Progressive Palaeontology 2020

Abstract Booklet

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Timetable

Thursday 11th June

Content launch	2am PDT / 5am EDT / **10am BST** / 5pm HKT	
Tea break 1	3am PDT / 6am EDT / **11am BST** / 6pm HKT (30 mins)	Discord
Careers Panel	6am PDT / 9am EDT / **2pm BST** / 9pm HKT (90 mins)	Zoom
Presenter Q&A 1	11am PDT / 2pm EDT / **7pm BST** / 2am HKT (60 mins)	Discord

Friday 12th June

Presenter Q&A 2	3am PDT / 6am EDT / **11am BST** / 6pm HKT (60 mins)	Discord
Workshop drop-in	6am PDT / 9am EDT / **2pm BST** / 9pm HKT (90 mins)	Zoom
Tea break 2	8am PDT / 11am EDT / **4pm BST** / 11pm HKT (30 mins)	Discord
Quiz	11am PDT / 2pm EDT / **7pm BST** / 2am HKT (120 mins)	Zoom

Saturday 13th June

Tea break 3	3am PDT / 6am EDT / **11am BST** / 6pm HKT (30 mins)	Discord
Presenter Q&A 3	6am PDT / 9am EDT / **2pm BST** / 9pm HKT (60 mins)	Discord
Tea break 4	8am PDT / 11am EDT / **4pm BST** / 11pm HKT (30 mins)	Discord

Presenter Q&A 1 – Thursday 11th June, 7pm BST

F07	James Dill-Russell
F17	Arsham Nejad Kourki
F19	Elvira Piqueras Ricote
F25	Adam Woodhouse
F26	Mariana Yilales
L01	Sophia Anderson
L02	Alexander Ball
L03	Charlotte Bowman
L07	Jennifer Farrant
L09	Natalia Jagielska
L12	Rob Loveday
L15	Catherine Mascord
L16	Hebert Bruno Nascimento Campos
L22	Jack Shaw
P08	Albert Chen
P09	Sam Coatham
P10	Luis Collantes
P15	Seán Thór Herron
P17	Aneta Hušková
P19	Ravi Kiran Koorapati
P22	Marcin Latas
P25	Case Miller
P27	Adrian Muirgheas O'Driscoll
P28	Roy Payne
P34	Jack Wilkin

Presenter Q&A 2 – Friday 12th June, 11am BST

F08	Daniel Falk
F10	Martha Gibson
F11	Beatrice Heighton
F14	Lorna Kearns
F15	Waisum Ma
F16	Alice Maher
F18	Emanuele Peri
F20	Arindam Roy
F23	Amy Shore
F24	Christopher Stockey
L05	Milan Chroust
L10	Tasnuva Ming Khan
L11	Miranta Kouvari
L14	Brett Martin
L18	Cecily Nicholl
L19	Frances Procter
L21	Lisa Schnetz
P01	Sophie Alexander
P03	Charlotte Beasley
P04	Juan Benito
P14	Elise Harris
P18	Billie Jones
P21	Pei-Chen Kuo
P23	Hui Wai Lee
P24	Luke Meade
P29	Garance Robin
P31	Lizzy Steell
P33	Klara Widrig

Presenter Q&A 3 – Saturday 13th June, 2pm BST

F01	Ruby Barrett
F02	Filippo Bertozzo
F03	Alessio Capobianco
F04	Sofia Chambi-Trowell
F05	Thomas Cowgill
F06	Will Crabbe
F09	Joseph Flannery Sutherland
F12	Struan Henderson
F13	Katie Jamson
F21	James Rule
F22	James Saulsbury
L06	Matthew Dempsey
L08	Euan Furness
L13	Katherine Marriott
L20	Edwin Rodriguez Dzul
L23	Savanna van Mesdag
L24	Oscar Wilson
L25	Yang Zhao
P02	Laura Austin Sydes
P05	Rebecca Bennion
P06	Charlotte Bird
P07	Emily Carlisle
P11	Rebecca Cooper
P12	Jack Cooper
P13	Florent Fayolle
P20	Callum Kunz
P26	Duhita Naware
P30	William Rutter

Meet the Committee

The ProgPal 2020 Committee are all students at the University of Leeds, in Yorkshire, UK, and have all been involved in the work of Palaeo@Leeds research group.

Bethany Allen - Final year PhD
Fearless leader and avid baker
@bethany_j_allen

Owain Fletcher Williams
MGeol Geological Sciences (2nd year)
Always found in a mosh pit

Adam Woodhouse - Final year PhD
Quiz Co-host and former TV star on Smart
@foradamifera

Karolina Zarzyczny
Integrated Masters in Zoology (Final year)
Avid rock climber
@KMZarzyczny

Andy Mair - Final year PhD
Quiz Co-host and fanatical balcony gardener
@andy_mair

Ailsa Roper - 1st year PhD
Social Media Strategist and shortbread addict

Connor O'Keeffe – 2nd year PhD
Quiz Constructor and resident mixology expert

Frances Procter - 1st year PhD
Careers Panel coordinator and aspiring ballet dancer
@FrancesProcter

Grace Lamyman – 2nd year PhD
Workshop tester and shark scuba diver
@grace_lamyman

For more info on the team see our lightning talk guide:
https://www.youtube.com/watch?v=EBFMljcjWCk&feature=youtu.be

Accessing the conference materials and platforms

Research presentations

Research presentations will be available to view for the full duration of the conference, from Thursday 11th to Saturday 13th June.

All presentations, including both posters and talks, will be available through the PalAss website. If you registered as a PalAss member, you will need to log in to the website to access the presentations using your PalAss log-in details. If you are not a member, you will be sent temporary log-in details prior to the conference which will enable you to view them.

https://www.palass.org/meetings-events/progressive-palaeontology/2020/progressive-palaeontology-2020-online-overview

Careers Panel and Quiz

Our 'live' events will take place using Zoom. You will need to download the app in order to see the broadcasts: you can do so in advance by visiting their website (https://zoom.us/), or automatically the first time you try to access a Zoom call. Each day of the conference we will email delegates with details of that day's activities, and these emails will include Zoom links which you can use to join the events.

Workshop

Materials for the Sampling Bias in the Fossil Record workshop will be available from Thursday 11th June for delegates to view at their leisure throughout the conference. You can access the workshop guidance and materials through our GitHub repository, which we will circulate a link to in due course.

The 'readme' includes instructions for downloading R and files for the practicals, links to the accompanying talks on YouTube and the slides used in these talks, and a short additional reading list.

There will be a drop-in session with the workshop developers (Alex Dunhill, Graeme Lloyd, Bethany Allen) via Zoom on Friday 12th June, during which you can ask questions about the materials and get help troubleshooting any issues.

Careers Panel

We have invited six panellists, all of whom have a background in palaeontology, to discuss their education and job history and to impart advice to those who might want to follow in their footsteps. The panel will be held via Zoom and hosted by committee member Frances Procter. Each panellist will introduce themselves, then the panel will collectively address questions submitted by delegates.

The panellists are:

Sam Giles, Royal Society Dorothy Hodgkin Research Fellow at the University of Birmingham

> Sam uses CT scanning to unlock the external and internal anatomy of living and fossil vertebrates, in particular the early history of bony fishes, which account for 99% of all living vertebrates. Sam also previously held a Research Fellow position at the University of Oxford, and in 2019 was awarded the Geological Society of London's Lyell Fund in recognition of her exceptional publication record.

Zoë Hughes, Curator of Fossil Invertebrates (Brachiopods and Cephalopods) at the Natural History Museum, London

> Alongside caring for the collections at the NHM, Zoë is heavily involved with the Integrated Pest Management Programme at the Museum, as well as being the Programme Secretary of the Geological Curators Group and Outreach Officer for the Palaeontological Association.

Elspeth Wallace, Education and Public Engagement Officer at the Irish Centre for Research in Applied Geosciences (iCRAG)

> Elspeth manages two public engagement programmes: Earth Science Education and Geocareers in iCRAG, including Girls into Geoscience Ireland. Elspeth has a passion for promoting women in science and works closely with the Public Perception and Understanding of Geosciences platform as part of her role. Elspeth is a palaeontologist by training, having completed undergraduate and postgraduate degrees at the University of Manchester where she is also currently studying part-time for her PhD.

Tom Fletcher, Researcher and Scientific Consultant for Silverback Films

> Tom is a graduate of the University of Bristol and University of Leeds, and an Honorary Fellow at the University of Leicester. He is currently working as a researcher and scientific consultant for Silverback Films, a wildlife documentary filmmaking company based in Bristol.

Harrie Drage, Development Editor for the Secondary Science UK Education team at Oxford University Press

> Harrie works on both digital content and textbooks for all the sciences in the UK school curriculum, and her main role is to ensure the science content published is accurate, accessible, and fit for purpose. Harrie works on a wide range of projects, from traditional publishing to innovative technological developments, focusing on the delivery of the curriculum and cognitive science principles.

Mark Bell, Senior Assistant Statistician for the Scottish Government

> Mark's primary role is in the production of official statistics relating to Scotland, specifically the justice system. In his four years in government, Mark has published statistics on several areas of the justice system including court proceedings and criminal activity recorded by the police, such as domestic abuse and homicide. Mark also provides briefing to ministers, ensuring they are properly informed of the latest information, and answers questions from other parties such as MSPs, journalists or members of the public, such as through Freedom of Information requests.

We will circulate a question submission form via email for delegates to submit their questions before the panel. Questions can also be asked during the panel using the '#careers-panel' channel on Discord.

Quiz

In the absence of ProgPal's usual social events, we will be holding a live-streamed palaeontology-themed quiz. The quiz will be held via Zoom and hosted by committee members Adam Woodhouse and Andy Mair.

Quiz teams should be made up of no more than four delegates. Delegates can form their own teams, but we will also organise a pooling system to put together teams; this is a great opportunity to meet other delegates, and we will endeavour to form teams with a breadth of subject specialisms. We will circulate a Google Form via email through which you can submit yourself, and up to one other delegate, to the pool.

On Friday 12th June we will email out links to both the quiz (via Zoom) and the answer submission sheet (a Google Form). Please ensure you have liaised with your team to come up with a team name before the quiz starts, as this will help us with marking your answers; fossil-based puns are actively encouraged. During the quiz, we recommend setting up a group chat for your team on Discord, however other messaging or video platforms may be more convenient. You should delegate one person to fill in and submit the Google Form for your team.

Please don't cheat! The format of the quiz means we can't make sure everyone is keeping to the rules, but we want all participants to have fun, and for the winners to do so fairly.

Discord

To create a space within which delegates can network and communicate with each other, we have set up a server on Discord. To access the server you will need to download the app (https://discord.com/) and sign up for an account. We will send all delegates a link to join our server via email. Upon first access you will need to be verified by the committee, but following this you will be able to contribute to instant messaging across various 'channels' set up for different facets of the conference.

We will be using Discord to hold our Presenter Q&A sessions. All presenters will be allocated to one of three sessions, during which they should be available on Discord to be asked questions by other delegates. Each presentation will have its own designated channel. We encourage delegates to attend as many of the Q&A sessions as possible.

We will also be holding four 'tea breaks' over the course of the conference via Discord. These sessions are intended to enable networking and general chatter between delegates, akin to a break for refreshments at an in-person conference. To develop conversation, each tea break will have an optional topic for discussion, including a mix of lighthearted and more serious questions.

There will be a Discord channel set up to emulate last year's successful LGBTQ+ meet-up. The channel will be private, but any delegate can request to join it by messaging a ProgPal committee member (please know that we will not ask any questions), who will then grant the necessary permission. Our intention is to strike a balance between ease of access and privacy, and we welcome discussion with delegates on how best to achieve this.

All aspects of the Discord server will be somewhat experimental, so please pass on to the Committee any ideas for additions or improvements, either by messaging one of us through Discord or by emailing progpal2020@palass.org.

Delegate expectations

In registering for ProgPal, all delegates agreed to abide by the PalAss Code of Conduct.

https://www.palass.org/meetings-events/code-conduct-palaeontological-association-meetings

While the online nature of this year's conference means that the technicalities of applying the Code of Conduct may be slightly different to previous years, the core ideas remain unchanged. There are two particular aspects of the Code of Conduct which we want to stress:

1) Be kind and respectful to other delegates. ProgPal has a long history of having a welcoming, inclusive environment for postgraduates to present their research and network, and we want to maintain that reputation. In particular, it's easy to misinterpret tone in written forms of communication such as instant messaging, so please check your language before being critical of others and their work.
2) Do not make copies or images of research presentations without the express permission of the presenter. Permissions signs may be used by presenters to indicate whether they wish to keep their work confidential, but if in doubt, please ask the presenter directly.

If you observe or experience behaviour over the course of the conference which is not in keeping with the Code of Conduct, please report it to a member of the ProgPal Committee, if possible with a screenshot. We will act on any reports in accordance with the guidelines given in the Code of Conduct document.

Contact the Committee

We will be posting on our social media channels throughout the conference, which are

Facebook: https://www.facebook.com/progpal2020

Twitter: @ProgPal2020, using #ProgPal2020

If you need to contact the ProgPal 2020 Committee at any point, you can use

Email: progpal2020@palass.org

Direct message via either Facebook or Twitter (above)

Direct message via Discord (right-click on any committee member's name on the right-hand panel in the server)

Thank you for taking part in ProgPal 2020! We hope that the conference proves to be a valuable and enjoyable experience.

