolution. Great Britain has yielded the greatest fraction of material of this age, primarily from the Bathonian of Oxfordshire and the Isle of Skye. The British record captures an important period in cladotherian evolution, with amphitheriids, peramurids and stem zatherians documenting intermediate talonid morphologies on the line towards more advanced tribosphenid molars. Although fragmentary "eupantothere" material was first reported from the Isle of Skye in the 1980s, it is yet to be described. Here, we present the nearly-complete lower jaw of a stem zatherian from the middle-Bathonian Kilmaluag Formation, near Elgol, Skye. The specimen, which preserves one incisor, the canine, four premolars and five molars, with one vacant alveolus between premolar and molars, shares dental characters with the contemporaneous amphitheriid *Amphitherium rixoni* and the slightly younger stem zatherians *Palaeoxonodon* and *Nanolestes*. Critically, the talonid exhibits a narrow, incipient basin bounded by two cristae, a feature absent in the less-derived amphitheriids. A small cuspule identified as the 'mesoconid' is shared with *Palaeoxonodon* and *Nanolestes*. The dental formula is intermediate between the primitively large number of postcanine teeth in *Amphitherium* and the reduced number in peramurids and boreotherians. The new taxon illuminates a key period of therian evolution, otherwise known largely from more fragmentary jaws and isolated teeth, and places new constraints on the timing of origin of an incipient talonid basin, a key feature of tribosphenic molars, occurring ~1 Myr earlier than previous records.

Probing the third dimension: are morphospaces derived from 2D and 3D fossil fish crania congruent?

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Landmark-based geometric-morphometric (GMM) studies of fossil fishes have focussed on two-dimensionally preserved compression fossils. In addition to being less abundant, three-dimensionally preserved fossil fish material presents technical challenges, and to date 3D GMM has rarely been applied. Two-dimensional GMM analysis of 3D biological structures is a common procedure in palaeontology and neontology, using photographs taken in standardised orientations to record the features of interest in a two-dimensional coordinate plane. By contrast, researchers studying compression fossils are constrained to landmark specimens in their preserved orientations, and it remains unclear how faithfully compression fossils capture shape information present in specimens prior to taphonomic flattening. To assess potential discrepancies between shape information preserved in 2D and 3D material, we quantified shape variation in the skulls of Late Cretaceous to Paleogene teleost taxa that are known from both inflated (drawn primarily from the English Chalk and London Clay) and compressed specimens (drawn from sites in Lebanon, Italy, USA and the former USSR) using geometric morphometrics. Mantel tests of matrix correlation suggest a significant - but weak - correlation between the relative positions of taxa within morphospaces derived from flattened specimens and fully inflated skulls. This covariation appears to be driven almost exclusively by the first shape axis which, in both datasets, summarises variability in skull elongation. Differences in skull proportions associated with the third dimension (e.g., broad versus laterally compressed skulls), dominate over more subtle forms of morphological variation in 3D morphospace; however, these are lost or conflated in compression fossils preserved in lateral view. Thus while the major axis of cranial variation is comparable in morphospaces derived from flattened and inflated fossils, three-dimensional landmark constellations capture substantial shape information that cannot otherwise be extracted from flattened specimens.

Testing developmental biology predictions with fossils - dental complexity and evolutionary rates of the Multituberculata

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The increase in maximum complexity of tooth morphology through the evolutionary history of mammals is marked. However, recent genetic and developmental studies suggest increases in morphological complexity are developmentally constrained and more difficult to achieve than reductions. Thus, over evolutionary time scales, we might expect increases in morphological complexity to occur less frequently than decreases. To address this hypothesis we studied patterns of change of tooth complexity in the extinct mammalian order Multituberculata, the most successful Mesozoic mammal clade and the longest-existing mammalian order known. We used diversification rate, phylogenetic comparative, and evolutionary rate analyses, allied with a phylogeny and dataset recording functional parameters including toothrow dental complexity, tooth cusp number, and estimated body mass, to determine patterns and rates of morphological evolution and change in complexity. Dental complexity was quantified using 3D digital tooth models from laser-/CT-scanning lower toothrows and Orientation Patch Count, a measure of morphological complexity. Results show significantly more increases in dental complexity than decreases across Multituberculata, suggesting selection for higher complexity outweighed developmental constraints. However, within the only clade to acquire sufficient dental complexity to become predominantly herbivorous, equal decreases and increases in complexity occurred. It appears that once selection pressures for further complexity increases were relaxed, reassertion of developmental constraints balanced selection. Results from this fossil clade can be used to test developmental results and predictions regarding rates and direction of change of morphological complexity, and offer hope for bridging the gap between micro- and macro-evolutionary studies.

Convergence vs. specialization in the ear region of moles

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We investigate the ear region of fossorial mammals to explore the extent to which they rely on vestibular vs. cochlear sensation. We find that the inner ear of fossorial mammals shows varying levels of convergence in form, but chrysochlorids differ from other burrowing mammals in their extensive cochlear coiling. Chrysochlorids show a much longer and more coiled cochlea than talpids (and most other mammals), which may be due to their greater ecological dependence on low frequency auditory cues. The relative lengths of the semicircular canals are similar in fossorial talpids and chrysochlorids, and within the family Talpidae there is significant variation in the form of the labyrinth depending on ecological niche specialisation. The absence of similar osteological evidence for low frequency hearing in the inner ear of talpids may indicate a greater reliance on other senses to enable hyperfossoriality, such as tactile sensation from vibrissae and Eimer's organs. The morphology of the bony labyrinth and middle ear shows that chrysochlorids are heavily reliant on acoustic perception. Although talpid and chrysochlorid moles exploit similar habitats, they do so with different modes of perception, with an emphasis on tactile sensation in talpids and on acoustics in chrysochlorids. The reliance of chrysochlorids on sound is evident in the diversity of its mallear types, and may explain the lack of any semiaquatic members of that group. In contrast, adaptations in the vestibular and trigeminal regions show some overlap in fossorial and semiaquatic mammals, enabling talpids to thrive in both habitats.

The birth of a dinosaur track: sub-surface 3-D motion reconstruction and discrete element simulation reveal footprint 'ontogeny'

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Footprints, both modern and fossil, represent sedimentary distortions that provide anatomical, functional, and behavioural insight into trackmaker biology. Such interpretations can benefit from understanding the mechanisms of footprint formation. Yet the development of track morphology is obscured by both foot and sediment opacity, which conceals animal-substrate and substrate-substrate interactions. We used X-ray Reconstruction of Moving Morphology (XROMM) to image and animate the hind limb skeleton of guineafowl traversing a dry, granular material. The reconstructed 3-D foot motion was integrated with a validated substrate simulation employing the Discrete Element Method (DEM), resulting in a quantitative model of limb-induced substrate deformation. By defining sedimentary layers based on initial particle position, we were able to observe the track at multiple levels throughout its formation, and thus link morphological features of tracks with the motion of the foot, both at the surface and at depth. What was initially most striking was that even in loose, granular sediment, tracks with high definition were formed throughout the track volume beneath the sediment-air interface. Transmission played only a very minor role, with most observable deformation occurring close to the path of the foot. Despite the appearance of clear tracks on multiple surfaces, which could easily be misinterpreted as shallow tracks, none accurately represented the geometry of the foot due to its oblique interaction with the sediment. Linking the DEM and XROMM techniques has allowed for a direct correlation between track features and foot motions, and serves to illustrate the complexities inherent in interpreting fossil tracks in light of track maker, behaviour, or function.

The Evolution of Speed

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The placoid scales of extant sharks have several important functions, amongst which drag-reduction has been a particular focus in biomechanical and engineering investigations. Several mechanisms contribute to this effect, including region-specific scale morphology, but the most important appears to be ribletting of the scale crown surface. The parallel riblets that ornament the dermal denticles of some of the fastest modern sharks are known to reduce skin friction by up to 10%, improving the efficiency and speed of their movement. Despite early observations that some Palaeozoic fish scales resemble those of modern sharks, the hydrodynamic significance in these extinct taxa has not been investigated. Riblets have been identified in several 'acanthodians' and thelodonts, allowing direct comparison with extant shark species of observable ecology. Analysis of 50 modern sharks revealed significantly narrower riblet spacing in faster-moving species, meeting a functional optimum for higher speeds. Values for the fastest pelagic sharks are comparable to those in both thelodonts and 'acanthodians' that show the same adaptation. *Tantalepis*, the oldest (mid Ordovician) microsquamation yet described, also has parallel riblets, with spacing in the mid-range of modern pelagic sharks.
These modifications are evidence for niche partitioning during the Palaeozoic nektonic revolution, which saw a large-scale ascent into the pelagic realm. In an environment with three dimensions, where food is unevenly distributed and with nowhere to hide, speed and efficiency of sustained movement is a key advantage. Our results demonstrate that novel and sophisticated drag-reduction adaptations existed at a remarkably early stage of vertebrate evolution.

A new metriorhynchid from the Oxford Clay Formation and its implications for the evolution of Geosaurinae

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The metriorhynchid thalattosuchians from the Oxford Clay Formation (OCF) (Callovian-early Oxfordian) of the UK are typically thought to represent a well understood fauna. However a newly described taxon, *Tyrannoneustes lythrodectikos*, shares some of the wide-gape macrophagous characteristics of the Late Jurassic to Early Cretaceous subclade Geosaurini. Moreover, *Dakosaurus*-like teeth have been known since the 19th Century. Here we show that there was a species in the OCF which seems to have strong affinities with the Late Jurassic to Early Cretaceous genus Geosaurus. The specimen is a slightly distorted anterior mandibular symphysis from an unusually small individual, which preserves numerous broken teeth in situ. It shares with *Geosaurus* three apicobasal facets on the labial surface of the tooth crowns. As with Late Jurassic specimens of *Geosaurus*, all preserved teeth have this 'faceting'. Scanning electron microscopy reveals microscopic denticles along the preserved carinae. The presence of *Dakosaurus*-like teeth in the OCF, and also this *Geosaurus*-like specimen, means that the timing of the evolution and radiation of Geosaurini is unclear. Previously, Geosaurini was thought to have diversified during the Late Jurassic, but these specimens suggest an earlier origin for this subclade. This raises tantalising evolutionary questions, which are currently under investigation. Finally, the discovery of Geosaurini-like taxa in the OCF emphasises the importance of a specimen-level re-evaluation of the metriorhynchid specimens held in UK museums.