Abstracts: Full Talks

F01: A high latitude record of planktic foraminifera resilience to climate change: insights from the past

Ruby Barrett[1], Jamie Wilson[1], Daniela Schmidt[1], Heather Birch[1]

[1]University of Bristol

Anthropogenic climate change is projected to warm and alter the carbonate chemistry of our oceans. These unprecedented changes will impact marine ecosystems and their services. Marine calcifiers - which we rely on to regulate atmospheric CO2 by production and burial of their calcium carbonate shell - are expected to be particularly vulnerable. Planktic foraminifera produce a quarter of the marine carbonate. As such, to investigate the impact of ocean acidification and global warming on carbonate production, we measure planktic foraminifera size throughout an analogous period of past climate change: the Palaeocene-Eocene Thermal-Maximum (PETM) at Ocean Discovery Program (ODP) Site 1135 in the Southern Ocean. Against expectation, foraminifera size increased at the onset of the carbon isotope excursion. A subsequent decline in size during the PETM fell within the bounds of size prior to, and following, the PETM. We interpret this as a change in assemblage composition due to immigration of warmer water taxa to the higher latitudes. The proportion of foraminifers to the sediment is not changing across the PETM. Our results indicate that planktic foraminifera at Site 1135 are resilient to past climate change.

F02: Frequency, distribution and implications of palaeopathologies in ornithopod dinosaurs

Filippo Bertozzo[1,2], Alastair Ruffell[1], Eileen Murphy[1]

[1]Queen's University Belfast

[2]Sociedade de Historia Natural, Torres Vedras, Portugal

Within Dinosauria, ornithopods are the group showing the highest number of palaeopathologies, which are fossilized lesions and diseases. However, an extensive review of such findings amongst the phylogeny of ornithopods, and their frequency and body distributions, has not been performed yet. Here, a general report and a statistical analysis of about 2000 fossilised injuries and diseases in ornithopods, recorded in different museum collections, are presented. To better describe and visualize differences along the phylogenetic tree, the specimens have been subdivided in three morphotypes: A, small and basal forms such as *Camptosaurus*; B, larger and quadrupedal taxa as Iguanodon; C, derived taxa with dental batteries as *Edmontosaurus*. The bones have been grouped in body parts, homologous between the three morphotypes, and each element is considered as a single individual. Morphotypes A and B show a lower frequency of palaeopathologies, mainly present in the trunk and in the hindlimb. Morphotype C has the highest frequency (about 98% of the total), likely due to i) the greater fossil record; ii) scaling effect with more basal taxa. Pathological conditions are subdivided in injuries, infections, arthritis, developmental and nutritional disorders, and tumors. The low frequency in morphotypes A and B does not allow to recognise specific pathological trends, but the higher numbers in the pedal and tail elements in C suggest causes and perhaps behavioural implications. The high frequency of osteochondrosis in pedal phalanx might indicate a loading stress in the locomotion of hadrosaurids, compared to basal iguanodontians, where this condition is not present.

F03: Alpha-diversity dynamics of fish assemblages across the Late Cretaceous and Palaeogene

Alessio Capobianco[1,2], Kara Feilich[2], Matt Friedman[1,2]

[1]University of Michigan *[2]University of Michigan Museum of Paleontology*

The fossil record is crucial to investigate long-term patterns of species richness. While raw counts of fossil taxa usually point to a monotonic increase in richness across the Phanerozoic, diversity estimates accounting for sampling biases of the fossil record often reveal long periods of stasis, sometimes punctuated by rapid changes in correspondence with major ecological changes, such as the Cretaceous/Palaeogene (K/Pg) mass extinction. Despite their relevance in modern ecosystems and a relatively rich fossil record, ray-finned fishes (Actinopterygii) and their long-term diversity dynamics have been severely understudied. We investigated patterns of local (alpha) diversity in fish communities through time by applying coverage-based rarefaction estimates of taxonomic richness to a newly assembled dataset of otolith and body fossil relative abundance counts from around 100 Late Cretaceous and Palaeogene localities. The otolith fossil record indicates a substantial stasis in maximum local diversity throughout the Late Cretaceous and Palaeogene, with no evidence of rapid change in correspondence with the K/Pg boundary. Similarly, the body fossil record suggests a long-term stability in alpha-diversity across the 70 million years span considered here, with some notable exceptions such as the unusually species-rich early Eocene Bolca Lagerstätte. Overall, our results suggest that maximum local diversity in fish communities might be constrained across long spans of geologic time, consistent with known patterns of alpha diversity in other taxa, such as terrestrial tetrapods.

F04: The biomechanical properties of the jaws of *Clevosaurus*

Sofia Chambi-Trowell[1], David Whiteside[1,2], Michael Benton[1], Emily Rayfield[1]

[1]University of Bristol *[2]Natural History Museum, London*

Clevosaurus was a globally distributed genus of lizard-like reptile (Rhynchocephalia) that lived during the Late Triassic–Early Jurassic, characterised by shearing bladelike teeth that may have been functionally analogous to the carnassial teeth of insectivorous mammals. No fewer than five species of *Clevosaurus* are found in early Mesozoic sediments in the UK but almost never where mammaliaforms were present, possibly suggesting competitive exclusion. Here, we investigate the dietary mechanics of *Clevosaurus* by applying a suite of techniques, including adductor musculature and bite force reconstruction, tooth pressure, tooth morphology, beam theory, mechanical advantage and geometric morphometrics, to the jaws of two near-complete skulls of two species of *Clevosaurus* from the UK. Our morphometric analysis shows that the dentary morphospace of clevosaurs differs significantly from that of other rhynchocephalians throughout the Mesozoic, suggesting that after its disappearance in the Early Jurassic the dietary niche of *Clevosaurus* seemingly became unavailable to rhynchocephalians. From our results we found that both species of *Clevosaurus* had bite forces and tooth pressures sufficient to break apart chitin, indicating that like some early Mesozoic mammaliaforms, *Clevosaurus* could feed on tough-shelled beetles, and possibly small vertebrates. Though we cannot demonstrate competitive exclusion between members of both clades, our results raise the prospect that they may have been functionally similar.

F05: Paranasal sinus system evolution in metriorhynchoid crocodylomorphs

Thomas Cowgill[1], Mark T. Young[1], Julia A. Schwab[1], Stig Walsh[2], Lawrence M. Witmer[3], Yanina Herrera[4], Stephen L. Brusatte[1]

[1]University of Edinburgh

[2]National Museum of Scotland

[3]Ohio University

[4]Universidad Nacional de La Plata

During the Mesozoic, metriorhynchoid crocodylomorphs adapted to life in marine ecosystems, culminating in the pelagic clade Metriorhynchidae. While the osteological changes that occurred during this transition are well-known, the soft-tissue ones are not. One poorly studied system is the paranasal sinus system. In extant crocodylians the rostrum has numerous pneumatic diverticula originating from the narial cavity, that become more extensive (in terms of size and number of diverticula) during ontogeny. To investigate the evolution of this sinus system we used µCT scans of six metriorhynchoid skulls, and for comparison used µCT scans of juvenile and adult longirostrine crocodylians (*Gavialis gangeticus* and *Tomistoma schlegelii*). We found metriorhynchoids to have exceptionally reduced paranasal sinus systems, solely comprising the antorbital sinus. The striking similarity in paranasal sinus extent and morphology in juvenile longirostrine crocodylians and basal metriorhynchoids suggest paedomorphosis in Metriorhynchoidea. The antorbital sinus is largely indistinguishable from the dorsal alveolar canal in basal metriorhynchoids, and we propose that they shared the same cavity. In Metriorhynchidae, the antorbital sinus has a conical morphology and extends posteriorly through the postnasal fenestra into the orbit, creating an accessory suborbital sinus. The function of the suborbital sinus is unknown, but it possibly allowed expansion and contraction of the sinus when diving. The nasopharyngeal ducts in basal metriorhynchoids are similar to extant crocodylians, but in metriorhynchids they are dorsoventrally enlarged and bordered ventrally by thickened palatines. The larger transverse area of the ducts could have enabled stronger ventilation, especially if metriorhynchids had increased lung capacity.

F06: Novel preservation of Cambrian paraconodonts as small carbonaceous fossils (SCFs) aids the study of ontogeny and diversity in the earliest vertebrates

Will Crabbe[1], Thomas Harvey[1], Mark Purnell[1]

[1]University of Leicester, UK

Paraconodont elements represent the radiation of skeletonized vertebrates within the fossil record and hold vital clues to the diversity of the earliest vertebrates. However, the structure of the paraconodont feeding apparatus is largely unknown, meaning that distinct element types have been impossible to incorporate into a more biologically realistic multielement taxonomy. Therefore, understanding these elements in a more biological context is of key importance for a greater understanding of the diversity of the early vertebrate lineage. The Furongian ('upper' Cambrian) Deadwood Formation of Saskatchewan, western Canada, yields a diverse assemblage of paraconodont elements including the enigmatic form-taxon *Westergaardodina*. The elements are preserved as small carbonaceous fossils (SCFs), rendering their internal growth structure visible under transmitted light. This assemblage therefore provides an excellent opportunity to identify early and late growth stages, showing how divergent 'form-taxa' can derive from a single biological species. Based upon the mode of basal growth in paraconodont elements, ontogenetic stages can be identified within elements through the digital removal of growth lines. Distinct ontogenetic stages have been identified within the newly defined *Westergaardodina bodavidus*, which develops allometrically from a thin, needle-shaped element, into a broad W-shaped element with wing-like flanges. The novel approach developed in this study has helped to reconcile biological affinities between morphologically distinct element types. This has shown that overestimation of biodiversity in the earliest vertebrates may be likely and that ontogenetic variation should be taken fully into account when defining biological species.

F07: Eocene-Oligocene turnovers of large benthic foraminifera in Florida

James Dill-Russell[1], Laura Cotton[2]

[1]University of Bristol *[2]University of Portsmouth*

The Eocene Oligocene transition (EOT) is one of the most dramatic climate shifts of the Cenozoic, associated with widespread cooling and biotic turnover. This includes the carbonate platform environment. Larger benthic foraminifera (LBF) are an important component of the platform ecosystem and have long been known to suffer global extinction of several long-ranging groups during the EOT interval. Whilst detailed studies of the LBF have been carried out in Tanzania, Sarawak and the Tethyan region, there are very few studies in the Americas, with only few recent papers addressing the EOT directly. The LBF assemblages of the Americas are very different to those of Europe and the Indo-Pacific, and therefore may have different responses to climatic events. It is therefore essential that the American LBF bio-province is included in studies of LBF evolution, migration and biodiversity, to understand these processes on a global scale. Here we present data from Florida Geological Survey site 19569 that spans the Middle Eocene to Oligocene. Nannofossil biostratigraphy has been used to constrain the EOT level and allow comparison with global records. Both analysis of petrological thin sections and oriented LBF section have been used to examine LBF ranges and response of the shelf ecosystem. Allowing for comparison with global sites to gain a wider perspective of the timings, causes and effects of LBF response across the EOT.

F08: Patterns in the skeletal taphonomy of anurans from the Eocene Geiseltal Konservat-Lagerstätte (Germany)

Daniel Falk[1], Oliver Wings[2], Maria E. McNamara[1]

[1]University College Cork *[2]Natural Sciences Collections (ZNS), Halle (Saale), Germany*

The Eocene Geiseltal Konservat-Lagerstätte (ca. 47.5–42.5 Ma) from central Germany contains >50,000 specimens, but their taphonomy is poorly understood. Anurans (n=140) show a spectrum of preservational states, including (1) near-complete specimens, (2) isolated, articulated skeletal units and (3) loose associations of disarticulated skeletal elements. No specimens are complete and many are truncated, usually by the edge of the slab. Specimens vary markedly in completeness (3 – 87% of elements present) and articulation (0 – 100% of joints articulated). Completeness, however, is typically low (24 ± 13%), whereas articulation of the joints present is high (73 ± 20%). The cranium (99%), vertebrae (94%), ilium (86%) and femura (86%) are present in most specimens, but few specimens retain the carpals (30%), tarsals (7%) and fore- (23%) and hindlimb phalanges (25%). There is a striking distal to proximal trend in the loss of limb bones, whereby the femur and humerus are usually present, but phalanges, usually absent. Patterns of articulation within the body are more complex than those for completeness. Articulation is highest for the astragalus-calcaneum-tarsals joint (100%), astragalus-calcaneum (97%), vertebrae (94%), ilium-pelvis (94%) and joints including carpals or tarsals (91–93%) and lowest for fore- (56%) and hindlimb phalanges (44%). Overall, patterns of loss and disarticulation are similar for bones of the fore- and hindlimb and for both sides of the body. The skeletal taphonomy of the Geiseltal anurans differs from that of frogs from the Libros biota (Miocene, Spain), suggesting different regimes for decay, transport, depositional controlling preservation and/or different collection biases.