A plesiosaur from the Aalenian of Ormalingen, Switzerland — or — How a creationist website contributed to science.

Richard Forrest
plesiosaur.com

Bones from an Aalenian locality in the Farnsberg near Ormalingen, Switzerland, were first discovered by Fritz Schmutz (Gelterkinden) in 1990. Additional fragments were collected by Herr Schmutz from the tallus over a period of several years and a systematic excavation was undertaken in 2003, during which the material from the stratigraphic horizon of the specimen was systematically collected. Very little has been published in the scientific literature on plesiosaurs from Aalenian deposits. Plesiosaurian faunas from the Lower Jurassic, and from the Callovian are well-known, form the basis for much of our knowledge of plesiosaur anatomy, and are important to an understanding of their phylogentic relationships. However, we know that there are substantial gaps in our knowledge because of considerable differences between the Lower Jurassic and Callovian faunas. The finds were initially identified as a collection of plesiosaur, ichthyosaur and marine crocodile material. A systematic investigation of the material concluded that all the bones are plesiosaurian. No elements are duplicated, and most come from the posterior portion of the skeleton. The loose elements are in general more anterior, and the large block from closest to the rock face contains the most posterior caudal vertebrae and a pubis. This suggests

that the more anterior portion has been lost to erosion. The area below the find locality is steeply sloping and heavily forested, which makes the recovery of any additional and more anterior elements of the skeleton highly unlikely. Although the material represents only a small part of the whole skeleton, there is sufficient to gain some taxonomically useful information, which throws some light onto plesiosaur evolution.

Do the large browridges in *Homo heidelbergensis* have a mechanical role?

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With the exception of *Homo sapiens*, all hominin species present a well-developed supraorbital ridge. Two main hypotheses have been suggested to explain large ridges. The first is that the morphology of the supraorbital region arises due to the spatial relationships of the brain, cranial base and orbits. Under this model browridges have no particular mechanical significance. The second posits that the supraorbital ridge develops to resist stresses and strains experienced by the craniofacial skeleton during masticatory loading. To test the second, mechanical hypothesis, a specimen of *Homo heidelbergensis* (Kabwe 1) was virtually reconstructed and the morphology of the browridge was manipulated by (1) reducing its size and (2) creating a post-orbital sulcus. Voxel based FE models of the non-manipulated and manipulated specimens were created, loaded and solved to compare modes and degrees of deformation among them. The results indicate that changing the morphology of the browridge does not impact significantly on facial mechanical behaviour during simulated masticatory function. These results falsify the mechanical hypothesis, indicating that growth and development of the browridge is not driven by biomechanical adaptation to masticatory loadings. The findings are consistent with the spatial hypothesis. However, the browridge is bigger than it needs to be to simply fulfil spatial demands. Thus, other factors, such as social signalling, may also partially explain the highly developed browridge of Kabwe 1.

Chisel-tooth digging behaviour strongly constrains cranial shape: the case of African mole-rats (Bathyergidae, Rodentia)

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African mole-rats are active fossorial rodents, and consist of five chisel-tooth digging genera (*Heterocephalus*, *Heliophobius*, *Georychus*, *Fukomys*, and *Cryptomys*) and one scratch digger (*Bathyergus*). *Heliophobius*, which is the most active digger, has been recently described as having a continuous replacement of cheek teeth. The influence of their fossorial mode of life in shaping the cranial morphology has yet to be evaluated in comparison to other Ctenohystrica, especially fossorial genera. We seek to determine how deeply fossorial activity and dental replacement constrained the evolution of the skull and its associated musculature. 3D geometric morphometric analyses were performed on 300 skulls encompassing 64 genera of Ctenohystrica and complemented by biomechanical studies for which we measured resistance arms of incisors, and moment arms of temporal, deep masseter and superficial masseter mucles. According to PCA and virtual deformations, mole-rats and fossorial rodents, differ from most Ctenohystrica in having a shorter rostrum, a wider crania with enlarged zygomatic arches, and a mandible enlarged in a marked hystricognathous way. These trends are amplified for chisel-tooth diggers. All mole-rats but *Bathyergus* differ in showing moment arms of the deep masseter less elevated. *Heliophobius* also displays the most important moment arms of temporal. These data are consistent with their fossorial activity and show that their skull shape and musculature are strongly constrained by the use of incisors during digging. They also point out that the continuous dental replacement has little impact on the cranial musculature, and is rather related to the intense digging activity involving strong dental wear.

Developmental integration channelled morphological response to environmental stress in Late Pleistocene carnivorans

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The study of phenotypic integration allows for the estimation of genetic and developmental interactions through the quantitative analysis of morphology, including that of fossil organisms. For example, the developmental contribution to integration, and its influence on morphological evolution, can be estimated by measuring fluctuating asymmetry. Comparative analyses of integration and asymmetry have the capacity to unify macro- and microevolutionary scales of study, and permit simultaneous analysis of intrinsic and extrinsic influences on organismal evolution. Lab experiments examining the microevolutionary effects of short-term environmental stress have demonstrated that fluctuating asymmetry increases in stressed population but that this variation was

channelled along the same directions as normal variation. To expand these studies to a macroevolutionary scale, we used 3-D morphometric data from 207 specimens of *Smilodon fatalis* and *Canis dirus* from the La Brea tar pits to quantify temporal trends in size, variance, integration, and fluctuating asymmetry in response to Late Pleistocene environmental change. Specimens were separated into four time bins spanning 24,000 years, and analyses demonstrated that *S. fatalis* and *C. dirus* responded differently to presumed environmental stress during this interval. *S. fatalis* showed a gradual decrease in overall integration and an increase in size, variance, fluctuating asymmetry through time, with developmental interactions channelling the increased variance from environmental stress. In contrast, *C. dirus* shows a more volatile pattern, with asynchronous shifts in all attributes through this interval. Consistent with studies of dental breakage, these results suggest that *C. dirus* was more sensitive than *S. fatalis* to short-term environmental changes.

Palaeocene taxa support a Cretaceous origin and Cenozoic diversification of placental mammals

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The end-Cretaceous mass extinction is traditionally considered to be a turning point in mammalian evolution, after which placental mammals are thought to have undergone an adaptive radiation. Counterintuitively, several recent studies of evolutionary rates during this interval have concluded that the end-Cretaceous had little to no significant effect on rates of character evolution. These studies, however, include little data, if any, from fossil taxa that occur just after the Cretaceous-Palaeogene (K/Pg) boundary, relying largely or solely on extant and Cretaceous taxa. Here, we used branch-sharing methods to date a new phylogeny of 174 eutherian mammals, containing the largest sample of Palaeogene taxa to date. Uncertainties in first appearance dates were accounted for by randomising dates within stratigraphic ranges. Rates of discrete character evolution were calculated for each branch under various optimisations. We identified branches for which the observed amount of change was significantly greater than expected by a clocklike model of character change, and time-binned the branches. We find an increase in the proportion of branches with significantly high evolutionary rates associated with the end-Cretaceous mass extinction, as well as a dramatic increase in absolute rate of evolution per unit branch length, indicating that an increase in evolutionary rate consistent with an adaptive radiation occurred across placental mammals coincident with the K/Pg boundary, but not with the origin of Placentalia. The difference between these results and analyses that failed to find any change in rates associated with the K/Pg boundary can be confidently attributed to the inclusion of Palaeocene mammals.

Dental development in sloths and armadillos (Xenarthra)

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Extant xenarthrans include the armadillos, anteaters, and tree sloths. Except for edentulous anteaters, xenarthrans are unique among mammals in retaining simplified teeth that are usually without enamel, rootless, homodont, and often reduced in number. For these reasons, it is difficult to determine tooth homologies with other mammals. The difficulty in distinguishing tooth types is compounded by the lack of a deciduous dentition (except *Dasypus*). However, the literature on mammalian dental ontogeny has not yet fully considered prenatal series of xenarthrans. Using a large dataset of scanned fetuses of xenarthrans, we provide data on xenarthran prenatal dental ontogeny and identify some developmental criteria with which to recognize homologies with other mammalian teeth. Sloths are an interesting species to study as they are unique in many respects, such as their limited speed, reduced muscle mass, weak endothermy, and variation in morphological features that are quite constrained in other mammals (e.g., vertebral count and patterns of cranial suture closure). Sloths also exhibit anomalous patterns of dental formation, including hyperdontia (extra teeth) and anodontia (loss of teeth). These anomalies occur at a rather low frequency, affecting preferentially the upper dentition. We apply computerized tomography to developmental series of prenatal sloths to further elucidate the patterns of morphological and developmental variation in their dentition.

Evolutionary history of antlers in Cervidae (Ruminantia, Artiodactyla, Mammalia)

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Antlers are unique organs and the synapomorphy of Cervidae (deer). They are branched, osseous outgrowths of the frontal bone, which are shed and rebuilt in intervals. The fossil record of the early Miocene yielded the oldest known antler remains, which were interpreted as non-shed, because of supposed perpetual skin coverage and

the lack of a burr (= well-developed osseous protuberance around the antler's base, always present in extant cervids). A typical indicator for antler shedding is an even, porous, and smooth abscission surface at the proximal end of the antler without sharp breaking edges and with a convex or concave topology; the separation between the deciduous antler and the permanent pedicle appears in the same transversal plane. We undertook comparative morphological scrutiny of the abscission area of antlers from extant cervids (burr-bearing) and of fossil cervids, including burr-less antler fragments of the earliest cervids, such as *Procervulus*, *Acteocemas*, and *Ligeromeryx* from several European early and mid Miocene sites. The results indicate the presence of the antler shedding mechanism in all studied early/mid Miocene cervids, suggesting that a burr is not required to shed antlers. Based on this evidence, we conclude that permanent antlers have not yet been demonstrated and that the process of shedding and regeneration occurred with the first appearance of these organs.