F09: Tracking the Permo-Triassic Archosauromorph Radiation in the TARDIS

Joseph Flannery Sutherland[1]

[1]*University of Bristol*

The diversification of archosauromorph reptiles from the Late Permian to Late Triassic is a classic example of an adaptive radiation. It has received significant attention from phylogenetic, morphological and ecological perspectives, but its biogeographical signature remains understudied. I conduct geographical ancestral state reconstruction using a taxonomically revised supertree of Permian and Triassic archosauromorphs. I then present a novel biogeographical model – TARDIS (traversing ancestrally reconstructed destinations in spacetime). The TARDIS model determines shortest routes of dispersal between pairs of ancestor-descendant nodes, generalising their calculation to account for changes in palaeogeography through time as well as across space. This basic model may be extended to incorporate variables which may affect the cost of traversal, including terrain complexity, climate conditions and habitability. I track the node-to-node dispersal of archosauromorphs using the TARDIS model to determine the biogeographical structure of their adaptive radiation. I discuss this structure in relation to its dramatic backdrop of ecological perturbations, including the Permo-Triassic mass extinction, the Early Triassic recovery of life on the land, and the Carnian Pluvial Episode, to assess the climatic and palaeogeographic factors underlying their diversification across space and time. Current limitations and future developments to the TARDIS model are also considered.

F10: A tale of 2 reconstructions: how we got the British Late Permian all wrong because we forgot about plants.

Martha Gibson[1], **Charles Wellman**[1]

[1]*University of Sheffield*

The established reconstruction for the Permian environments of the U.K. depicts high surface temperatures and aridity due to its location within the continental interior of Pangaea. Permian strata in the U.K. belong to the Zechstein Supergroup (~258-252Ma; Lopingian), which represents the deposits of the Zechstein Sea; a semi-isolated inland sea characterized by its thick evaporite sequences. A reliance on climate-sensitive sediments at the expense of other climate indicators e.g. fossil pollen and local palaeobotany, has led to a misinterpretation of the environment.

Here we present the results of quantitative analysis of spore-pollen assemblages, integrated with macropaleontological data, from borehole material from northeast Yorkshire, providing an updated reconstruction. Spore-pollen assemblages show that arid-adapted conifer and pteridosperm forests inhabited upland slopes and dunes, while ginkgos, horsetails, and tree ferns inhabited the lowland shoreline. A new technique for extracting pollen grains from rock salt, developed for this study, shows how vegetation persisted in upland refugia during periods of intense evaporation. The recovery of the youngest Permian fish, foraminiferal test linings, and phytoplankton indicate the persistence of normal marine conditions, and the first report of parasitic fungus from the British Permian provides valuable insight into nutrient cycling and fungal evolution.This reconstruction extends the temporal range of the Zechstein vegetation by 3-4 myr, suggesting the climate was damp enough to sustain extensive conifer forests, instead of continuously arid. Furthermore, it improves our understanding of how arid-adapted vegetation responded during the only example of an Icehouse-Hothouse climate transition in Earth's history.

F11: Convergence and disparity in aquatic tetrapods: revelations from morphospace

Beatrice Heighton[1], Mike Benton[1], Tom Stubbs[1], Susana Gutarra Diaz[1]

[1]University of Bristol

Convergence, which is essential evidence for adaptive radiation, is investigated through morphospace. The skeletal morphology of aquatic tetrapods, which have been recommended as excellent models of convergence, was measured to create a morphospace model which can be used to predict the locomotory mode of fossil taxa. Three exploratory analyses resulted in two morphospaces which are recommended as models: one which can be used with hindlimbless taxa; and one which is preferable as the locomotory modes are more distinguishable from each other, but which can only be used for taxa with hindlimbs. Derived, lift-based modes were more distinguished than drag-based modes. Removal of hindlimb-related measurements resulted in hindlimb-oscillators being statistically indistinguishable from the undulators. Longer forelimbs and hindlimbs compared to the trunk indicate greater use of the limbs compared to axial locomotion. A mixture of skeletal morphology was found to distinguish lift-based modes from drag-based modes. The forelimb-oscillators' disparity tended to be higher. Statistically significant convergence, calculated as the Wheatsheaf index, was found in all of the locomotory modes except for the forelimb-oscillators and caudal-oscillators; the former is likely a result of the high disparity of forelimb-oscillators whilst the latter may be due to most caudal-oscillators being cetaceans, so phylogenetically related, and being difficult to distinguish from undulators and hindlimb-oscillators. Phylogenetic relationships did influence skeletal morphology but locomotory mode affected it enough to be distinguishable in the morphospace. Preliminary analyses with fossil taxa have shown expected locomotory modes, interpreted from morphospace position, compared to previous studies.

F12: Morphological diversity in an actinopterygian fish following the end-Devonian mass extinction

Struan Henderson[1], Sam Giles[1]

[1]University of Birmingham

In the aftermath of the end-Devonian mass extinction, aquatic faunas underwent significant restructuring, with actinopterygians and chondrichthyans replacing placoderms and piscine sarcopterygians. The Tournaisian (~359-347 Ma), immediately succeeding the end-Devonian, is therefore a key interval in the history of the Actinopterygii, a group that now dominates global aquatic ecosystems. Empty niches following mass extinctions potentially allow for high taxonomic diversity and morphological disparity in surviving lineages. Understanding of whether actinopterygians fulfilled this potential in the Tournaisian is curtailed by poor comprehension of the available taxa: of nearly 30 described species, only three have been included in phylogenetic analyses. The majority of taxa are known only from brief descriptions and idealised line drawings made in the 19th and early 20th centuries, with few being re-examined since the advent of CT scanning. *Carboveles ovensi* is a notable example: known from several fossils from the Tournaisian of Scotland, it was originally described nearly a century ago, and its taxonomic validity is uncertain. CT scanning reveals that the jaws and palate possess an extensive covering of enlarged conical teeth, as well as a melange of characters shared with both Devonian and Carboniferous taxa. Preliminary phylogenetic analyses resolve *Carboveles* in a polytomy with other Carboniferous taxa; an unsurprising result given the near-absence of contemporaneous taxa and detailed anatomical data. More importantly, our results suggest that actinopterygians diversified morphologically in the immediate aftermath of the end-Devonian. *Carboveles* highlights that the fundamental descriptive and taxonomic aspects of palaeontology are essential to understanding the actinopterygian rise to dominance.

F13: Diversity dynamics of planktic foraminifera across the Cretaceous–Palaeogene and Eocene–Oligocene transitions.

Katie Jamson[1], Andrew Fraass[1], Benjamin Moon[1]

[1]University of Bristol

Planktic foraminifera are cosmopolitan organisms with an exceptional, well-studied fossil record and their diversity fluctuates temporally and spatially. Microfossil diversity has been documented, but how this diversity arises and the effect of major events on speciation and extinction rates is uncertain. PyRate, a program operating within Python, calculates speciation and extinction rates from global occurrence data within a Bayesian framework, to accurately determine taxon longevity. This method is used here to estimate diversification dynamics across two extinction events: The Cretaceous-Paleogene boundary and the Eocene-Oligocene transition.

Results from these analyses demonstrate a steep rise in extinction rate at 66Ma coupled with very low speciation rates. This coincides temporally with the end-Cretaceous impact that devastated almost all planktic foraminifera populations. A decline in net diversification rates and mean species longevity reflect this extinction event, indicating a perturbation in diversity for 4-5Ma. Following the impact, disaster fauna with low diversity and short species turnover, recolonised vacant niches and are likely the cause of a highly significant change in speciation rate at 64Ma. Results for the Eocene-Oligocene transition show two periods of significant extinction: at the Middle Eocene Climatic Optimum and at the Oligocene-Miocene boundary. However, speciation rates show little change, contrasting a gradual biotic turnover shown to occur across the Eocene-Oligocene from the literature. This analysis indicates that different preservation models within PyRate need to be examined to reduce uncertainty. Additional work with palaeoclimatic modelling will ensure increased understanding of what external factors drive diversity change across extinction events.

F14: Diversity in Eocene planktic foraminifera communities accelerated by climatic fluctuations

Lorna Kearns[1], Steve M. Bohaty[1], Sandra Nogue-Bosch[1], Kirsty M. Edgar[2], Thomas H.G. Ezard[1]

[1]University of Southampton *[2]University of Birmingham*

Extinction events are stochastic. Understanding the effects of abiotic and biotic forcing on life is therefore difficult and further hindered by scientific infatuation with mass extinctions. Background extinctions may be more systematic and provide insights into the response of communities to progressive species loss. Here, we present biodiversity changes in planktic foraminifera (PF) through gradual Eocene cooling whilst capturing transient warming of the Middle Eocene Climatic optimum (MECO).

In total 21,569 individuals were counted, at two different size fractions, and identified to 19 genera and 11 morphogroups over 3 depth habitats. Diversity was measured using effective (Hill, qD) numbers, where diversity is measured along a gradient of q where integers correspond to common diversity metrics (q=0-Richness, q=1-Shannon's diversity, q=2-Simpson's Evenness). We found that despite a scientific focus on the MECO it had little effect on the diversity record of PF. Instead, biotic turnover occurred in the preceding background interval. In the larger size fraction at all levels of diversity (0-2D), assemblages became increasingly diverse alongside Eocene cooling. This diversity peaked at ~41.75Myr and was followed by a dramatic shift at 2D to uneven assemblages dominated by subthermocline dwellers. A similar, but more subdued pattern is observed in the smaller size fraction.

We show that the preceding background interval, and not the MECO, may have acted as a tipping point for previously reported subsequent diversity decline at the Eocene Oligocene Transition. Additionally, we show that by focusing only on larger size fractions biotic consequences can be exaggerated.

F15: Dietary evolution in oviraptorosaurian and scansoriopterygid theropod dinosaurs

Waisum Ma[1], Michael Pittman[2], Stephan Lautenschlager[1], Luke E. Meade[1], Xing Xu[3,4]

[1]University of Birmingham

[2]University of Hong Kong

[3]Institute of Vertebrate Paleontology & Paleoanthropology, Beijing, China

[4]CAS Center for Excellence in Life and Paleoenvironment, Beijing, China

Oviraptorosauria and Scansoriopterygidae are clades of theropod dinosaur that include members suggested to be partially or fully herbivorous. Obligate carnivory and herbivory are two ends of the theropod dietary spectrum, but it is unclear how diet within these two clades might have varied. Clarifying their diet is important as it will deepen understanding of dietary evolution close to the non-avialan dinosaur-bird transition. Here a study is presented that investigated oviraptorosaurian and scansoriopterygid diet by conventional comparative anatomy as well as by measuring mandibular characteristics that are plausibly indicative of the animal's feeding habit. The latter was conducted with reference to modern herbivores that may also have non-herbivorous ancestry. In general, the skulls of scansoriopterygids appear less adapted to herbivory compared with those of oviraptorid oviraptorosaurians. This is because they have a lower dorsoventral height, a smaller lateral temporal fenestra, a smaller jaw-closing mechanical advantage and lack a tall coronoid process prominence. These results show that oviraptorid mandibles are more adapted to herbivory than those of caenagnathid oviraptorosaurians, early-diverging oviraptorosaurians and scansoriopterygids. It is noteworthy that some caenagnathids possess features like an extremely small articular offset and a low average mandibular height, which may imply that they had a more carnivorous diet than other oviraptorosaurians with larger offsets and higher average mandibular height. Our study provides a new perspective to evaluate dietary hypotheses of scansoriopterygids and oviraptorosaurians, and shows high dietary complexity among early-diverging pennaraptoran theropods.

F16: The evolution of body shape, locomotion and ecology in terrestrial vertebrates

Alice Maher[1], Philip Cox[2], Tom Maddox[1], Karl Bates[1]

[1]University of Liverpool

[2]University of York

Most previous studies on body shape in vertebrates are focused on research into squamates or semi-aquatic vertebrates, but it is largely unknown (in a quantitative way) how body shape has evolved more widely across terrestrial vertebrates in concert with changes in behaviour, locomotor style and ecological niche. I used three-dimensional computer models of vertebrate skeletons with phylogenetic reconstructions to quantify the evolution of body segments and whole-body shape across 420 taxa of all major extinct and extant terrestrial vertebrate groups. Results using non-phylogenetic statistics yield many statistically significant differences in body shape between various locomotor and dietary types. However, when phylogeny is considered, most differences lack statistical significance, which together with high values of Pagel's lambda, suggests a strong phylogenetic signal in the data set. Most remaining statistically significant differences involve the forelimb, which has been highly modified during evolutionary transitions in locomotion. For example, flying animals tend to have a relatively long humerus, while aquatic and semi aquatic animals have a short humerus. Identifying significant differences between locomotor type and ecological niche may allow quantified body shape analysis to be applied to extinct species for the prediction of ecology when behaviours cannot be directly observed.

F17: The Ediacaran *Dickinsonia* is a stem-eumetazoan

Arsham Nejad Kourki[1]

[1]*University of Bristol*

The evolution of key early metazoan characters is currently hotly debated, despite over a century and a half of research. Traditionally, inferring these evolutionary steps has relied heavily on evidence from comparative morphology and embryology of modern taxa, and more recently from developmental genetics; however, direct evidence of ancestral characters can only come from the fossil record. *Dickinsonia* is a macroscopic, benthic, heterotrophic extinct genus from the Ediacaran which has long been hypothesised to be of metazoan origin—a hypothesis strongly supported by recent geochemical evidence. Here, we reassess the suite of characters possessed by *Dickinsonia* and the closely related *Yorgia* through analogy with extant metazoans, followed by reconstructing a phylogeny of metazoans incorporating *Dickinsonia* and *Yorgia*. Our results strongly support the placement of these two genera as stem-eumetazoans. This finding provides the groundwork for reconstructing key steps in the evolution of eumetazoans, especially their body plans, without over-reliance on neontological evidence. It also strongly raises the possibility that, contrary to the mainstream view, bilateral symmetry evolved independently of gastric cavities or cephalisation.

F18: Application of CT analysis for the study of a fossil sperm whale from the Miocene of southern Italy

Emanuele Peri[1], **Alberto Collareta**[1], **Giacomo Aringhieri**[1], **Davide Caramella**[1], **Giovanni Bianucci**[1]

[1]*Università di Pisa*

In these last years, CT analysis have been extensively used in vertebrate palaeontology. Indeed, this method of imaging allow to study the internal structure of fossils vertebrates in a non-invasive way. Here we present the study of a fossil sperm whale realised through CT analysis and an open source software.
The studied specimen was found inside six quarry slabs from the “Pietra leccese” (Burdigalian–Tortonian, southern Italy), a calcareous formation that is well-known for its fossil vertebrate content. This sperm whale fossil includes an incomplete cranium, a partial mandibular ramus, two detached teeth and two vertebrae. The bones are still partially enclosed in the host rock and the cranium is strongly dorsoventrally compressed. The first aim of this study was to verify whether the CT technology can successfully image specimens entombed in the hard Pietra leccese limestone. After the acquisition at the Cisanello University Hospital (Pisa, Italy), we processed the CT images to improve the visualization of the specimen and, subsequently, we manually segmented the fossil bones using the open source platform 3D Slicer. Despite the presence of a hard matrix and conspicuous diagenetic deformation, we obtained a digital 3D model of the skull with a good level of detail.
This study demonstrates that CT can prove useful for the study of fossils inside a rock matrix. Moreover, using such a radiological approach, it will be possible to study this important physeteroid specimen, opening new horizons for further studies on the Pietra leccese vertebrate fossil assemblage.

F19: *Eolarva kuanchuanpuensis* is not the earliest metazoan larva

Elvira Piqueras Ricote[1]

[1]*University of Bristol*

Eolarva kuanchuanpuensis was recovered from the Kuanchuanpu Formation in Southern China and its age has been constrained to ~535 million years old, making it one of the earliest Cambrian formations. The specimen has been interpreted as the oldest metazoan non-feeding larva found in the fossil record, and therefore the oldest evidence for indirect development. However, no internal anatomy has been previously described and affinities remain uncertain. Studying its internal anatomy resulted in the identification of a gut-like structure continuous to an invagination at its apical-most part through which it must have been feeding, suggesting *Eolarva* is not a lecithotrophic larva. Parsimony and Bayesian phylogenetic analyses resolved *Eolarva* as potential stem or crown cnidarian.

F20: New multidisciplinary directions in fossil colour reconstruction and the way forward

Arindam Roy[1], **Michael Pittman**[1], **Thomas Kaye**[2], **Evan Saitta**[3]

[1]*University of Hong Kong*

[2]*Foundation for Scientific Advancement, Arizona, U.S.A*

[3]*Field Museum of Natural History*

Reconstruction of integumentary colour and patterning in fossils from global lagerstätten has become a burgeoning research area that provides a glimpse into the appearance of long extinct animals. The cornerstone of this work has been the study of melanin pigments preserved in fossilised integumentary structures from several amniote lineages including fishes, frogs, snakes, marine reptiles, non-avialan dinosaurs, birds, and mammals. Reconstructed colours and patterns have enabled the articulation and testing of complex ecological and behavioural hypotheses including those relating to countershading, crypsis and predator-prey interactions. In 2019, research progress as well as identified priorities for future exploration were organised into a single study framework with a single consistent workflow. Here we detail progress made in two of the previously identified priority areas of research. Firstly, we present how sediment-encased thermal maturation has been used to experimentally identify the physical and chemical taphonomic variables affecting preservation of melanin and integumentary macrostructures. The aim of this work is to determine if it is possible to simulate the elimination of labile diagenetic products while retaining more recalcitrant chemical entities in the sediment matrix, in other words to recreate key properties of the fossilisation process. Secondly, we present a review of how shape data is collected from fossil melanin-bearing melanosomes to reconstruct melanin pigment colour and make recommendations for best practices moving forward. Based on these two areas of progress, we present a further refined workflow for palaeoreconstruction and suggest the new research avenues that this opens up.

F21: Establishing a fossil record for true seals (Family Phocidae) in Australasia rewrites their evolution

James Rule[1,2], Justin Adams[1], Felix Marx[1,2,3], Alistair Evans[1,2], Alan Tennyson[3], Paul Scofield[4], Erich Fitzgerald[1,2,5,6]

[1]Monash University

[2]Musuems Victoria

[3]Museum of New Zealand Te Papa Tongarewa

[4]Canterbury Museum

[5]Smithsonian Institution

[6]Natural History Museum, London

The evolution and biogeographic history of monachines (southern true seals) is currently thought to have occurred in the North Atlantic, despite the majority of monachines (southern true seals) being present in the Southern Ocean today. However, seal fossils are rare, and the published fossil record has currently been missing fossils from Australia and New Zealand; meaning Australasian fossils have been lacking from phylogenetic and biogeographic hypotheses.

Here we describe new phocid fossils from the Neogene of Australia and New Zealand. Specimens from Taranaki (New Zealand) represent a new species of monachine seal, filling in a major gap in the monachine fossil record. These australasian fossils were included in a phylogenetic and biogeographic analysis. The total evidence Fossil Birth-Death Bayesian analysis included 168 morphological characters, 28 genes, and tip and node dates. Both analyses support a monophyletic Phocinae and Monachinae. The Taranaki phocids were found to be early diverging monachines. The biogeographic analysis suggests that southern latitudes played a larger role in the dispersal and evolution of monachines than previously thought. Southern dispersals were coupled with increases in body size for the Monachinae. This highlights that the southern hemisphere was critical to the evolution of Monachinae.

F22: Following the marine biodiversity hotspot with crinoids

James Saulsbury[1]

[1]Independent

Studies of geographical patterns in species richness have historically sought explanations in terms of differences in speciation rate, yet no general association between speciation and richness has been recovered. Modern marine species richness is highest in the Indo-West Pacific (IWP), but prior to the Neogene was in the West Tethys. I evaluate two models for this shift in the center of greatest richness: a “multiple hotspots” model driven by changing in situ diversification rate, and a “single hotspot” model in which the constituent lineages of the ancient hotspot dispersed to and established the new one. Among comatulid crinoids, modern richness is concentrated in the IWP, but a comprehensive new fossil database shows that all Mesozoic occurrences are from the West Tethys and Atlantic. An origin and initial diversification of comatulids in the West Tethys is corroborated by ancestral range estimation on a phylogeny of extant comatulids, with which I also recover elevated dispersal into the IWP. Taphonomic controls suggest the Mesozoic absence of comatulids from the IWP does not result from poor preservation or sampling. Moreover, phylogenetic analysis recovers Jurassic forms deep in crown Comatulida, implying that the major lineages originated and diversified in the West Tethys before dispersing to the IWP. Consilient paleontological and neontological evidence thus favors a “single hotspot” model in which the new IWP hotspot was assembled by asymmetrical dispersal from the adjacent West Tethys, probably as tectonic activity generated shelf area in the former and closed off the latter.

F23: Multiple branching and attachment structures in cloudinomorphs, Nama Group, Namibia

Amy Shore[1], Rachel Wood[1], Andrew Curtis[1], Frederick Bowyer[1,2]

[1]University of Edinburgh *[2]University of Leeds*

The Ediacaran-Cambrian cloudinomorphs, which include *Cloudina*, are the first putative skeletal metazoans. They have a benthic ecology and tubular, organic or biomineralized stacked funnel morphologies, but an unresolved phylogenetic affinity. Rare dichotomous branching has been described in *Cloudina*, but here we demonstrate the presence of multiple (polytomous), dichotomous branching in cloudinomorphs from a microbial mat-community from the Nama Group, Namibia, as revealed by 3D models created from serial sections. Branches share an open, central cavity, and branching is achieved via external budding. These cloudinomorphs show attachment and mutual cementation to each other, and also to *Namacalathus*, via extratubular skeletal structures to potentially form a horizontal framework. Polytomous branching excludes a bilaterian affinity as proposed for other cloudinomorphs. This raises the possibility that the Ediacaran tubular, funnel morphology is convergent, and that cloudinomorphs may, in fact, represent taxa of diverse affinity.

F24: Multi-proxy dental morphological analysis – a quantitative approach to inferring diet across distantly related taxa

Christopher Stockey[1], Neil Adams[1], Thomas H. P. Harvey[1], Philip Donoghue[2], Mark Purnell[1]

[1]University of Leicester *[2]University of Bristol*

Diet is a core component of any animal's ecology. Within palaeobiology, diet has primarily been inferred through the analysis of dentition and jaw morphology. Quantitative metrics derived from the shape of dental tools (i.e., food processing structures, teeth and mandibles) have been shown to correlate with diet; multi-proxy dental morphology analysis (MPDMA), combining several of these metrics, provides a more accurate measure of 3D dental tool morphology and correspondingly stronger inferences of diet. The results of MPDMA are hypothesised to be directly comparable between non-homologous dental tools, regardless of their owners' phylogenetic relatedness. However, MPDMA has previously only been used to investigate the diets of crown mammals. Here, we demonstrate that MPDMA produces metric values that are directly comparable between phylogenetically distant taxa with non-homologous dental tools. Specifically, we analysed the bilaterally occluding mandibles of 46 species of extant orthopterans (grasshoppers and crickets) for which diet is well constrained through field observation, gut content analysis and feeding experiments. Our results indicate MPDMA can successfully recover the relationship between dietary categories and mandible morphology within extant orthopterans. Additionally, metric values are directly comparable between orthopteran mandibles and previously published studies of vertebrate teeth, with each dietary category having consistently similar ranges of values. This suggests that MPDMA of a fossilised animal's dental tools can produce accurate inferences about its diet, through direct comparisons with previously published results. Thus, MPDMA has the potential to provide powerful new insights into trophic interactions and ecosystem functioning throughout deep time.

F25: Triton: the new extension of the Neptune Database

Adam Woodhouse[1], Isabel Fenton[2], Tracy Aze[1], Johan Renaudie[3], Jeremy Young[4], David Lazarus[3], Erin Saupe[2]

[1]University of Leeds

[2]University of Oxford

[3]Museum für Naturkunde

[4]University College London

Over the past 50 years, a series of international ocean drilling projects have sampled sub-seafloor sediments using a number of vessels and mission-specific platforms. The microfossil data collected from offshore sampling and post-expedition research is extensive, and several attempts have been made to collate this data to produce a microfossil occurrence database for use among the palaeontological community (most notably, the Neptune database). Microfossil data from these ocean cores are important for constraining macroevolutionary and macroecological patterns over the Cenozoic and can be utilised to address fundamental questions on extinction and speciation for groups such as planktonic foraminifera (PF).

Triton builds upon the success of previous databases, incorporating the current iteration of Neptune (NSB) and ForCenS core-top data, among others. All ocean drilling cores absent from Neptune were assessed individually for reliability of microfossil records and for any tectonic or stratigraphic features that may have affected chronological interpretations. All available biostratigraphic and magnetostratigraphic data was extracted to construct site-specific age models and assign absolute dates to each microfossil occurrence. Triton contains > 400,000 individual Cenozoic PF occurrences, representing the largest occurrence database of any fossil group on the planet (the previous most complete dataset, Neptune, contained 121,647 records).

The construction of this dataset allows us to develop our understanding of ancient PF global distribution patterns and permits us to further interrogate the primary drivers of biogeography within fossil, modern and possibly future marine ecosystems.

F26: What triggered calcification in coccolithophores?

Mariana Yilales[1], Rachel Wood[1], Rosalind Rickaby[2], Fabio Nudelman[1], Sylvain Richoz[3], Matthew Clarkson[5], Tianchen He[4]

[1]University of Edinburgh

[2]University of Oxford

[3]Lund University

[4]University of Leeds

[5]Eidgenössische Technische Hochschule Zürich

Coccolithophores are single-celled calcifying nannoplanktons that were crucial in establishing modern ocean biochemical conditions and carbon cycling dynamics since the evolution of their calcification process in the Late Triassic, ~215 million years ago. The causes that triggered biomineralization in these organisms, however, remains unknown. Oxygen availability has been proposed as a driver for macroevolutionary novelty and innovation, but the relationship between coccolithophore evolution and ocean oxygenation has not been addressed. Here Iodine-to-calcium ratios (I/Ca) and trace elemental analysis were used to build a high-resolution record of upper-ocean redox conditions during the Triassic in order to assess the relationship between oxygen concentration and the evolution of coccolithophore biomineralization. Initial measurements on carbonates from the Early of the Musandam Peninsula, UAE, and the Late Triassic from the Austrian Alps, yield evidence of local oxygenation increase prior to the onset of coccolithophore calcification, as shown by the appearance of the oldest fossil representatives of the group.