The long tails of sauropods did not evolve to counter-balance their long necks

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It has been hypothesized since the early 20th century that sauropods required long tails to balance their long necks. To test this idea we used 3D digital models of seventeen sauropodomorphs to measure the lengths, masses, and mechanical moments of the neck, tail, and trunk. The models incorporate lung cavities, and low density regions representing systems of air sacs and pneumaticity within the neck and trunk regions. With increasing body mass, the mass of the neck scales positively (1.21 ± 0.10) whereas that of the tail scales inversely (0.88 ± 0.05), and although the moments of both the neck and tail scale positively, neck moments scale up much faster (1.61 ± 0.15) than do tail moments (1.15 ± 0.09). The masses and moments of sauropod tails did not keep pace with those of their necks. We also analysed a giraffe (*Giraffa camelopardalis*), a living, long-necked herbivore with a very small tail. The relative neck mass fraction of the giraffe (21%) is much greater than in any of the sauropod models (up to 11%), yet the giraffe centre of mass is located at 53.2% of the hip-shoulder distance, farther forward than in a tail-less *Diplodocus* model (45.1%). That giraffes can walk, run, and gallop suggests that a tail-less sauropod would have been perfectly stable. We conclude that any function of the tail as a counterbalance to the neck in sauropods was incidental, and that their long tails did not evolve to counterbalance their long necks.

Thermoregulation and scaling of ear size in the Proboscidea

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African elephant ears have been shown to be adapted to dissipate excess body heat heat. However, the limited studies in this area were carried out on one or two individuals. Here we examine scaling of ear size in extant elephants in relation to the physics of heat loss. The results suggest that ears in Asian elephants are not well suited to dissipate heat. Limited brain size data also suggests that this heat-generating organ scales very weakly with mass in African elephants, but more strongly in Asian elephants. Fossil endocasts suggest that the ancestral Proboscidea followed the brain scaling of the Asian elephants. We discuss the implications of this for both thermal ecology and social tendencies of the Proboscidea.

Variation of *Apodemus* mandibular morphology: functional implications

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The ecology and landscape in Western Europe during the Holocene has been considerably altered by human activity, primarily through the introduction of agriculture. It is known that this has resulted in biodiversity changes, although it has been rarely investigated if there have also been concomitant evolutionary changes in native species. *Apodemus syvalticus* has been present in Western Europe prior to the introduction of agriculture, and due to its anthropogenic tendency has not dramatically declined and continues to persist. Micro-mammal species, which have short generation times, can evolve rapidly. The mandibular morphology has also been shown to be highly evolutionarily responsive to functional demands associated with ecological changes, therefore providing a good model for investigating these patterns. A biomechanical model constructed using extant data is used to test the changes in mandibular shape of *Apodemus* from archaeological material across the Holocene. We predict either a functional mandibular change, or non-functional changes reflecting random drift over time, or alternatively that the inherent versatility in *Apodemus* feeding biomechanics has allowed it to persist in a drastically altered ecology. These results will provide important data of long-term human effects on the evolution of organisms in

altered ecosystems. This perspective may permit predictions on how human activity will continue to alter and affect micro-mammal phenotypes and ecological systems.

Hettangian Lufeng predation: more teeth, more taxa?

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Over seventy years since it was first reported by Yang Zhongjian (‘CC Young’), the Hettangian- Sinemurian Lufeng Formation of Yunnan Province continues to provide fresh insights into the Early Jurassic evolution of dinosaurs and other terrestrial fauna. The term 'Lufeng Formation' is now restricted to the unit previously known as the Lower Lufeng Formation or Series; within this revised nomenclature, the formation consists of two subunits: the older Shawan Member and the younger Zhangjia'ao Member, representing the former 'Dark Purple' and 'Deep Red' Beds, respectively. In July 2013, a specimen of the sauropodomorph *Yunnanosaurus* was recovered from a locality near DaWaShan, in the Shawan formation. It consisted of three closely associated sequences of articulated vertebrae (cervical, cervico-dorsal, caudal). One of the cervicals displayed distinct signs of localised brittle deformation, and within 200 mm of this vertebra, 3 teeth and two tooth fragments were found. One of the teeth fitted well in one of the brittle deformation recesses in the centrum of one of the cervical vertebra, and this recess is interpreted as a bite mark. Although the teeth are not as well-preserved as the three shed theropod teeth from *Sinosaurus triassicus* noted last year amongst the remains of a *Yunnanosaurus* recovered from the Qingliangshan Ironworks site, enough of their morphology is identifiable in terms of shape, size and denticulation to make it distinct and likely to represent a new taxon. Thus, the Lufeng Formation continues to contribute to our sparse global knowledge of Hettangian-Sinemurian dinosaur fauna.

***Ichthyosaurus* from Somerset: One variable species or more?**

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During the 19th century, many well preserved specimens of the parvipelvian ichthyosaur genus *Ichthyosaurus* were collected from the uppermost Triassic/lowermost Jurassic strata of Somerset, from quarries in the village of Street and surrounding areas. At that time, two distinct species of *Ichthyosaurus* were recognized from these strata, *I. communis* and *I. intermedius*, the latter based mainly on tooth morphology. Currently, *I. intermedius* is considered to be a junior synonym of *I. communis*, but there is some debate. Our examination of Somerset specimens suggests that more than one *Ichthyosaurus* species is represented, differing in features of the skull, forefin, hindfin, and pelvic girdle. *I. communis* may actually be relatively rare in collections from Somerset. Whether the other species is *I. intermedius* or something else remains to be determined. Unfortunately, the type specimen of *I. intermedius* seems to be lost.

The relationship between skeletal mass and total mass in birds

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The estimation of bone density and mass in extinct animals requires comparative data from living taxa. However, methods of extrapolating total mass from living animals have been controversial even though several methods have been proposed over the years. The traditional approach using total volume and density to calculate mass has often been replaced in favour of the application of allometric relationships such as those between skeletal mass and total mass in birds and mammals. This has been applied to pterosaurs by geometrically estimating the volume of the skeleton. The general consistency of the results suggested that the relationships were representative of all tetrapods, even among distantly related groups. In this study, the results for birds, from previous work, are re-analysed and compared to a new dataset of over 450 specimens, 70 species, and 15 avian orders from the Royal British Columbia Museum (RBCM), Victoria, Canada. Unlike previous studies based on values from the literature, these data include weights taken at the time of collection. The RBCM dataset recovers similar relationships to previous work, but in spite of methodological improvements, correlations are not strong and contain significant scatter. Errors in both studies may exceed 50% concerning the measured mass and mass predicted from the relationship, suggesting that these methods should be avoided as a means of estimating mass in fossil taxa.

The effect of digging on craniodental form in subterranean rodents

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This investigation highlights the specialization of the digging methods observed in a sample of subterranean rodents, with an emphasis on African mole-rats (Bathyergidae). In African mole-rats, the majority of the genera predominantly use their incisors in burrow construction. However, one genus (*Bathyergus*) only uses the forelimbs to dig. It has been observed that in tooth digging mole-rats, the root of the upper incisor extends behind the cheek teeth, whereas in the forelimb digging mole-rat the incisor is rooted above the cheek teeth. It was therefore hypothesised that upper incisor curvature of tooth digging rodents would be distinguishable from rodents that use forelimbs for burrow construction. To quantify upper incisor curvature, the incisor was approximated as a sector of a circle, from which radius of curvature was calculated. Geometric morphometrics was used to quantify the shape of the cranium and mandible to analyse its covariation with the incisors, using 2-block partial least squares analysis (PLS). To account for size, log basilar length was regressed against log curvature of upper and lower incisors. Analysis of covariance showed a significant difference between tooth digging and non-tooth digging upper incisor curvature. PLS also showed a stronger covariation between the cranium and upper incisor in chisel-tooth-digging rodents than in non-tooth-digging rodents. The results therefore show that, for their size, chisel tooth-digging rodents have a larger upper incisor than their non-tooth digging counterparts. To accommodate these larger incisors, the upper incisor and cranium must be closely integrated during ontogeny.

SVPOTW -Sauropod Victim Picture of the Week

Robert Nicholls[1] and Donald Henderson*****[2]
1 - Paleocreations.com
2 - Royal Tyrrell Museum

Motivated by the work of palaeo-art “Double Death (2011)”, a biomechanical analysis using three-dimensional digital models was conducted to assess the potential of a pair of the large, Late Cretaceous theropod dinosaur *Carcharodontosaurus saharicus* to successfully lift a medium-sized sauropod and not lose balance. *Rayosaurus tessonei* from the Late Cretaceous of South America was chosen as the sauropod as it is more completely known, but closely related to the rebbachisaurid sauropods found in the same deposits with *C. saharicus*. The body models incorporate details of the low density regions associated with lungs, systems of air sacs, and pneumatised axial skeletal regions. These details, along with the surface meshes of the models, were used to estimate the body masses and centres of mass of the two animals. It was found that a 6 t *C. saharicus* could successfully lift a mass of 2.5 t and not lose balance as the combined CM of the body and the jaw load would still be over the feet. However, the neck muscles were found to only be capable of producing enough force to hold up the head with an added mass of 424 kg held at the midpoint of the maxillary tooth row. The jaw adductor muscles were more powerful, and could have held a load of 512 kg. The more limiting neck constraint leads to the conclusion that two, adult *C. saharicus* could successfully lift a *R. tessonei* with a maximum body mass of 850 kg and a body length of 8.3 m.

A three dimensional structural model of a large pterosaur wing: implications for the membrane properties.