Abstracts: Lighting Talks

L01: The Osteology of *Goniacodon*: Understanding a Poorly Studied Paleocene Mammal

Sophia Anderson[1], Steve Brusatte[1], Ornella Bertrand[1]

[1]University of Edinburgh

Goniacodon was first described over 130 years ago from a partial jaw bone and teeth. Since then, further jaw and tooth material has been discovered and described while attempts are made to place the genus within the enigmatic phylogeny of the archaic ungulates of the Paleocene (66-56 million years ago). No postcranial material has been described for the genus, leaving much of its functional morphology in question and up for speculation. This ongoing work provides the most complete description of *Goniacodon* material to date, including a thorough description of postcranial material from *Goniacodon levisanus*, and studies what this can say about the animal's functional morphology. The work will add significantly to the diagnostic characteristics of *Goniacodon*, and ultimately help us understand one of the early mammals to emerge and thrive after the K-Pg extinction, providing insight into the type of ecology which was most advantageous to a mammal at the time.

L02: Two new *Emphanisporites* McGregor 1961 producers from the Lower Devonian of the Welsh borderlands

Alexander C. Ball[1], Charles H. Wellman[1], John B. Richardson[2], Stephen Stukins[2], Paul Kenrick[2]

[1]University of Sheffield *[2]Natural History Museum, London*

The Late Silurian – Early Devonian saw a major ecological turnover from simple, liverwort-like pioneering plants to more complex tracheophytes, establishing the 'modern' terrestrial ecosystem and altering Earth's biogeochemical cycles and atmosphere. Because these earliest plants typically lacked preservable tissues, the plant megafossil record from this critical period is restricted and fragmentary; a stark contrast with the more ubiquitous dispersed spore record, from which many species are known in depth. The limited number of detailed megafossils means that even general characteristics, including affinities and morphology, of the parent plants of many dispersed spore species remain unknown. Fortuitously, smouldering wildfires burned through 'forests' of these tiny plants, preserving fragmented organs including axes and sporangia in exceptional detail as charcoalified mesofossils. When spore masses or sporangia are found with undispersed (in situ) spores inside which are comparable to a dispersed species, a parent plant for this spore species is revealed. It is then possible to investigate the wider affinities, morphology and evolutionary relationships of the plant from which a particular dispersed spore species was released. The dispersed spore species *Emphanisporites* is a distinctive and widespread Siluro-Devonian trilete spore. Despite its extensive occurrence, only three examples are known in situ. Here, a further two species of *Emphanisporites*-containing sporangia are presented, curiously with differing sporangial morphologies. These are the earliest examples of in situ *Emphanisporites* found so far (Early, but not earliest, Lochkovian), and initial insights into their morphology, affinities and evolutionary patterns of the parent plants are explored.

L03: Neurovascular rostral system evolution in metriorhynchoid crocodylomorphs

Charlotte Bowman[1], Mark Young[1], Julia Schwab[1], Stig Walsh[2], Lawrence Witmer[3], Yanina Herrara[4], Stephen Brusatte[1]

[1]Edinburgh University

[2]National Museum of Scotland

[3]Ohio University

[4]Universidad Nacional de La Plata

During the Jurassic, metriorhynchoid crocodylomorphs underwent a major evolutionary transition, adapting to living in open marine environments. The osteological changes that occurred during this transition are well known (tail fin, flippers, loss of osteoderms) but the enopcranial ones are not. In other secondarily marine tetrapods, such as cetaceans, the sensory and physiological demands of the underwater life necessitated a shift in internal rostral anatomy – such as sinus reduction and increased vasculature. In order to investigate if these changes are a common response to life in the sea, we digitally segmented the rostral neurovascular from µCT scans of eight extant and extinct crocodylomorphs. Our sample includes metriorhynchids (*Cricosaurus araucanensis, C. schroederi, Metriorhynchus superciliosus* and *Torvoneustes coryphaeus*), basal metriorhynchoids (*Pelagosaurus typus* and *Eoneustes gaudryi*), and a juvenile and adult example of two extant longirostrine species (*Tomistoma schlegelii* and *Gavialis gangeticus*). Interestingly, the metriorhynchoids had rostral neurovascular canals more similar to those of extant juveniles than adults, suggesting a paedomorphic shift early in their evolution. Trigeminal innervation is markedly different between the metriorhynchoids and extant taxa. Extant crocodylians have a complex network of nerve channels that are spaced to fully innervate all sides of the rostrum, whereas basal metriorhynchoids had fewer, larger channels, with a linear arrangement of openings on the skull. Furthermore, metriorhynchids had a greatly reduced trigeminal system, implying that facial somatosensation was no longer a principal sense; an intriguing possibility as during metriorhynchoid evolution, orbit size rapidly increased.

L04: Reconstructing the neck of *Dicraeosaurus hansemanni*

Amy Campbell[1,2], Daniela Schwarz[1]

[1]Museum fur Naturkunde, Berlin

[2]Humboldt-Universität zu Berlin

The cervical region of dicraeosaurids display an array of unusual morphological characters including shortened necks; a character taken to the extreme in *Brachytrachelopan*, elongate neural spines, and reduced pneumatisation of the vertebrae. Here we present a 3D reconstruction of the articulation and posture of the neck of *Dicraeosaurus hansemanni* from surface scans of the holotype, which is mounted in the Museum fur Naturkunde, Berlin. The cervical and dorsal vertebrae were dismounted and scanned individually in January 2020 and subsequently rearticulated in Blender. The posture and flexibility of the neck is constrained by a multitude of factors, many of which do not preserve well in the fossil record. These include overlap of articulation facets between vertebrae and thickness of intervertebral cartilage, both characters that are heavily affected by taphonomy. There is minimal post-mortem deformation of the vertebra and the holotype was found largely articulated, though the anterior cervicals were rotated and separated from the posterior ones. Unfortunately, there is neither a field map of the recovery site, nor any clear photos of the holotype in situ and so the reconstruction of the zygapophyseal elements and inference of volume of intervertebral cartilage is based upon comparison with extant taxa and models of other sauropod dinosaurs. This is part of ongoing work on producing an artiulcated virtual model of *Dicraeosaurus hansemanni* and forms the basis of future biomechanical analysis of the neck and shoulder girdle.

L05: In Europe alone: A revision of the soft-shell turtle *Rafetus bohemicus* (Liebus 1930) from Břešťany Clay (Lower Miocene, Czech Republic)

Milan Chroust[1,2], Martin Mazuch[1], Martin Ivanov[3], Àngel Luján[3,4]

[1]Charles University

[2]Institute of Geology of the Czech Academy of Sciences, Prague

[3]Masaryk University

[4]Universitat Autònoma de Barcelona

The fossiliferous Břešťany Clay represents one of the richest early Miocene (early Burdigalian) sites in the world. It is famous mainly for the fossil record of plants, but vertebrates are abundant as well. Although many almost complete shells, cranial and postcranial bones of soft-shell turtles are currently available, however, some of these remains were unable for studying due to its preservation conditions. Despite this fact, and thanks to new technologies, we performed CT scans in order to obtain 3D models of the preserved skulls, which have more value in taxonomy compared to complete shells. We here present the first skull description of the trionychid turtle *Rafetus bohemicus* including new diagnostic characters. Our preliminary results show that *Rafetus* differs from *Trionyx* in having: (1) a shorter and broader snout; (2) a non-concave medial edge of the maxilla in palatal view; (3) a short intermaxillary suture; and (4) a large intermaxillary foramen. Although the biogeographic range of *Rafetus bohemicus* is still unclear, the new remains suggest that this species inhabited Central and Eastern Europe, restricted by Carpathian mountain range and Parathetys sea in the south, whereas *Trionyx vindobonensis* occupied Western, Southern and Central Europe. The cranial remains here presented will allow not only to update diagnosis of *Rafetus bohemicus*, but also differentiate both trionychid genera in the European record during the early Miocene.

L06: Constructing 3D multi-body dynamic models to investigate the evolution of forelimb anatomy and function in ornithischian dinosaurs

Matthew Dempsey[1], Susannah C. R. Maidment [2], Karl T. Bates[1]

[1]University of Liverpool

[2]Natural History Museum, London

The evolution of quadrupedality from a bipedal ancestral state is unique to Dinosauria and its closest relatives. At least three independent reversions to quadrupedality occur in ornithischian dinosaurs. Previous study of these transitions has involved the identification of osteological correlates to posture, analysis of relative limb bone scaling, and the use of 3D models to investigate how changes in mass distribution may have driven quadrupedal reversion. These studies demonstrate that despite basic morphological convergence, quadrupedal ornithischians displayed a high diversity of postures, suggesting that quadrupedal reversion was driven by a variety of selection pressures. By constructing 3D multi-body dynamic models of key ornithischian taxa from across the convergent trends to quadrupedality, we aim to quantitatively analyse the biomechanical changes to the forelimbs from assisting in foraging and feeding to being principal weight-bearing components of the locomotor system. Our focus is directed towards investigating changes to muscle function mechanistically linked to posture and gait. Using the basal neornithischian *Hypsilophodon foxii*, the iguanodontian *Tenontosaurus tilletti*, the ceratopsian *Chasmosaurus belli* and the thyreophoran *Stegosaurus stenops* as examples, the multi-software workflow required to construct these 3D forelimb models is outlined here, including specimen digitisation, osteological rearticulation, myological reconstruction and preliminary muscle moment arm analysis.

L07: Using mass spectrometry with benthic foraminifera to investigate Early and Middle Eocene climate variability in the Rockall Trough, NE Atlantic

Jennifer Farrant[1]

[1]*University of Birmingham*

The Eocene is an internationally recognised chronostratigraphic series spanning 22 million years, marking a global shift from a greenhouse to an icehouse climate. This period is punctuated with hyperthermal events, which can be studied as potential analogues for modern global climate change and global warming processes. The study of the Rockall Trough core "16/28 Sb-01" can reveal new insights into the more regional climatic shifts in the north-east Atlantic Ocean during the Eocene. There is high level of recovery and exceptional preservation of microfossils across the early and middle Eocene. This project will produce a new low-resolution record of stable isotopes; δ18O and δ13C through the core. This will be contrasted against the existing bulk isotope data, and the δ18O and δ13C curves from the work by Cramer et al. (2009). The benthic foraminifera identified and picked for this project were *Cibicidoides sp*., *Lenticulina sp.* and *Nuttalides truempyi*. 30 core depths were sampled for the above benthic foraminifera and submitted for stable isotope analyses in December 2019 to the NIGL facilities at the British Geological Survey. This new data may support the long-term cooling trend reflected in the existing bulk records or provide evidence for more localised climatic processes. Paired isotope analyses are also analysed to interpret differences between the three genera in this project. This data will be used in conjunction with the planktic foraminifera record compiled by Ulrike Baranowski through the same core to contrast planktic Sea Surface Temperatures (SSTs) and benthic Bottom Water Temperatures (BWTs).

L08: Simulating biodiversity in a disturbed landscape

Euan Furness[1]**, Mark Sutton**[1]**, Philip Mannion**[2]

[1]*Imperial College London* [2]*University College London*

Controls on biodiversity are imperfectly understood, but are likely to include the rate and scale of environmental disturbance; variations in disturbance may thus underlie prevalent large-scale phenomena such as the latitudinal biodiversity gradient. There are two, apparently conflicting, hypotheses about the impact of disturbance on species richness: the stability-time hypothesis states that minimal disturbance leads to maximal niche partitioning and allopatric speciation, and minimal extinction risk, whereas the patch-mosaic hypothesis states that localised disturbance increases the variety of environments available and, therefore, increases niche partitioning. We used REvoSim, a digital eco-evolutionary system that models mutation, reproduction and selection, to investigate the impacts of habitat heterogeneity and disturbance on species richness over geological timescales. We found that the impact of disturbance on species richness was dependent on the spatial scale of the disturbance relative to the spatial scale of any disturbance-independent habitat heterogeneity: disturbance generally decreased species richness, but could increase it if it occurred on a sufficiently small scale. These results allow for reconciliation of the stability-time and patch-mosaic hypotheses, and can be used to predict the impacts of disturbance in the geological record.

L09: Fossil analysis for the new age: A chemical, taxonomic and anatomic assessment of a Zygodactylid avian (TCMI 2018.82.1) from the Green River Formation (Eocene)

Natalia Jagielska[1,2], Roy Wogelius[1], Phil Manning[1], Victoria Egerton[3]

[1]University of Manchester *[3]The Children's Museum of Indianapolis*

[2]University of Edinburgh

Zygodactylidae are a clade of small extinct perching birds from Eocene, distinguished by zygodactylous (parrot-like) digit arrangement. Zygodactylidae are related to the successful extant avian orders Passeriformes (finches) and Psittaciformes (parrots); and are pivotal to the understanding of modern bird evolution. Despite their essential position on the avian evolutionary tree, Zygodactylidae remain relatively understudied. TCMI 2018.82.1 is a complete, articulated fossil of an unknown Zygodactylid hailing from the Green River Formation (Wyoming, North America). The stellar preservation of the fossil prompted the use of the de novo analytical technique, Synchrotron Rapid Scanning X-ray Fluorescence (SRS XRF), to map endogenous chemical proxies providing clues to taphonomy and biology of the organism. This is a first detailed anatomical and chemical assessment of TCMI 2018.82.1. Reduced sternum and keel, rough bone texture, diminutive size and relatively large cranium suggest TCMI 2018.82.1 being the youngest Zygodactylid on the record.