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Using CT scans of ornithocheirid specimens in the Natural History Museum and the University of Portsmouth, the structural properties of the complete wing spar of a circa 6 m wingspan pterosaur have been reconstructed. The model confirms earlier, more tentative conclusions that the axis of greatest bending stiffness changes along the spar, from dorsoventral in the proximal bones to anteroposterior in the distal wing phalanges. This unbalanced disposition of cortical material in the phalanges suggests that resisting membrane tension was a strong functional constraint, which in turn implies that membrane flutter (which is controlled by membrane tension) was a major influence on the evolution of the wing morphology. In the absence of extensive soft tissue preservation it is impossible to directly reconstruct the mechanical properties of the membrane, but the well defined properties of the wing spar allowed upper limits to membrane tension to be determined. These results were combined with a generalised analysis of membrane fluttering to establish the mechanical properties needed to provide membrane stability. These values were in turn used to determine the likely composition of biological materials in the membrane. The result showed that reinforcement with a high modulus material such as keratin is required: a skin-like soft tissue membrane alone would have inadequate tensile strength and be excessively elastic. This result provides a clear functional explanation for the well established presence of fibrous actinofibrils in the distal wing.

Testing a morphological dataset for the robustness of fossil placement: a case study using salamanders

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Prevalent neoteny and associated convergence in morphology has made it difficult to resolve salamander interrelationships using purely morphological characters. However analysis of morphological data is still the only way to incorporate fossils into phylogenetic analyses. Many new fully articulated fossil salamanders have emerged, especially from China, and it is important to be able to place them within a phylogenetic framework to better understand the origin and radiation patterns of early salamanders. A new morphological data set comprising 249 characters has been created to encompass representative taxa from all ten families worldwide. Methods for identifying incongruence due to homoplasy were applied to the new dataset. Both tree-dependant parsimony-based (retention index) and tree-independent compatibility-based (Le Quesne) probability-measures for evaluating character quality were used to produce reduced datasets that it is hoped are more likely to reflect true phylogenetic signal than convergent neoteny in salamander relationships. Fossils were simulated by creating subsets of characters (those commonly found in the fossil record) for extant taxa. Analyses using parsimony and Bayesian inference were performed to test the robustness of the placements of these simulated fossils. The impact of missing data caused by poor preservation and incomplete specimens can therefore be tested by simulating reduced/limited character scores for living taxa, and then comparing the phylogenetic placement of these artificially degraded taxa with their 'true' position based on complete data. While the new morphological dataset has not yet resolved the relationships between salamander families, it can group the simulated fossils accurately to family.

The jaw adductor muscles of wild canids.

Fay Penrose, Graham Kemp and Nathan Jeffery

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Canids have evolved a diverse range of morphologies and body masses to enable them to exist in many different environments. Both convergent and divergent patterns of morphological adaptation are found within and amongst the different genera. This indicates that canids are highly adapted to their specific environmental niches and that anatomical form and biomechanical function are closely aligned. Across all canid species the most morphologically diverse region is the head. The masticatory apparatus is used for prey capture as well as food processing and so must be adapted to seize, kill and butcher prey. Different trophic groups place different demands on their masticatory apparatus and as such biomechanical trade-offs must occur between competing constraints such as gape, jaw closing speed and bite force. Previous studies that have considered bite force and jaw biomechanics in carnivores have focused mainly on dry skulls to estimate jaw adductor muscle masses. However, this provides no detail of the geometry and internal architecture of specific muscles. In addition, previous studies have used estimated muscle masses as a proxy of muscle force production. This study describes the temporalis, masseter and pterygoid muscles of eleven canid species and calculates their force production capabilities. The architecture of the muscles was consistent across species. Muscle masses and total jaw adductor forces were found to scale isometrically with body mass. We found the temporalis contributed less muscle force capability than predicted by muscle mass, whereas the masseter and pterygoids contribute a greater percentage of muscle force than predicted by muscle mass.

Morphological and functional variation in the theropod dinosaur mandible

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Ecomorphological variation can be used as a proxy for variation in feeding ecology in extinct animals, where behaviour cannot be directly observed. Whether inferences from ecomorphology are congruent with inferences of feeding behaviour from biomechanical analysis within clades is unclear. Here we use Geometric Morphometrics (GMM) and finite element (FE) modelling to discern the variation in mandibular shape and function in non-avian theropod dinosaur taxa. Six two-dimensional landmarks and 50 semilandmarks were used to capture the variation in jaw shape from 103 taxa. We focused upon the lower jaw so as to minimise the influence of non-feeding structures found in the cranium (sensory organs, possible display structures) on jaw shape and hence feeding signal. After Procrustes superimposition and Principal Component Analysis (PCA) was performed in PAST, MorphoJ and R, we find that the largest proportion of variation is explained by changes in jaw robustness (mandibular length and depth), with a change in the relative size of coronoid process playing a key role. Oviraptorids are morphologically and biomechanically distinct to all other taxa in the analysis (NPMANOVA, $p<0.05$) and contribute disproportionately to overall disparity. There is some partitioning of taxa based on feeding

ecology, with supposed omnivorous and herbivorous taxa occupying statistically distinct regions of morphospace from carnivorous taxa (NPMANOVA, $p<0.05$). Morphological disparity (sum of variance) increases from the Late Triassic to the Late Cretaceous, with a rapid increase from the Late Jurassic onwards, linked to the diversification of Maniraptora. We find that jaw strength is tied to morphological variance, and demonstrate how changes in morphology influence the feeding capabilities of the theropod jaw.

The gerenuk's reversal: an integrative approach to the evolutionary history of the giraffe-necked antelope

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The gerenuk (*Litocranius*) is a remarkable antelope of east Africa. Most striking is its capability to hold a balanced bipedal posture on remarkably long and robust hind limbs during foraging. This, in combination with an elongated neck, enables the gerenuk to select delicate plant parts among thorns from high bush levels without competition. Many more peculiar allometries related to this unique feeding strategy render the gerenuk profoundly different from other antelopes.
This raises interest in the evolutionary history of *Litocranius*. But although ruminant remains from the Plio-Pleistocene are especially abundant in east Africa, the fossil record hasn't yielded *Litocranius* specimens so far, suggesting a relatively recent divergence from its ancestor. Phylogenetic analyses place the gerenuk within gazelles, predominantly intermediate feeders in semi-arid and arid areas of Asia and Africa.
Here we report on different aspects of the gerenuk's dentition and digestive physiology. Within a framework of comparative morphology and physiology we demonstrate that the gerenuk, one of the most exclusive of browsers among modern antelopes, has built its extremely specialized adaptation on one of an already highly specialised intermediate feeder. Taking a more general view, we highlight the relevance and potential of such integrated approaches for revealing the evolutionary history, especially reversals, of traits and adaptations. This may well be of use in assessing character evolution and any kind of relationship (e.g. in phylogenetics, palaeoecology, functional morphology, evolutionary theory).

Dental morphology of mammals is less reliable than osteology: Phylogenetic differences align with taphonomic biases

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In order to construct the evolutionary relationships of extinct taxa, palaeontologists rely on the morphology of fossils. The fossil record is, however, beset with missing data and preservational biases. Under such circumstances, it is doubly important to consider whether phylogenetic signal is evenly distributed across classes of morphological data. Mammal teeth are robust and are concomitantly preserved more frequently than bones. This, combined with their morphological variability, means that dental data are often the focus of phylogenetic investigations of mammals, despite doubts concerning their utility in this context. Analysis of 44 published mammal datasets finds significant differences between the phylogenetic signal contained within dental and osteological character partitions. This in itself raises questions about interpretations of fossil mammal phylogeny but does not indicate which of the two partitions are more indicative of evolutionary history. Optimization of morphological characters onto published molecular trees available for 29 of the extant mammal clades finds higher retention indices for osteology in 72% of datasets. Osteological data are therefore significantly more consistent with molecular trees than dental data are. These combined analyses reveal problematic biases with respect to mammal phylogeny: dental morphology is more likely to be preserved but is also more likely to be at odds with phylogeny inferred from independent molecular data. This indicates that caution needs to be applied to the wide range of evolutionary inferences based solely or largely on fossil mammal teeth and, more broadly, that taphonomic biases disrupt phylogenetic reconstruction.

Chondrichthyan diversity in the early Carboniferous: new evidence from the Tournaisian of northern Britain

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The end-Devonian extinction event marked a profound change in the diversity of fishes. The dominant Devonian taxa, the acanthodians, placoderms and sarcopterygians, were suddenly and irrevocably replaced by minor components of the fauna, the actinopterygians and chondrichthyans. This replacement began in the early Carboniferous but the evidence for it is poor. Few localities are known and fossils are rare. Until recently, the earliest Carboniferous chondrichthyans were known mainly from teeth collected from two localities in Russia and one in Canada. In the UK, the entire Tournaisian chondrichthyan fauna was represented by two teeth. During the past three years field work at two new sites in the Scottish Borders has uncovered an extraordinarily diverse fauna of chondrichthyans. Represented by well-preserved cladodont, xenacanth and bradyodont teeth, most of the taxa are new and undescribed. The bradyodont teeth have been found in large numbers and cover a broad size range, adding to growing evidence that a durophagous feeding habit was common during the recovery following the end-Devonian extinction. This contrasts with later Viséan chondrichthyan faunas which are usually dominated by sharks with cladodont, petalodont and orodont-type teeth. In these later faunas bradyodonts are rare.

First evidence for a monophyletic, non-monospecific Euparkeriidae, and a reassessment of the Chinese euparkeriids

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Euparkeria capensis from the South African Middle Triassic (Anisian) of South Africa is found as the sister to crown Archosauria or on the immediate stem in most phylogenetic analyses. Euparkeria is thus of key importance in elucidating the archosaur radiation following the end Permian extinction events and the subsequent evolution of crown Archosauria. Several taxa have been referred to Euparkeriidae, but whether these taxa in fact form a monphyletic grouping has remained largely untested. Three taxa from China have been referred to Euparkeriidae: *Halazhaisuchus qiaoensis*, "*Turfanosuchus*" *shageduensis*, and *Wangisuchus tzeyii*, all from the Anisian Ermaying Formation (northeast China). We reassess these taxa in light of more recent work on archosaur evolution, and place them for the first time in a numerical phylogenetic analysis. We find *Wangisuchus tzeyii* to be a nomen dubium based on the holotype's lack of diagnostic features; we also conclude that there is not sufficient evidence to unite other material referred to the taxon under a single genus. We find "*Turfanosuchus*" *shageduensis* to be a junior subjective synonym of *Halazhaisuchus qiaoensis*, with no morphological differences of interspecific magnitude distinguishing the taxa. When placed in a cladistic analysis, we find *Halazhaisuchus qiaoensis* to be the sister taxon to *Euparkeria capensis*, with this monophyletic, non-monospecific Euparkeriidae in turn the sister taxon of Phytosauria+Archosauria. This represents the first quantitative evidence of a monophyletic Euparkeriidae which includes taxa additional to *Euparkeria capensis*, though support for the clade is weak and based primarily on osteoderm characters.

Slender Giants

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The giant sauropod dinosaurs are often perceived as having a single uniform body plan: in fact there is great variation between different sauropods. For example, *Apatosaurus* has much more robust limbs than the closely related *Diplodocus*.The brachiosaurids *Brachiosaurus* and *Giraffatitan* have disproportionately narrow dorsal centra compared with diplodocids. They also have the slenderest humeri of all sauropods -- both by length:width ratio, and in proportion to their own femora, which are about 50% bigger in cross-sectional area. This is surprising, as their tall, broad torsos and small tails meant they carried more of their weight on their forelimbs than other sauropods. Exacerbating this paradox, the coracoid of *Brachiosaurus* has a unique ventrolaterally oriented glenoid articulation -- perhaps suggesting a mechanically inefficient sprawled posture, putting the slender humeri under great stress.The femora of brachiosaurids pose another puzzle, being more eccentric than those of other sauropods: the mediolateral width is more than twice the anteroposterior diameter for most of the length of the shaft. The humerus of *Giraffatian* is 5% longer than the femur; the humerus of the *Brachiosaurus altithorax* holotype is eroded at its distal end, but reasonable reconstructions suggest that it too was longer than its femur when complete. The radius and ulna of *Giraffatitan* are also longer than the tibia and fibula, and the forefoot much taller than the hindfoot. These proportional differences show that the shoulders of brachiosaurs were even higher, relative to the hips, than most current restorations show.

Cranial Development in Marine and Terrestrial Mammals

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Numerous anatomical modifications have made cetaceans the most fully aquatic mammals that exist today. Among the most derived of these modifications are those in the cetacean auditory apparatus, whose morphology has no direct parallels to date among extant species. We document cetacean inner ear development over several ontogenetic stages, focusing on the semicircular canals and cochlea. While scientists have published much about the structure and scaling of cetacean ear specializations, there is a shortfall in knowledge of how allometric relationships between cetacean inner ear elements vary at different life stages. Using high-resolution micro-CT data for 31 juvenile and 3 adult cetaceans, we demonstrate that cetacean semicircular canals, known for their miniature size in relation to other mammals, have reached near-adult or adult proportions by the time of ossification during foetal development. Meanwhile, foetal cochleas demonstrate comparable turn diameters and number of turns to those of adult cochleas, but are compressed along the central axis. We also present the inner ear dimensions of a terrestrial artiodactyl, *Sus*, using histological data to compare the early developmental stages of two closely related species and place cetacean ontogenetic development into a phylogenetic context.

Some unusual sauropod dinosaur tracks in the Broome Sandstone (Lower Cretaceous) of Western Australia

Tony Thulborn

The Broome Sandstone (Lower Cretaceous, Valanginian?) of the Dampier Peninsula, in the Kimberley region of Western Australia, is now known to contain many, varied and unusually well-preserved dinosaur tracks. This ichnofauna constitutes practically the entire fossil record of dinosaurs in the western half of Australia and is more ancient than the better-known Cretaceous dinosaur faunas of eastern Australia (Aptian-Albian of Queensland and Victoria). The vast majority of tracks are those of sauropods, most probably brachiosaurs and titanosaurs (or, at least, titanosaur relatives such as *Diamantinasaurus*, *Wintonotitan* and, perhaps, ?*Austrosaurus*). Most of their tracks are transmitted reliefs ('undertracks') but wherever possible observations have been based on examples which are definitely primary impressions ('true' footprints). The distribution of footprints through a range of environmental settings, from intertidal to fully terrestrial (with palaeosols and plants in growth position) provides some insight into the habitat preferences of sauropods. The mean size of the Broome Sandstone sauropod tracks is about the same as that for tracks in the Glen Rose Formation (Trinity Group, Early Cretaceous) of Texas and Arkansas, though both tails of the size distribution are more attenuated in the Broome Sandstone sample. The smallest specimens discovered to date in the Broome Sandstone are well-preserved manus-pes couples; it is difficult to specify the exact size of the largest, though in these the pes print is certainly greater than 150 cm in length (a conservative figure). Some seemingly unique specimens reveal how sauropods interacted with the other animals, plants and obstacles they encountered in life.

3D geometric morphometric analysis of the breast-shoulder apparatus: implications for the locomotor kinematics of anole (Squamata: Dactyloidae) ecomorphs on Caribbean islands

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The breast-shoulder apparatus (BSA) of lizards (consisting of the ribcage, presternum, interclavicle, paired clavicles, and paired scapulocoracoids) is a structurally and kinematically complex entity. The variability of this complex has seldom been the focus of functional explanation, possibly because the BSA has been difficult to analyse and compare as a composite contrivance. Here we apply geometric morphometric techniques to the analysis of the BSA in situ, in an attempt to more fully understand its configuration in relation to differential use in locomotion. Our approach centers upon anoline lizards, a cluster that has been extensively studied from an ecomorphological perspective. The species selected for study represent distantly related forms of both the trunk-crown and trunk-ground ecomorphs sourced from Hispaniola, Jamaica, and Puerto Rico. We hypothesized that species will exhibit variation in the configuration of the BSA that is chiefly explained by its ecomorph assignment. Our findings indicate that the three-dimensional configuration of the shoulder girdle of island anoles is directly associated with specializations related to habitat occupancy (ecomorphology). The members of each ecomorph studied share morphological similarities that have been derived independently, rather than being shared through phylogenetic history. This indicates that the form and function of the BSA is subject to convergent evolution within the anoles of the Greater Antillean islands, in a similar manner to the external morphological traits that have been employed to characterize the various ecomorphs.

Hatchling pterosaurs: still in the air, or back on the ground

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The image of flight-incapable pterosaur hatchlings being fed by their parents has been depicted in several well-known illustrations and further encouraged by the supposed similarities of these Mesozoic fliers to extant birds and bats. Recent studies have challenged this view, arguing that pterosaurs were able to fly soon (hours, or days) after hatching, an idea that has, in turn, been disputed by claims, based on histological analyses, that early growth stages lacked the physiological capability for flight. We used three independent criteria to assess the ontogenetic status of all pterosaurs <0.4 m in wingspan and identified embryonic, hatchling, or near-hatchling growth stages in 13 species distributed among seven principal clades. Flight capability of individuals in these early growth stages (represented by nearly 60 specimens) was assessed against several criteria: ossification of limb bones; relative proportions of limb bones; skeletal growth patterns; presence of flight membranes; aerodynamic properties; and taphonomy. Specimens representing each of the 13 species achieved a positive score for all those criteria against which they could be assessed; overwhelming evidence in favour of the idea that pterosaurs were flight capable from a very early age. Multiple records of small tracks, likely made by juveniles, support the idea that early growth stages were competent locomotors. A counter-argument, that relatively rapid growth rates, inferred from the presence of fibrolamellar bone, precluded flight, lacks an empirical basis: it is not possible to infer particular physiologies from general bone tissue types and the precise energetics of pterosaurs remain unknown and likely unknowable.

Life history of Pleistocene dwarfed hippopotami from Cyprus and Crete

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Fossil insular mammalian dwarfs have variably been reported to show rapid ontogenetic development, slow development, as well as truncation of growth. These three modes of dwarfing have different implications for the life history of the animals under consideration and their morphological plasticity. The three modes of dwarfing have been recognised in different species, on different islands, using different methodologies. It may, thus, be hypothesised that different taxa show different responses to island environments, or that environmental differences are the cause for the different dwarfing modes. Alternatively, the difference may even be a methodological artefact. The main objective of this study was to determine the mode of dwarfing in insular hippopotami using bone histology. Bones of Pleistocene dwarfed hippopotami from Cyprus (*Phanourios minor*) and Crete (*Hippopotamus creutzburgi*), and their normal sized relatives (*Hippopotamus amphibius*), were thin-sectioned and studied under an optical microscope. Type of bone matrix, bone lacunae densities and counts of lines of arrested growth (LAGs) served as proxies for development rate and time. Bones of *P. minor* and *H. creutzburgi* both display highly organised primary bone and multiple LAGs in the outer cortex. These features are incompatible with the typical *H. amphibius* life history and indicate that dwarfed hippopotami had slower growth rates than the common hippopotamus and grew for a longer period of time.

The evolutionary dynamics of dinosaurian body size

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Between 200 and 250 million years ago, the terrestrial Triassic Period was dominated by crocodile-like archosaurs and synapsids, the group from which mammals would eventually evolve. Yet a group of small bodied bipedal animals, the dinosaurs, diversified rapidly in the Late Triassic to seize many ecological niches by undergoing rapid shifts in body size, eventually exhibiting an impressive size range. Previous attempts to understand this radiation have reached ambiguous conclusions because, until recently, only uniform processes could be modelled across the dinosaur tree. We take a phylogenetic approach to show how three evolutionary processes (Cope's rule, speciation, and evolutionary rate) combine to explain the diversification of body size in non-avian dinosaurs. We show that across all non-avian dinosaurs these processes alone interact to account for a large proportion (~30%) of the variance observed in body size. Our results demonstrate for the first time that dinosaurian body size diversity is the product of interdependence between these evolutionary processes.