The chemical analysis aided the separation of the skeleton from the matrix, but also established phosphorous, iron and zinc as endogenous to the skeletal remains. The chemical traces can be treated as biomarkers, however, due to the strong influence of post-depositional oxidising fluids introducing ferric iron and manganese in slab fractures, complicates the process. The chemical analysis differentiated endogenous organic remains from exogenous components of the matrix and oxidising precipitate, illustrating the complexity of the taphonomic processes.

SRS-XRF scans demonstrate the importance of fossil study under more than visible light and help to shed the light on the early avian evolution.

L10: The Effects of Sampling on Extinction Selectivity in Deep Time

Tasnuva Ming Khan[1], Nussaïbah B. Raja[1], Ádam Kocsis[1], Wolfgang Kiessling [1]

[1]Friedrich-Alexander-Universität Erlangen-Nürnberg

Assessing the selectivity of extinction over time has been made possible by compilations of fossil occurrences in time and space in databases such as PBDB. Selectivity can be assessed with regards to taxonomy, ecological traits and distributional patterns. One approach in measuring selectivity is logistic regression methods. Here, the odds-ratios between a trait and a binary outcome (extinction versus survival) is computed. Existing studies posit that widespread geographic ranges are generally associated with survivorship at background intervals only, and large bodied taxa uniquely and preferentially go extinct in the modern oceans. However, these studies take recorded stratigraphic ranges at face value. They are subject to Signor-Lipps effects, where the preservation potential and sampling completeness cause backward smearing of last occurrence dates. Extinction is therefore not a binary outcome, as the probability of observing an extinction event depends on the sampling probability. We hypothesize that current extinction selectivity studies are biased by the completeness of the fossil record, which we will quantify by computing the completeness of each temporal bin using three-timer rates. We propose using capture-mark-recapture methods, with completeness as a convolving variable. We will test our methods on Phanerozoic occurrences of marine invertebrate genera, and focus on two traits: geographic range and body size. We will assess the rigor of our methods through multiple simulations of the fossil record, where we will control for unbiased and size-biased extinction rates, and vary sampling probability. By minimizing sampling biases, our model will be robust and replicable for future analyses.

L11: Diversity patterns of terrestrial eutherian mammals & the first appearance of the modern-day Latitudinal Biodiversity Gradient in South America

Miranta Kouvari[1,2], Phil Mannion[1], Anjali Goswami[2]

[1]University College London *[2]Natural History Museum, London*

The rapid climatic changes that take place today hugely affect biodiversity worldwide. One of the most fundamental macroecological patterns that describes today's diversity distribution is the Latitudinal Biodiversity Gradient (LBG) that first appeared around the Neogene period but its forming and causes remain unclear. In order to predict future biodiversity loss, it is critical to understand how it works and how past diversity reacted to climatic changes. This study focuses on terrestrial eutherian mammals and aims to understand the macroevolutionary patterns of Cenozoic diversity through time and space as well as the drivers that shape them. Here, I focus on South American eutherian mammals. For this, I compile data into the Paleobiology Database (PBDB) to reconstruct palaeodiversity curves through space and time, taking into account fossil bias using subsampling methods and test the effect of global palaeotemperature on diversity with regressions. Preliminary results show newly observed diversity patterns in the Cenozoic that are, however, not correlated with global palaeotemperature change. They also show evidence of the modern-day LBG first appearance taking place in South America in the last 5 Myr, something that has been evidenced in North America as well.

L12: Make it snappy: ichthyopterygians had more efficient jaws than sauropterygians

Rob Loveday[1]

[1]University of Bristol

The study of functional jaw morphology gives us an insight into the behaviour and ecology of long-dead creatures, and a new method of combining morphometrics and finite element analysis lets us quantify the functional trade-offs in favour of other factors made by organisms during their evolution. Preliminary results from applying this method to the mandibles of ichthyopterygians and sauropterygians – two highly successful Mesozoic marine reptile clades – reveal that ichthyopterygian jaws generally had greater rotational efficiency than those of sauropterygians, which may be a result of phylogenetic constraints.

L13: Sedimentological and Morphological Basis for Probable Life Appearance of Nostoceratid Heteromorph Ammonoids

Katherine Marriott[1]

[1]*Brooklyn College*

Soft tissue preservation in ammonoid cephalopods is rare. The appearances and behaviors of nostoceratid heteromorphs are especially difficult to ascertain due to their extreme shell shapes. However, interpretations based on sedimentological associations, and shell form (e.g., suture geometry, mouth parts, muscle scars, phylogenetic proximity to coleoids, and living chamber capacity) can direct the visual imaging of how heteromorphs looked and behaved.
While assumptions of apparent planktivory may be applied to some members of the genus *Baculites* due to radular reconstruction (Landman et al, 2007) the aptychus (beak) of an in-situ *Didymoceras nebrascense* appears to be adapted for cutting and crushing larger prey (Kruta et al 2010). However, *Didymoceras'* limited nektonic agility may relegate its macrophagous species to ambush hunting and scavenging (Larson, 1997). By contrast, no buccal masses or aptychal remains have ever been recorded for the nostoceratids' most extreme genus, *Nipponites*. Reconstructions of heteromorph life appearance can be interpreted from ecological cues derived from depositional environments: because *Didymoceras* is found most abundantly in shales associated with the most extreme deep-water facies of the Pierre Seaway, *Didymoceras* probably had three possible modes of life: epibenthic, epipelagic, or vertical migrator. Three separate mechanisms were examined in the extrapolation of heteromorph life appearance: stratigraphy, septal configuration (including suture geometry and living chamber dimensions), and aptychal adaptations.

L14: Palaeoenvironment Reconstruction and Biostratigraphy of the Maltese Archipelago and its Implications for Modern Climate Change

Brett Martin[1]

[1]*University of Derby*

Modern climate change threatens the integrity and productivity of marine ecosystems across the planet. One of the most advocated ways of predicting the path and effects of modern climate change is through the use of a geological analogue. The Maltese Archipelago, consisting of accumulated marine sediments, is of Upper Oligocene to Upper Miocene age capturing the Mi-1 cooling event, Mid-Miocene Climatic Optimum and Mid-Miocene Climatic Transition. A comprehensive account of microfossil and macrofossil biostratigraphy is made using an extensive random sampling method, robust statistical testing and the completion of a Maltese Palaeontological Handbook. For the first time, absolute dating of Maltese limestones using LA-ICP-MS U-Pb chronology attempts to accurately correlate palaeontological changes to known climatic events. Palaeoenvironment reconstruction includes the palaeogeography of the Central Mediterranean through the Late Oligocene and Miocene epochs as well as carbonate ramp spatial change analysis due to sea level change. Events of phosphogenesis closely associated with ocean acidification and benthic hypoxia are prominent in the stratigraphy and are also consulted as a potential effect of climate change. With observable drastic changes in marine palaeofauna following palaeotemperature closely, implications for the effects of modern climate change can be discussed in relation to ecosystem integrity and habitat change. This will give us the information necessary to adapt in order to save our marine ecosystems.

L15: Worms on Film: Metazoan colonisation of matground dominated sediments during the Cambrian Explosion.

Catherine Mascord[1], Liam Herringshaw[1], Krysia Mazik[1], Dan Parsons[1], Duncan McIlroy[2]

[1]University of Hull *[2]Memorial University of Newfoundland*

Infaunal (burrowing animal) activity and microbial mat growth can affect conditions within the seafloor. Most infauna will preferentially colonise oxygenated seafloors and will help to maintain sediment oxygenation by mixing in dissolved oxygen from the water column as they burrow. Conversely, matgrounds thrive in anoxic environments and increase sediment stickiness, thus reducing sediment mixing, and further promoting anoxic conditions.

Infauna-colonised and oxygenated seafloors were dominant throughout most of the Phanerozoic and are typical of marine sediments today. However, Precambrian and early Cambrian sediments were characterised by anoxia and matground growth. Understanding the transition from matground- to infaunal-dominated seafloors, in particular how early infauna colonised microbially bound sediments, is crucial to a fuller understanding of the Cambrian Substrate Revolution.

Fossil evidence of the interaction between early infauna and Phanerozoic matgrounds, found on Bell Island, Newfoundland, indicates that complex, deeper tier trace-makers were unable to survive in matground dominated environments. However, simple, near surface, deposit feeding infauna were commonly found within, and around, the fossilised matgrounds.

Although the Bell Island trace fossils are well preserved, some infaunal groups or behaviours that were likely present in the early Phanerozoic, including small metazoans (meiofauna), are rarely found in the fossil record. These gaps in the fossil record can be filled by assessing the behaviour of modern infaunal groups in lab-grown matgrounds and anoxic sediments. Initial experimental results indicate that smaller meiofauna, in addition to the larger, deposit feeding trace makers, may also have played a significant role in the Cambrian Substrate Revolution.

L16: A summary on the exceptionally well-preserved pterosaurs

Hebert Bruno Nascimento Campos[1], Edio-Ernst Kischlat[2]

[1]Universidade Estadual da Paraíba

[2]Serviço Geológico do Brasil (CPRM - SUREG-PA), Divisão de Bacias Estratigráficas (DIBASE)

Exceptionally well-preserved pterosaurs occur in several deposits around the world. The first mention of the occurrence of soft tissue associated with pterosaur remains is related to the holotype of the non-pterodactyloid pterosaur *Scaphognathus crassirostris* from the Solnhofen Lithographic Limestone (Upper Jurassic). The most common soft structure reported is wing membrane with more than 30 specimens known: "*Eudimorphodon*" *ranzii* (MCSNB 8950 A and B, Argillitu Riva di Solto Formation), "*Eudimorphodon*" sp. (MFSN 1922, Dolomia di Forni Fomation) and *Carniadactylus roselfeldi* (MFSN 1797, Dolomia di Forni Fomation) until the Lower Cretaceous Romualdo Formation: Pterodactyloidea indet. (MCT 1534-R, MN 4728-V, MN 6575-V, DGM 1475-R and SMNK PAL unnumbered). Between the cranial integuments, soft cranial crest has been the most common reported, being more frequent and with expressive occurrence in tapejarid pterosaurs from the Lower Cretaceous Crato Formation of Brazil. The rarer report of soft structure is attributed to manual webbing. Here are mentioned three undescribed specimens with soft tissue association: *Germanadactylus cristatus* (SMNK PAL 6592), which present short pycnofibers on the neck; *Rhamphorhynchus intermedius* (NHMW 1998z0077/0100), that exhibit a wing membrane with vascular tissue preserved; and, the counterpart of the holotype of *Tupadactylus imperator* (MCT 1622-R), that preserves besides the soft cranial crest, the complete nasal septum and the frontal part of the rhinotheca. New method of analysis (e.g., laser stimulating photographs) applied to already described and undescribed pterosaurs can reveal the presence of soft tissue on specimens with potential for this type of preservation.

L17: Reappraisal of Early Jurassic dinosaur fossils from Lesotho at the UCL Grant Museum of Zoology

Hin Ching Ng[1], Michael Pittman[1], Paul Upchurch[2]

[1]University of Hong Kong *[2]University College London*

The Early Jurassic is an important time in dinosaurian evolution when they transition from humble beginnings in the shadows of their contemporaries to forms that begin to dominate their habitats and start to show the specializations theropod, sauropodomorph and ornithischian dinosaurs are known for. Here we contribute to the knowledge of Early Jurassic dinosaurs through the study of postcranial dinosaurian material collected from the Upper Elliot Formation of the Karoo Supergroup, Lesotho, southern Africa. Part of this fragmentary and often deformed material was briefly described and referred to two early sauropodomorph species, Massospondylus and Ignavusaurus, but the totality of this material has yet to be evaluated, especially in the context of recent discoveries from contemporaneous sites in the region. Here the results of the first exhaustive description of this material is presented, including refinements to existing taxon referrals. Comparisons were made among previously studied materials stored in the UCL Grant Museum of Zoology UCL and unstudied materials in the Natural History Museum, London. The later batch of materials is identified as early sauropodomorph for the first time.