By the mouse divided: testing sub-segmentation volume values in avian endocasts

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External brain morphology can be determined in fossil birds and some dinosaurs because the brain and brain cavity are so closely associated that the external shape of the brain is impressed on the endocranial surface. The relative development of most major brain regions (e.g., telencephalon, optic tectum of the mesencephalon, cerebellum) can therefore be assessed to some degree by examining regional boundaries on the external surface of fossil brain cavity endocasts. Current micro-CT approaches can be used to create large comparative datasets of brain morphology from digital endocasts in extant avian taxa, in which patterns of taxonomic- and behaviour-related relative brain region composition can be analysed. However, regional volume estimation in endocasts is likely to be unreliable because internal boundaries of these regions, observable within fresh brain tissue ," cannot be traced in these digital models. Here we present preliminary results of a test to determine how closely digital endocast-derived (ED) relative brain region volume fractions (region volume/whole brain volume) approximate the same fractions derived from fresh brain dissections (FD) in a sample of avian taxa. Our results indicate that ED values for some regions (e.g., telencephalon) are not significantly different from the FD values, although other regions are less reliable. Further testing using a broader taxonomic sample is required to investigate whether these findings can be replicated reliably across avian species. If so, this approach may offer a valuable tool for determining the size of some brain regions in fossil birds, and possibly some dinosaurs.

Pneumatic diverticula associated with the spinal cord in birds, sauropod dinosaurs, and other ornithodiran archosaurs

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By the dawn of the 20th century, palaeontologists had realized that sauropod dinosaurs have small neural canals relative to their large size, and therefore their spinal cords must have been small as well. The neural canals of sauropods are also unusual in that they are often taller than wide. This is shown by the fact that the spinal cords of vertebrates are highly constrained in cross-sectional shape, and almost always slightly wider than tall. Therefore not only are the neural canals of sauropods oddly small, it would appear that the meningeal sac containing the spinal cord almost certainly did not fill the entire space. In extant birds, much of the cross-sectional area of the neural canal is occupied by the canalis supramedullaris, a pneumatic diverticulum derived from the lungs and air sacs. The canalis supramedullaris is present in hummingbirds and ostriches and in most size-intermediate taxa where it has been surveyed, so its presence is likely ancestral for birds. It probably evolved much earlier, however. We have identified supramedullary pneumatic foramina in unfused neural arches of a juvenile titanosauriform from the Cloverly Formation (Lower Cretaceous, Aptian-Albian) of Montana, and juvenile *Alamosaurus* from Javelina Formation of Texas (Upper Cretaceous, Maastrichtian). Furthermore, pneumatic features on the vertebrae tend to cluster around the neural canals in both saurischian dinosaurs and pterosaurs. Although the function of supramedullary diverticula is unknown, such diverticula are probably primitive for saurischian dinosaurs, and may have been present in most ornithodiran archosaurs.

SVPCA POSTERS

The Kimmeridge Clay ichthyosaur collection project

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Natural History Museum

The collection is contained within 24 drawers of ichthyosaur specimens from the Kimmeridge Clay stored in the stratigraphically arranged section of the collection and assigned to *Ichthyosaurus* sp. The material is predominately from Dorset, Wiltshire, Somerset and Oxford. Many notable collectors such as Beckles, Bowerbank, Cunnington, Damon, Egerton, Mansell-Pleydell and Mantell contributed to this collection. The aim was to revise the taxomony and re-write documentation by referring to the McGowan & Motani 2003 Handbook of Palaeoherpetology, Part 8, Ichthyopterygia and by checking records in the online KE Emu database completed in 2012. Labels and specimens were cleaned using conservation techniques and re-stored using conservation grade materials. A photographic record was made of sampled storage drawers 'before' and 'after'. New drawer labels were made for both the taxonomically stored specimens and the remaining specimens were re-stored in the stratigraphically arranged section. At least 55% of the *I*. sp material was re-identified as *Nannopterygius*, *Brachyopterygius* or *Opthalmosaurus* and a number of specimens are available to be selected for illustration in the Palaeontological Association Field Guide to the Kimmeridge Clay.

Romer's Gap: Breaking the log-jam

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The previous scant knowledge of fossil vertebrates from the Tournaisian stage has been amplified over the past two years by the discovery of new sites and horizons from the Ballagan Formation of northern Britain. We introduce some of the latest findings from the TW:eed project here. The lowest horizon from Burnmouth, dated as VI zone, is a black organic-rich layer containing gyracanths, *Ageleodus* teeth, rhizodonts, lungfishes and actinopterygians. The gyracanth elements and *Ageleodus* teeth may be associated. Large and small lungfish individuals are represented, including a 100 mm operculum, small skull bones and an unusual tooth plate. In the Tweed Basin a newly discovered vertebrate-bearing horizon at Crumble Edge has yielded at least one lungfish plus rhizodonts and includes endoskeletal preservation. The locality of Tantallon has recently yielded a new type of lungfish tooth plate and a small but highly derived tetrapod humerus. Gyracanth material from a new locality near the River Till promises further finds, as does the recovery of a large tetrapod maxilla and a new lungfish tooth plate from the Heads of Ayr in the Midland Valley Trough. Although superificially similar to the Ballagan Formation, the coeval Horton Bluff Formation (HBF) of Nova Scotia represents quite different conditions, with few cementstones or massive sandstones. Lower parts of the HBF appear more marine in character. Large actinopterygians are relatively plentiful lower in the sequence, including deep-bodied forms. Tetrapod trackways and bones occur higher in the section. Throughout, rhizodonts dominate, but gyracanths are less common and lungfishes are almost entirely absent.

Elucidating Differences in the Feeding Ecology of Extant Apes Using Finite Element Analysis

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Finite element analysis (FEA) is a technique now used by functional morphologists to make predictions about diet in extinct species. For fossil hominins this includes the australopiths, however even in extant specimens we still have minimal understanding of how variations in FE results reflect dietary adaptations. This study investigates whether relative patterns of strain in two extant apes reflect their dietary niches. *Pan troglodytes* and *Gorilla beringei beringei* are closely related yet have distinct morphologies and diets. Due to an abrasive folivorous diet we predict *G. b. beringei* will show a greater resistance to load during molar bites than incisor bites compared to the generalist feeder *P. troglodytes*. Two female crania were reconstructed from CT scans and converted into FE models. A series of loading scenarios compared incisor vs. molar bites at comparable bite forces in both specimens. Strains recorded during molar loading in *G. b. beringei* were significantly lower than those during incisor bites. This suggests *G. b. beringei* is better adapted to resist mechanical loads during molar bites. However, the results of *P. troglodytes* also showed a similar trend and a relatively higher level of strain during an incisor bite. The patterns of strain recorded for these distinct apes were not hugely dissimilar nor could they easily be related to dietary strategy. This study highlights the difficulty of using FEA to infer dietary ecology and suggests caution should be taken when using this technique for the elucidation of feeding behaviours and diet, particularly when examining fossils.

Evolution of the lower jaw of gnathostomes

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The origin of the lower jaw is a key innovation that underpins the adaptive radiation of vertebrates. The jaw has undergone fundamental changes to its composition and has endured major ecological changes including the transitions from water to land, from land to the air, and from land back to water. A shift in lower jaw anatomy or rather a transformation in lower jaw shape may have facilitated the emergence of different feeding behaviors. Here we present an analysis to deduce the timing and tempo of lower jaw shape change through gnathostome evolutionary history. We achieve this via an exploration of lower jaw morphospace and an evaluation of the functional and ecological consequences of lower jaw shape variation. Preliminary results indicate that principal component (PC) 1 accounts for 73% of lower jaw shape variation. PC1 shape variation describes changes to the relative length of the dentary bone and robustness in the posterior lower jaw. PC2 accounts for 14.4% of lower jaw shape variation and describes differences in jaw depth and slenderness of the dentary bone (i.e. changes to the vertical height of the mandible). Acanthodians and amphibians make relatively minor contributions to overall disparity. Archosaurs are distributed along the PC1 axis, but also share a region of morphospace (near the PC2 axis) with both stem amniotes and chondrichthyans. From these results, it is probable that both ecological and functional consequences affect lower jaw shape variation and that transformation in lower jaw shape allowed different feeding behaviors to emerge.

A Possible New Crocodylomorph Partial Skull from the Isle of Wight, England

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The Isle of Wight (IOW)is a well-known island within the United Kingdom that yields unique assemblages of vertebrate fossils. These include a number of archosauromorphs, particularly Dinosauria and Crocodylomorpha. Crocodylomorph taxa include goniopholids, atoposaurids, eusuchians, and various other incertae sedis specimens. Here an incomplete skull of a crocodylomorph from the IOW is examined. The specimen, borrowed from Sandown Bay Academy, has never been recorded in the literature. The exact geological location of the specimen is unknown, as it is supposed to have been collected during the 1800s. It is Cretaceous in age and currently thought to be from the Vectis Formation. It consists of a partial skull, in addition to other elements, embedded in a hard, pyrite-filled limestone, a few of them visible. CT scans and image analysis showed that more bone elements were present within the limestone. Most of the material is highly pyritized and therefore difficult to interpret; however, we currently have identified part of the frontal and parietal, one exoccipital, part of a pterygoid, and possible other bits of skull, as well as three osteoderms. This specimen is being compared to other fossil neosuchians, specifically with: *Goniopholis*, *Hulkepholis* (previously *Goniopholis*) and *Anteopthalmosuchus* specimens in the Booth Museum, Dorset County Museum, and the Natural History Museum, as well as *Vectisuchus* (using photograps and literature) from the Staatliches Museum für Naturkunde Stuttgart. Currently, we believe the specimen to be a species of *Goniopholis* or *Hulkepholis*, as the frontal, exoccipital, and dorsal osteoderm pit pattern resemble those taxa. Further studies in comparative anatomy and phylogenetic analysis (using the updated matrix by Andrade et al. 2011) is underway.

First report of the late Triassic fissure fauna from Woodleaze Quarry, Gloucestershire, UK

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Several Upper Triassic and Lower Jurassic fissure faunas have been reported from the Southwest of the UK. The fissures formed in Carboniferous limestone on an island archipelago spanning from the south of Wales to the north and south of Bristol. They have yielded terrestrial reptiles and mammaliamorphs of great significance, such as *Thecodontosaurus*, *Diphydontosaurus*, *Planocephalosaurus* and *Morganucodon*. Material was collected in 1989, 2012 and 2013 from two fissures from Woodleaze Quarry, beside Tytherington Quarry, whose vertebrate fauna is already well known. The new fissure site extends the lateral distribution of fissures in this vicinity to over 700 m, and fissures sampled along that transect show a southward change in the dominant species and reduction in diversity. The Woodleaze fissure fauna is nearly monofaunal, consisting >99% of a *Clevosaurus* species, as well as a handful of *Diphydontosaurus* fragments, an undescribed lepidosaur and some marine material. Its dentition identifies the clevosaur as *C. hudsoni*, but average long bone length is 20-60% below what is expected. The occupation of a narrow coastal niche may have driven the evolution of a specialised variant

form. Our results reveal a unique fauna with a similar preservation, and comparable in monofaunality, only to *Oligokyphus* in Windsor Hill. The collection also contains individual skeletal elements which were not previously well described, thus expanding our knowledge of clevosaur anatomy. Together with Tytherington, this location offers an exceptional opportunity to study a Triassic terrestrial biota across an extended distance.

Patterns of ecomorphology, functional trade-offs, and masseter evolution in the feeding system across rodents

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Rodents harbour discrete differences in the structure (and presumably function) of their adductor muscles, which characterize the classic masseter muscle configurations (MMCs) of major rodent groups. There are four MMCs, three of which are highly derived and seem to have evolved a number of times independently. Vast ecomorphological radiations, at times ranging all the way from folivores to piscivores, have occurred within each clade that independently evolved derived MMCs. This pattern challenges the view that each distinct type of MMC is good for a certain feeding style, such as specialized chewing or gnawing. An open question is thus whether functional differences in MMCs require morphologically distinct tactics for exploiting the same diets. Using 3D linear morphometrics of mandibles sampled across clades of independently evolved MMCs, we found support for ecomorphological similarity across MMCs when using simple characteristics of the dentition and mandible shape, and we also found a consistent evolutionary trade-off in predicted gnawing vs chewing adaptations across non-myomorph MMCs based on the depth of the incisor beam and occlusal surface area of the cheek teeth. However, adductor muscle attachments that are usually not described as fundamentally different between MMCs, such as the superficial masseter and temporalis, showed opposite trends with ecomorphology depending on MMC type. These data are suggestive of some universal patterns in rodent ecomorphology as well as some undescribed discretely different morphological characters that may be useful for understanding the evolution of biomechanics in morphologically complex rodent feeding, as well assessing the ecomorphology of fossil taxa.

A humerus tale: physically investigating and recording the forelimb of a new species of *Ichthyosaurus* from Pliensbachian deposits at Charmouth, England.

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In the palaeontology collection of Doncaster Museum and Art Gallery an almost complete ichthyosaur skeleton in matrix (DONMG:1983.98), collected from Upper Jurassic Pliensbachian deposits near Charmouth in Dorset, was recently identified as a new species. However, if studied closely it was clear that at some point in the past some of the forefin bones had been set within a filler. The skeleton was purchased by the museum in 1983 and no details about the discovery, excavation, conservation or mounting of the specimen had been recorded. As the morphology of the humerus represents a diagnostic feature of the new species, the authors had to be clear exactly which bones were in situ and which if any had been introduced (possibly from other specimens). Therefore the current positions of the forefin bones (including one humerus) had to be recorded, the paint had to be removed, the exact outline of the filler recorded and the filler removed along with the introduced bones – which included one of the humeri. This meant that the *in situ* and much less visible humerus had to be completely prepared and removed, to check if it was a perfect symmetrical match or not. Because the morphology of the humerus would be the key diagnostic feature of the new species, the opportunity was taken to photograph, video, illustrate, CT scan and mould the pair of bones before re-setting them in the matrix. A set of casts are now stored with the specimen for future study.

Constraints and efficiency in the evolution of birds

Qingyu Ma and Emily Rayfield
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There is a long standing perception in vertebrate evolutionary studies that the evolution of flight demands a lightening and stiffening of the skeleton to reduce the metabolic cost of locomotion, but without compromising the functional demands emplaced by powerful muscular contractions. This may have been achieved in part by reduction and fusion of skeletal elements and increased pneumatisation of bones. In the cranium we have a notion of birds thinning their skulls, expanding their brains whilst reducing adductor muscle mass, and replacing teeth with a lightweight keratin beak. By using computed tomography (CT) scan data and finite element analysis (FEA) to compare the mechanical efficiency of five skull specimens (*Haplocheirus*, *Sinovenator*, *Archaeopteryx*, ostrich and buzzard), this project will test the hypothesis that bird and aerial non-avian dinosaur skulls are more “mechanically efficient” than the skulls of terrestrial and flightless taxa, and converge in terms of their mechanical performance. Osterological correlates on the skull surface of the reconstructed CT models of *Haplocheirus* and

Sinovenator show that these taxa have a similar arrangement of adductor muscles to non-paravian theropods. The small size and slim bones of the skull of *Sinovenator* suggests that *Sinovenator* and extant birds lose muscle mass on their skulls.

Convergent evolution of diprotodonty or a rodent-like masticatory system in therian mammals

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Rodents are characterised by a distinctive masticatory apparatus comprising a pair of enlarged and continually growing upper and lower incisors, termed diprotodonty, separated from a highly reduced posterior dentition by a large diastema. While diprotodonty is present in all living and extinct rodents, it has independently evolved in a phylogenetically diverse range of non-rodent therian mammals, including hyraces and lagomorphs as well as one species of marsupial (the common wombat) and primate (the aye-aye). Here we examine whether the independent evolution of diprotodonty across therian mammals is limited to the dentition or constrains disparity of the whole masticatory system. Using microCT scans, three-dimensional landmarks were collected from the cranium and mandible of rodent-like diprotodont specimens and taxa representing the main extant rodent families. Geometric morphometrics methods were used to examine the convergence between the rodent and non-rodent specimens. The taxa in this study samples large phylogenetic distances however in both the cranium and mandible morphospaces all taxa group very tightly together. Within the rodents, taxa from the main groupings based on masticatory musculature (hystricomorphs, myomorphs and scuiromorphs) form discrete groupings. Partial least squares (PLS) show a high level of covariation between cranium and mandible in all taxa. The findings of the study clearly demonstrate that convergence in diprotodont mammals is not restricted to the dentition, convergence is also found in the cranium and mandible and their pattern of covariation. This indicates that there are strong functional constraints on the masticatory system associated with diprotodonty.

DINOSAUR BUILD LIVE! Building a life-size model of *Thecodontosaurus antiquus*

Robert Nicholls
Paleocreations.com

Thecodontosaurus antiquus is a sauropodomorph dinosaur known mostly from Triassic ‘fissure fillings’ in South England. The first remains were excavated in 1834 at the Durdham Down quarry in Clifton and it has become affectionately known by Bristolians as ‘the Bristol dinosaur’. The process of building a life-size model of *Thecodontosaurus antiquus* began in the palaeontology laboratories of the University of Bristol, 2012. After the fossil bones had been prepared the soft tissue anatomy was rendered from the inside out in the art studios of Paleocreations.com, before the reconstruction process climaxed in a unique event called DINOSAUR BUILD LIVE! For eight weeks, through October and November 2013, tens of thousands of visitors to Bristol’s M Shed Museum were able to watch *Thecodontosaurus* being sculptured from steel and clay to mould and cast. The completed model was unveiled to the media and the people of Bristol in December 2013, at the University of Bristol where it is now exhibited.

Analysing the Form and Function of the Hominoid Scapula: a Morphometric and Biomechanical Approach

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Primate forelimbs have an impressively large movement repertoire. Its overall mobility depends on the structure and function of the shoulder region. Consequently, the evolution of shoulder mobility is an important evolutionary process participating in the generation of locomotor diversity in primates. The present study has analysed how the form of the scapula is related to locomotor function in hominoids. This group of species was selected because even though they are highly related, they show a broad range of locomotor behaviours. The scapulae were scanned using computed tomography and each dataset was converted into a finite element mesh to perform finite element analysis. Loading scenarios were applied and strains values were calculated at different locations. On the same specimens, several landmarks were collected in order to perform geometric morphometric analyses. Biomechanical performance and shape differences were compared by means of independent contrast methods. Finally the covariation between form and function was assessed by carrying out a partial least squares analysis of both the strain values and the shape coordinates.

Phylogenetic and ecological correlates of inner ear morphology and ontogeny in pinnipeds (Mammalia, Carnivora).

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Pinnipeds are caniform carnivorans secondarily adapted to an aquatic environment, and extant families (Phocidae, Otariidae, and Odobenidae) differ markedly in ecology and locomotory performance on land and in water. While most studies of pinnipeds have focused on cranial, dental, and postcranial traits, the inner ear provides key information on hearing and locomotory ecology. Because the petrosal is well preserved in fossils, study of the cochlea and semicircular canals (SCC) could help reconstructing the phylogeny and ecology of fossil specimens, crucial to understanding this major transition. Principal component analyses of measurements from 3D-reconstructions of SSC and cochlea of adults of 13 living species revealed complete separation of the three families with no overlap (PC1). Adding younger ontogenetic stages to the PCAs revealed divergent routes of ontogenetic direction, with no consistent pattern within or across families. Addition of the Miocene-Pliocene monachine phocid *Acrophoca* to the cochlea PCA showed that this specimen was consistently closest to *Leptonychotes weddellii*, a deep diving monachine. Phylogenetic least-squares regressions of adult-only measurements and PC scores against 17 ecological and life history variables found significant correlations of PC scores with latitude, mean diving depth, and temperature, of anterior SSC measurements with temperature and gestation, and of cochlear measurements with latitude, growth rate, and mean diving depth. Although no relationships were significant following a Bonferroni correction, the correlation between cochlear measurements and diving depth, and the similarity of *Acrophoca* to *L. weddellii* in cochlear morphology suggests that this extinct phocid may have achieved moderate to deep diving depths.