L18: A New Notosuchian Crocodylomorph Phylogeny: Effects of Increased Character and Taxon Sampling on Tree Topology Via the Inclusion of Continuous and Postcranial Data

Cecily Nicholl[1], Philip Mannion[1], Diego Pol[2,3]

[1]University College London

[2]Museo Paleontológico Egidio Feruglio

[3]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)

Notosuchia is an extinct group of terrestrial crocodylomorphs noted for their bizarre, morphologically disparate bauplans, as well as their varied diets and preference for hot, semi-arid environments. Since the erection of the clade, disputes have occurred regarding notosuchian inter-relationships, most notably in terms of the position of the group (sebecid sebecosuchians) that survived the Cretaceous/Paleogene mass extinction event (66 Ma). Here, these discrepancies are confronted through improved character and taxon sampling, with emphasis placed on the increased inclusion of continuous and postcranial data. Both data types are currently poorly represented in crocodylomorph character lists, potentially limiting the amount of information that can be recovered from fossil specimens. We present a new character-taxon dataset produced via standardized approaches to character construction; it comprises the largest matrix yet to be compiled for Notosuchia, consisting of 470 characters and over 60 notosuchian taxa. Continuous and postcranial character contribution to this matrix is increased by 11% and 9% respectively compared to the largest previous notosuchian-relevant dataset. The new data are included in phylogenetic analyses implemented under maximum parsimony. Sebecosuchia is positioned as a derived notosuchian clade, comprising a monophyletic Baurusuchidae and Sebecidae. In the majority of analyses, the stratigraphically oldest known putative member of Notosuchia, *Razanandrongobe sakalavae* from the Middle Jurassic of Madagascar, is recovered as an early-diverging notosuchian, by contrast to recent analyses which found it to be well-nested within the clade. The incorporation of previously neglected data provides a revised and nuanced view of notosuchian evolutionary interrelationships.

L19: How low can you go: method developments for analysing small amounts of foraminiferal calcite neodymium isotopes (εNd) in palaeoceanography

Frances Procter[1], Jason Harvey[1], Tracy Aze[1]

[1]University of Leeds

The world's oceans are facing unprecedented challenges in response to the rapidly changing climate. Palaeontological proxies from the fossil record can provide analogues of future change, and an opportunity to benchmark global responses to a high CO_2 world. Planktonic foraminifera, microscopic zooplankton living in the oceans globally, record ambient seawater conditions in their tests (shells) and due to their excellent species level fossil record enable us to investigate high resolution records into deep time. The neodymium (Nd) isotope proxy (εNd) can be used to infer patterns of past ocean circulation. Whilst Nd signals can be locked into planktic foraminifera tests, a major limiting factor to this palaeoceanographic proxy remains the large sample sizes required to ascertain a reproducible εNd signal. Often, hundreds of individual foraminifera specimens are required, which considerably limits the spatial and temporal resolution at which this proxy can be applied due to lack of material. This study aims to develop analytical methods which significantly reduce the amount of calcite required, through a series of experiments combining more effective separation of Nd from near-neighbour rare earth elements, with improved ionisation on the filament in thermal ionisation mass spectrometry (TIMS). Methods include testing chemical activators, measuring Nd as an oxide, and testing 10^{13} ohm resistors in the amplifiers of the mass spectrometer. Development of such methods could enable masses of collected seafloor material previously considered unsuitable, to be analysed. Improving sampling resolution of εNd could further our understanding of past ocean circulation and subsequent changes in a warming world.

L20: Fossil microorganisms from the Rhynie Chert: importance and implications for early ecosystems

Edwin Rodriguez Dzul[1], Sean McMahon[1], Bryne Ngwenya[1]

[1]University of Edinburgh

The Rhynie Chert is a unique fossiliferous silica deposit from the Lower Devonian, located in Scotland and dated to ~407 million years old. Formed in a terrestrial hydrothermal setting, it contains exquisitely preserved organic and silicified remains of early land plants and their associated animals, fungi, algae and bacteria. Although several studies have been accomplished focusing on plants and fungi, the fossil bacteria have received little attention despite the clear potential for exciting studies of terrestrial microbial ecology. In this study, we aim to identify and characterize new microorganisms and bacteria from the Rhynie Chert and their relationship with their specific environment, using petrographic analysis and mapping of thin sections, along with optical analytical methods as Raman microscopy, confocal laser scanning microscopy (CLSM), and limited scanning electron microscope (SEM) for additional mineralogical and compositional information. Preliminary results show cyanobacteria (possible Anabaena-like bacteria, microbial mats and *Rhyniosarcina devonica*), fungi (*Glomites*-like) and amoebae (the recently described *Palaeoleptochlamys hassii*). Further analysis of thin sections and optical methods would be utilised for more detailed descriptions of microorganisms, their taphonomy, microenvironments and ecological settings.

L21: Skeletal and soft-tissue completeness of the acanthodian fossil record through time

Lisa Schnetz[1], Richard Butler[1], Ivan Sansom[1], Michael I. Coates[2]

[1]University of Birmingham *[2]University of Chicago*

Acanthodians are a peculiar group of extinct fishes from the Palaeozoic. While they show comparatively little diversity in lifestyle and range of known body shapes, they play a prominent part in our understanding of vertebrate evolution as part of the chondrichthyan stem-group. Their history, however, is poorly understood, which is largely a consequence of the limited preservation of their cartilaginous skeleton. This results in a preservational bias towards isolated remains such as fin spines and scales. Thus, considerable uncertainties remain in how the completeness of acanthodian fossils impact on the phylogenetic narrative of chondrichthyans and other jawed vertebrates. Here, we address these issues by using variations of the previously defined Skeletal Completeness Metric (SCM), an approach to calculate how complete the skeletons of individuals are compared to their theoretical complete skeleton, to quantify the quality of the acanthodian fossil record. Information from museum collection visits and literature were compiled into a dataset of >1600 specimens comprising >200 taxa. Acanthodian completeness peaks in the Lower and Middle Devonian, Mississippian and again in the early Permian (Asselian), with lowest scores in the early Silurian (Llandovery). Change in completeness of acanthodians shows a significant correlation through time with higher completeness in the later stages of the Palaeozoic. Acanthodians show a significantly lower completeness distribution than other vertebrate groups, including theropods, plesiosaurs, sauropodomorphs, ichthyosaurs, pelycosaurs and parareptiles, but are similarly low as bats. Our assessment of completeness reveals only weak spatial biases influencing the acanthodian fossil record while temporal biases are much higher.

L22: Fossilization potential of marine assemblages and environments

Jack Shaw[1]

[1]Yale University

The fossil record provides the only direct record of the history of life, but it is incomplete. Discriminating between what was absent, and what is simply not preserved, is critical to macroevolutionary and macroecological inferences. A comparison of diversity data in over 20,000 modern marine assemblages with fossil occurrence data yields the first global assessment of fossilization potential. Two different metrics are informative: (i) taxon fossilization potential, the proportion of taxa in a modern community with a fossil record; and (ii) assemblage fossilization potential, the proportion of taxa from a given environment with a fossil record in the same environment. Both vary between environments and, predictably, assemblage fossilization potential is lower. The results inform estimates of the completeness of fossil assemblages in different settings and constrain paleoecological inferences.

L23: Hyperossification in the vertebral column of Devonian placoderm fishes (Arthrodira)

Savanna N. K. van Mesdag[1], Jan den Blaauwen[2], Mason N. Dean[3], Zerina Johanson[1]

[1]Natural History Museum, London *[3]Max Planck Institute, Potsdam, Germany*

[2]University of Amsterdam

Skeletal bone enlargement (hyperossification) was thought to only occur in endochondral and dermal bone (e.g., endoskeletons of marine tetrapods and dermal bones of certain jawless vertebrates and placoderms, and teleost fishes). However, in some arthrodiran placoderms (basal jawed vertebrates)—*Millerosteus minor, Compagopiscis croucheri, Eastmanosteus calliaspis*—several types of bone enlargement also occur within the endoskeleton, affecting the vertebral column. Significantly, placoderm endoskeletal bone is thought to be thin-walled, ossifying only in the fibrous layer surrounding a cartilage precursor (historically called perichondral bone), rather than endochondrally/dermally. Hyperossification differs among these three species, revealing a range of internal and external bone morphologies undescribed for the placoderm endoskeleton. Thus, neural arches of *Millerosteus minor* are swollen in external appearance, in cross-section showing considerable deposition of layered, compact bone. In contrast, *Eastmanosteus calliaspis* arches are unswollen externally, with the neural spine cortex composed of the thin perichondral bone expected for placoderms. Histologically, though, the arch comprises numerous layers of perichondral bone. In *Compagopiscis croucheri*, as in *Eastmanosteus calliaspis*, the spine and arch are unswollen externally, but the perichondral bone is thickened and compact, more similar to *Millerosteus minor*. Vertebral hyperossification in these taxa differs considerably in the degree and mode of cortical tissue thickening, via addition of tissue to the bone's external (periosteal) and/or internal (endosteal) surfaces. Hyperossifcation in these arthrodires demonstrates that increases in endoskeletal bone mass are not restricted to crown group gnathostomes (Chondrichthyes + Actinopterygii), representing a first step in the evolution of this process, involving modifications to cortical bone layers.

L24: Reassessing the phylogenetic affinities of the South American Native Ungulates

Oscar Wilson[1], Robert Asher[1]

[1]University of Cambridge

The South American Native Ungulates (SANUs) were a diverse group of mammals, endemic to South America, with a contested phylogenetic affinity. Phylogeny reconstructed from molecular and morphological data have yielded contrasting results, and compared to other taxa, combined approaches have so far led to reduced resolution of their position within the placental phylogeny. Our work greatly increases the sampling of SANUs, expanding on the 3660-character matrix of Carrillo and Asher (2017) with five new notoungulates and two litopterns added to the matrix. Three crown perissodactyls further allow testing of the hypothesis of Perissodactyl affinity of SANUs. These new morphological data, combined with molecular sequences from the literature, allow for the most comprehensive reassessment of the position of SANUs within placentals to date, using both parsimony and Bayesian approaches. This comprehensive approach will test the assumption of monophyly for SANUs. Using RStudio, scaled Robinson-Foulds values and shared clades will be used to investigate how the addition of morphological data impacts the similarity to the consensus tree in this group, to elucidate the interaction between morphological and molecular data. Predicted ancestor experiments will be performed for the first time in an entirely fossil group, which we predict increase the congruence with the consensus tree. Artificial extinction experiments will allow for the testing of the role of taphonomy in interpreting the position of the SANUs within placental mammals. These analyses will aim to provide resolution on the radiation of this enigmatic group of mammals in South America.

L25: The early evolution of ctenophores, a perspective based on fossils from the early Cambrian Chengjiang biota

Yang Zhao[1,2], Jakob Vinther[2], Luke A. Parry[3], Xianguang Hou[1], Peiyun Cong[1]

[1]Yunnan University

[2]University of Bristol

[3]University of Oxford

Ctenophores are unusual diploblastic animals united by a biradial symmetry, eight locomotory comb rows made of large compound cilia and paired adhesive tentacles in most lineages. Ctenophores have a net-like nervous system like cnidarians, but lack other eumetazoan features such as Hox genes, which are either primitively absent or a lost. A long branch leading to ctenophores, as well as a recent (~250 Ma) origin of the crown group has made them difficult to place in molecular phylogenies. Are ctenophores the sister group of all other animals, the cnidarian sister group or somewhere in between? Fossil ctenophores may help unravel their ancestry and first appear during the Ediacaran-Cambrian. The Chengjiang biota in southwest China is a key Cambrian Konservat-Lagerstätte that documents extinct ctenophores with high morphological disparity and taxonomic diversity. Currently, ~10 Chengjiang ctenophore species have been identified, which can be grouped into two morpho-groups: dinomischiids and scleroctenophores. These fossils display distinctive combinations of characters shared with both cnidarians and ctenophores, illustrating a transition from a sessile polyp to the swimming ctenophore bodyplan. Dinomischiids are the earliest branching taxa, are sessile, and suspension fed using 18 tentacles with rows of cilia that are homologous with ctenophore comb plates. Taxa recovered close to the ctenophore crown include the skeletonized scleroctenophores, and non-skeletonised and more crown group-like taxa from the Burgess Shale. We identify a new fossil ctenophore with narrowly arranged ctenes, that bifurcate from the apical organ, suggesting this stem ctenophore is closest to the crown among known fossil taxa.

Abstracts: Posters

P01: Utilising foraminifera, ichthyoliths and nannofossils to study the biological pump during Eocene extreme warmth

Sophie Alexander[1], Philip Sexton[1], Pallavi Anand[1], Steven Bohaty[2]

[1]The Open University *[2]The University of Southampton*

The biological pump draws atmospheric carbon into the ocean, before sequestering it into sediments. The early-to-middle Eocene interval (~42 to 50 Ma) witnessed elevated CO_2 levels and acute greenhouse warmth and is thus a valuable interval with which to better understand possible changes in biological pump operation under future anthropogenically induced warming. In this study, we utilise accumulation rates of ichthyoliths (IAR) and benthic foraminifera (BFAR) within sediments, combined with smear slide analysis at sites across the Atlantic basin. It is well established that BFAR reflects organic carbon delivery to the seafloor. We find a positive correlation between IAR and BFAR, suggesting the two are similarly recording organic carbon transfer through the water column. It remains unclear whether IAR is representative of surface or export productivity; via the transfer of energy up the food web from primary producers to fish. Smear slide analyses reveal that at high latitudes calcareous nannoplankton were the dominant primary producer. Yet there is no correlation between either IAR or BFAR and nannofossil abundance. One possibility for this discrepancy is that signals of ballasting dominate abundance of nannofossils in seafloor sediments, obscuring the true primary production signals. Ongoing work seeks to both reconcile these discrepancies and analyse ichthyolith morphotypes. Morphometric analysis may allow comparison to the existing fossil record, allowing semi-quantitative comparison of the volume of organic carbon flux that each morphotype represents. If an agreement is reached with BFAR, this could represent a validation of the utility of IAR in palaeoproductivity studies.