Arthur Smith Woodward and the Jurassic 'Sea Croc'

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The NHMUK fossil reptile collections contain a set of fossils sent to Smith Woodward in 1908 by the Argentinian palaeontologist Florentino Ameghino. This collection includes an incomplete skull of *Cricosaurus*, a metriorhynchid thalattosuchian ('sea croc') of the Jurassic period. There are also other skull fragments that preserve the salt gland cavities and other anatomical details. Several handwritten notes by Smith Woodward are with the specimens, initially stating that the specimens were a research loan, but later saying that they were a gift. Ameghino's original correspondence with Smith Woodward is in the NHMUK archives and is also collated by Torcelli (1936). We have used these sources to investigate the history of the specimens, and to help us to decide upon their fate. First we must determine if they are privately owned, or belong to a museum in Argentina, and if Ameghino intended them to be a gift or a loan. To comply with museum policy and best practice, it is necessary to either accession them into the NHMUK fossil reptile collection or return them to their legal owner in Argentina. However, this decision rests upon a thorough investigation of Ameghino and Smith Woodward's correspondence.

SPPC TALKS

Challenges encountered during the preparation by acid-resin transfer of fossil fish from Monte Bolca, Italy

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Natural History Museum, London

The Monte Bolca outcrops near Verona, Italy, represent a limestone *Lagerstätte* containing extremely well-preserved fossil fishes of Eocene age. The area was discovered in the 16th century and has so far produced around 250 fish species along with crocodiles, snakes, invertebrates and plants. Due to their undisturbed but two-dimensional nature, the fossil fishes from Monte Bolca are ideal for preparation by the resin transfer technique.
The collections at the Natural History Museum, London, UK (NHM) contain numerous specimens prepared by this method. These have been created over several decades and with varying success. Unfortunately the exact processes and the names of resins used are not all fully documented. This presentation outlines the issues encountered during the application of the resin transfer technique to five fish requested for active research. It also includes a comparison of a selection of resins which are currently commercially available.

GB/3D fossil types online - not only the largest collection of 3D digital fossils, but also of major format, schema and vocabulary conundrums

Mike Howe, Simon Harris and Tim McCormick
British Geological Survey

The ICZN and the International Code of Nomenclature for algae, fungi and plants require that every species or subspecies has a type specimen to define its characters. With time, collections have been moved or amalgamated, and type specimens can deteriorate or become lost. The partners in the Jisc funded project, the British Geological Survey, the Sedgwick Museum Cambridge, the National Museum Cardiff, the Oxford Museum of Natural History and the Geological Curators' Group (representing other national, university and local museums) have collaborated to create an online database of British macrofossil types: www.3d-fossils.ac.uk .
The web portal provides data about each specimen, searchable on taxonomic, stratigraphic and spatial criteria. High resolution photographs, stereo anaglyphs and many 3D digital models are available. The portal is equally accessible to academia and the public, and represents the largest online collection of virtual fossils. It is improving the quality and efficiency of research, reducing unproductive loans and visits, and providing a valuable resource for amateur palaeontologists and the public. The project's progress since its launch one year ago will be reviewed. Combining 2,500 years of legacy data proved a major challenge. Museum databases – even different implementations of the same product – tend to use different schemas and different dictionaries. The lack of general agreement over file formats necessitated careful consideration of the options. JPEG2000 was selected for images, because of its speed in accessing large files, and .PLY (relatively small file size) and .OBJ (flexibility) were chosen for 3D digital models.

Resourcing Palaeontological Collection Care in a Time of Crisis: The Legacy of the Earth Science Review, Twenty Years On.

Jeff Liston
Yunnan University

The current round of cuts resulting from the global financial crisis once again places museum collections in a vulnerable position in terms of resource allocations from national, regional and private funders. Often, cuts in institutional funding are proposed in the context of being intended to reshape an organisation for a more streamlined role, better designed to meet the challenges of the future. But however well museums are redesigned, they rarely escape being viewed as legitimate targets for funding cuts whenever a new round of belt-tightening comes up. The inherent implication of the language of institutional reshaping is that a certain amount of protection, if not immunity, will be conferred on the museum come the next round – but that rarely happens. This is true across the range of funders: it is simply hard in political terms for funders to justify resources going to cultural preservation instead of hospitals or nursery education. Within museums, geological collections traditionally have a particularly hard time in terms of funding and justifying their existence. Whereas artworks, archaeological, historical or ethnographic objects appear to have an intuitively obvious value to external assessors, arguing the case for natural science in general, and geology in particular, has always been an uphill struggle. This presentation will review how an unusual manifestation of this phenomenon in the late 1980s - the Earth Science Review, when cuts in funding actually led to an increase in long-term funding for some geological museum collections - has survived to the present day.

Preparation of *Ardiodus* sp? from the Eocene Moclay in Denmark: New approaches in acid preparation.

Frank Osbæck

Museernes Bevaringscenter i Skive

During 14 months from summer 2012, an 80cm long fish specimen, probably *Ardiodus* which is also known from the London clay, was prepared at Museernes Bevaringscenter I Skive. The concretion containing the large exceptionally well preserved fish was approximately 95x75 cm large, 25 cm thick, weighing more than 90 kg. It consisted of 5 large pieces and around 100 small fragments. The normal procedure at our lab is to use an epoxy, Araldite 20-20 as adhesive. Its extremely low viscosity allows the parts of the specimens to be pressed very tightly together, avoiding even the slightest gaps between bone fragments. Resins are not entirely acid resistant and will swell considerately (up to 10%) during acid preparation when it goes on for as long as it takes to prepare the large concretions (months). This would not be acceptable in this case, as the entire length of the fish was split in two, lengthwise. The swelling would pry the very fragile bones apart and could have caused a large part of the specimen to be lost. It was decided, after tests on other specimens, to use Paraloyd B72 as an adhesive, itself not entirely acid resistant but featuring other advantages that were essential in this context. The result is a very beautiful fossil featuring extraordinary details and very interesting taphonomic information.

The Upper Jurassic Marine Reptiles from Spitsbergen: from field conservation to laboratory preparation

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3 - Norwegian University of Science and Technology

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Ten years of field excavation and lab preparation of the Upper Jurassic marine reptiles from the Slottsmøya Member of central Spitsbergen, have yielded new techniques in Arctic field excavation and the following preparation. Here we present these new methods and their results, which may be of use to others considering excavation in high latitude environments. Unique field techniques have been devised to work under harsh Arctic conditions, using limited electrical equipment. Varying lithologies during field collection; from paper shale, iron stone to frozen fresh shale require different field conservation and excavation techniques. All the specimens were collected in thawed or frozen permafrost, and are therefore subject to congelifraction, often resulting in heavily fragmented material. Each individual specimen is in a unique state of preservation, which can also vary throughout the preserved material. Respectively, each of these different types of preservation requires a different type of preparation, resulting in the development of new methods of laboratory preparation. A combination of different cleaning techniques along with the use of a stabilizing polyvinyl acetate temporary adhesive and permanent adhesives, has made the preparation of these specimens feasible.

SPPC POSTERS

A Tale of Two Mysticeti

Nigel Larkin[1,2]

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2 - Norfolk Museums and Archaeology Service

In 2009 the partial skeleton of a large and fragile 5,200 year-old baleen whale was excavated in coastal sediments in Abu Dhabi (UAE). In 2013 a similar sized (70-ft long) skeleton of a 150 year-old finback whale that had been suspended from a ceiling for 25 years outside the Zoology Museum of Cambridge University was cleaned, dismantled and moved into temporary storage for the duration of a refurbishment project. In Abu Dhabi the 4m long fragile skull was in a few pieces due to taphonomic processes in the burial environment. In Cambridge the 4.5m long skull was complete and weighed over a tonne. Despite the whales' very different contexts and ages and the fact that one skeleton had to be lifted from desert sediments and transported several miles whilst the other skeleton had to be removed from its mount and moved fifty metres, some of the processes used were very similar. The excavated skeleton had to be cleaned and recorded, assessing the sediments and taphonomic processes evident at the site. The displayed skeleton had to be cleaned and the way it was mounted and suspended had to be recorded in detail to facilitate remounting in a couple of years. Interesting pathologies exhibited by the bones were noted in both cases. In particular, both projects necessitated constructing protective and supportive frameworks around the skulls and mandibles, bolting together lengths of galvanised steel 'Unistrut' to enable the large and heavy yet fragile specimens to be safely moved with airjacks and cranes.

Using infrared thermal imaging as a collections management tool.

Nigel Larkin

Natural-History-Conservation.com

A palaeontology collection may contain specimens with conflicting environmental requirements. Therefore the (sometimes subtle) differences in environmental conditions within a collections storage area or display area should be exploited appropriately if the different microenvironments can be identified and quantified. Digital infrared thermal imaging cameras can be used to measure and visualise even subtle temperature gradients within a store instantly and accurately, to provide a much more detailed understanding of the complexities of a three-dimensional space than any other datalogging equipment can currently provide. The differences in temperature can be used to infer likely differences in relative humidity levels as well. Digital infrared images present their temperature data immediately in a highly visual format that is generally intuitively understood but it can also be very easily numerically analysed with the software so that areas within and between images can be compared. Using an infrared camera to investigate storage or display areas will reveal, for instance, temperature gradients due to stratification, hot spots, cool drafts, damp patches and unlagged heating pipes under floors etc – all of which would otherwise be invisible. Whilst infrared cameras are sometimes used in museums to investigate where energy (and therefore finances) can be conserved, their application for collections management purposes is rare simply due to a lack of awareness of how the technology can be usefully applied. Several factors influence the accuracy of the interpretation of the data so training is required.