P02: A geometric morphometric analysis of plesiosaur flippers with reference to behavioural groups and predator categorisation

Laura Austin Sydes[1], William Sellers[1]

[1]University of Manchester

Plesiosaurs are among the most diverse marine reptiles to have ever lived. Existing from the Late Triassic through to the end Cretaceous, they evolved and diverged into two very different bauplans. The plesiosauromorphs and pliosauromorphs, predominantly varying in skull size and neck length but also in proportions of limb elements. Much research has been conducted into behavioural categories of plesiosaurs using evidence from body shape, skull anatomy and tooth morphology. The categories produced are generally concordant within existing morphotype groups which vary from cruising, ambush predators (plesiosauromorphs) to fast pursuit predators (pliosauromorphs). Such differences in locomotor behaviour must affect swimming biomechanics and as plesiosaur locomotion comprises limb dominated movement; these groups would therefore be expected to be reflected in flipper morphology. A such, this analysis statistically compares plesiosaur flippers between behavioural and predatory groups in order to demonstrate whether this morphology is really diagnostic of differing locomotor abilities. Various analyses have been conducted, involving digitisation of 2D landmarks for Jurassic (n = 17) and Cretaceous (n = 22) species ensuring all major families are represented. Analyses conducted include; flipper outline assessed using sliding landmarks and limb element proportions assessed via fixed landmarks. Preliminary analysis using PCA shows poor discrimination of groups for shape analysis, however behavioural groupings are much stronger within the proportional analysis. Suggesting that while limb shape appears to be non-reflective of behavioural group, a strong morphological signal remains within this via the proportion of limb elements which dictates the key drivers for flipper shape in these animals.

P03: Liberating microfossils from indurated carbonates: comparison of three disaggregation methods

Charlotte Beasley[1], Daniel B. Parvaz[2,3], Laura Cotton[4], Kate Littler[1]

[1]University of Exeter

[2]Lightning Machines

[3]SELFRAG AG

[4]University of Portsmouth

A lack of reliable disaggregation techniques for indurated carbonate sediments is a common problem when working with larger foraminifera and other shallow water taxa. As such, three disaggregation methods have been applied to a number of heavily lithified, shallow water (<250 m), carbonate-rich sedimentary rock samples of Paleogene age. The methods applied were two more traditional disaggregation methods of immersion in either Calgon or acetic acid, and a novel method of electric pulse fragmentation (EPF). The EPF method utilises electrical discharges to break a material apart along internal compositional boundaries. The effectiveness and efficiency of each method has been compared, as well as the preservation of the resultant liberated microfossil material (primarily larger foraminifera). Of the three methods, EPF was the most efficient and effective, with calcitic, silicic, and clay matrix materials successfully disaggregated. As this study primarily focussed on the liberation of larger foraminifera, we discuss nuances to the method which may allow for more effective recovery of smaller microfossil specimens. We also suggest a best practice methodology for implementing EPF in micropalaeontological studies.

P04: Reinvestigating the 'Maastricht ichthyornithine' from the Latest Cretaceous of Belgium

Juan Benito[1,2], John W. M. Jagt[3], Daniel J. Field[1]

[1]University of Cambridge

[2]University of Bath

[3]Natuurhistorisch Museum Maastricht

Ichthyornithes may be more representative of the ancestral condition of crown birds than any other Mesozoic avialans. However, diversity and morphological disparity within the group is severely understudied. Though many fragmentary specimens have been identified as part of Ichthyornithes, only one well-studied taxon is currently recognized, Ichthyornis dispar.

A partially described specimen from the Maastricht Formation of Belgium has been previously suggested to show affinities with the 20 ma older Ichthyornis, though it has received minimal further attention. The previously identified material includes several elements encased in matrix, including limb bones, some vertebrae, and a tooth. Here, we investigate the specimen using high-resolution CT-Scans, revealing the preservation of at least 13 cervical and thoracic vertebrae, a well-preserved humerus, scapula, major manual phalanx and a partial femur.

The morphology of the Maastricht bird is remarkably similar to that of Ichthyornis in almost every regard beyond its much larger size. The new specimen shows several diagnostic features of Ichthyornis, including the morphology of the cervical vertebrae and the presence of an internal index process, but it lacks a comparable scapular acromion process. Phylogenetic analyses of the new specimen using two alternative morphological matrices recover it in a well-supported clade with Ichthyornis, stemward of the clade uniting Hesperornithes and crown-group birds. The study of this and additional specimens of crownward Mesozoic ornithurines will allow a better understanding of the diversity and morphology of these Late Cretaceous taxa, having crucial implications for clarifying patterns of morphological evolution preceding the origin of modern birds.

P05: Charting new waters: changes in skull ecomorphology during the initial aquatic radiations of mosasaurs and cetaceans.

Rebecca Bennion[1,2], Jamie MacLaren[1], Ellen Coombs[3,4], Olivier Lambert[2], Valentin Fischer[1]

[1]University of Liege

[2]Royal Belgian Institute of Natural Sciences

[3]Natural History Museum, London

[4]University College London

The earliest fully aquatic cetaceans (Middle to Late Eocene) had a serpentine body shape which was adapted for locomotion by axial undulation. This has drawn comparisons to the mosasaurs, a group of Late Cretaceous marine squamates, with whom these early cetaceans also share broad similarities in skull morphology (triangular snout; widely spaced teeth; unfused mandibular symphysis). Both groups filled a wide range of niches and achieved global distributions. As they became increasingly adapted to aquatic life, each clade modified their body plan to allow more efficient tail-based 'thunniform' locomotion, which enabled colonisation of the open ocean. Cetaceans continued to diversify after reaching this form, whereas the evolutionary history of the mosasaurs was cut short by the end-Cretaceous mass extinction.

We investigated the evolution of skull ecomorphology through the initial aquatic radiations of mosasaurs and cetaceans. Thirteen ecologically informative craniodental measurements and ratios were taken from 3D models of well-preserved skulls. The initial dataset consisted of ten cetaceans and eleven mosasaurs, sampling across the first twenty million years of evolution in each group. These data were subjected to ordination techniques to reconstruct patterns of morphospace occupation. Preliminary results show that Eocene cetaceans had a conserved skull morphology, only branching out into new morphologies in the Oligocene (early odontocetes more so than early toothed mysticetes). By comparison, mosasaurs show much more ecomorphological variation in a similar time span. Future work will use 3D landmarks to further compare differences in skull shape through the evolution of each group.

P06: Brainteasers: Evolution and variation in cynodont endocranial anatomy

Charlotte Bird[1,2], Stephan Lautenschlager[1], Paul Barrett[2]

[1]University of Birmingham

[2]Natural History Museum, London

The fossil record is inherently biased against soft-tissue preservation, yet these tissues provide some of the most crucial insights regarding form and function for extinct organisms. Without them, there is a wealth of evolutionary knowledge missing. Virtual palaeontology has hence come to the rescue – a pioneering methodology permitting 3D digital reconstruction of soft tissues, deformed skeletal structures and absent elements from CT scans, overtaking the previously destructive methods of serial sectioning.

Through visualising CT scanned skulls belonging to ancestral mammals – non-mammalian cynodonts – the brain, inner ear and neurovascular anatomy has been reconstructed for three specimens of the most widely known cynodont, *Thrinaxodon liorhinus*. The previously unknown endocranial anatomy was uniquely analysed linearly and volumetrically for instances of variation in two forms: intraspecific (between members of a species) and ontogenetic (during the lifecycle of an individual). Results show that notable shape changes occur within the olfactory region between individuals, though the lack of ossification in this part of the braincase requires a larger dataset to be considered to determine the significance of this variation. When comparing the *Thrinaxodon* brain shape across cynodont endocranial evolution towards contemporary equivalents, such as the opossum, the olfactory bulbs are markedly larger in *Thrinaxodon*, consistent with previous works proposing a nocturnal, burrowing lifestyle.

Future analyses will assess the bias in the reconstruction techniques impacting the inferences that can be made when reconstructing cognitive and sensory capabilities, and ultimately behavioural patterns.

P07: The preservation potential of nuclei, chloroplasts and pyrenoids, especially with regards to the early eukaryote fossil record

Emily Carlisle[1], John Cunningham[1], Philip Donoghue[1]

[1]University of Bristol

Eukaryote cells make up most of the macroscopic life on Earth, but their origin and early evolution is poorly understood. Their fossil record is difficult to interpret: prokaryote and eukaryote cells appear very similar as fossils. Although large size and complex ornamentation can sometimes be used to identify eukaryote cells, neither of these are reliable methods. Organelles are a fundamental characteristic of eukaryotes and could provide a definitive means for identifying early eukaryotes in the fossil record – if they can be preserved in fossils. Putative fossil organelles have been described but are largely discounted based on the perception that organelles have little to no fossilisation potential. However, there has been little research into the fossilisation of eukaryote organelles. Here, we used experimental taphonomy to characterise patterns of decay in the nuclei, chloroplasts and pyrenoids in four species of algae. This allows us to assess whether eukaryote organelles persist on a time scale consistent with known mechanisms for fossilisation and establish criteria for their identification in the fossil record. Our experiments show that nuclei, chloroplasts and pyrenoids can remain within cells for several weeks after cell death if autolysis is prevented, with chloroplasts displaying the most decay resistance. Nuclei remain consistent in shape and size throughout decay, while chloroplasts undergo a sequence of deformations. Given the decay resistance of these organelles, an organelle interpretation for intracellular structures in putative early eukaryote fossils cannot be dismissed.

P08: Phylogenetic utility of the avian pectoral girdle and forelimb skeleton

Albert Chen[1,3], Roger B. J. Benson[2], Daniel J. Field[3]

[1]University of Bath

[2]University of Oxford

[3]University of Cambridge

Although recent phylogenomic analyses have clarified the interrelationships among crown-group birds, the results of these studies nonetheless exhibit notable incongruities with each other and with morphology-based hypotheses. However, evaluating the merits of applying morphological data to avian phylogenetics is challenging, because existing crown-avian morphological datasets are often limited by restricted taxon or character sampling, inconsistent character construction, incorrect scoring, or a combination of several of these factors. This in turn hampers our understanding of the early evolution of crown-birds and the affinities of enigmatic fossil avians.

As part of a broader effort to produce a novel crown-avian morphological dataset, we focused on identifying phylogenetically informative characters of the avian pectoral girdle and forelimb skeleton, elements of which are commonly preserved as avian fossils. A dataset of 172 characters was assembled based on personal observations and previous literature. Each character was vetted against established criteria for formulating morphological characters and revised as necessary.

The characters were scored for a phylogenetically diverse range of 20 extant avian taxa and analysed in preliminary phylogenetic analyses. Although these analyses do not recover identical topologies to recent molecular analyses, implementation of molecular scaffolds allows identification of diagnostic character combinations for several clades previously only recognized through molecular data, and potentially provides an independent avenue with which to assess support for alternative molecular topologies. Future work will greatly expand the sampling of extant and fossil taxa to further elucidate the phylogenetic utility of osteological characters and the effects of different analytical parameters on morphological tree topology.

P09: Convex Hull Estimation of Body Segment Inertial Parameters in Non-Primate Mammals

Sam Coatham[1], William Sellers[1]

[1]University of Manchester

Obtaining accurate values for body segment inertial parameters (BSIPs) is fundamental for gait analysis. However, given the rarity of soft tissue preservation, these properties must be approximated when simulating the gait of extant taxa. Convex hulling, whereby the smallest-possible convex object that surrounds a set of points is calculated, has been suggested as an effective and time-efficient method to estimate these parameters.
We investigated the consistency of convex hull-based BSIP estimation in a range of extant non-primate mammals, to inform the potential future usage of this technique with extinct taxa. We found relatively consistent segment-specific relationships between estimated and actual BSIPs. Consequently, we suggest the usage of segmental conversion factors in future convex hull reconstructions, although caution is required given the degree of interspecific variation observed. Overall, we recommend the use of convex hulls to approximate BSIPs for gait simulation of extinct non-primate mammals.

P10: Stratigraphy and paleontology of the Herrerías Cubeta, SW Spain

Luis Collantes[1], Eduardo Mayoral[1], Rodolfo Gozalo[2]

[1]Universidad de Huelva *[2]Universitat de València*

Cambrian rocks of the northern Huelva province are divided into three main tectosedimentary basins limited by faults, commonly named as ‘Cubetas’: Cumbres, Arroyomolinos and Herrerías. The better studied Cubeta both by its stratigraphy and paleontological content is the Herrerías Cubeta. This unit extends approximately over 30 kilometres within the Sierra de Aracena y Picos de Aroche Natural Park. From a stratigraphic point of view, the Herrerías Cubeta is formed by rocks with an age that extends from Neoproterozoic to Tremadocian, although only early and middle Cambrian rocks are described. At its base is composed of rocks assigned to Carbonatada Formation (Ovetian), giving rise to a transitional contact to siliciclastic rocks formed by shales with carbonatic nodules (Kramenzel shale). Above these materials, we find an informal unit called 'Herrerías shales': The age of these rocks is ranging from early to late Marianian, given by the presence of trilobites of the genera *Delgadella*, *Sdzuyomia*, *Rinconia* and *Strenuaeva* in the lower and middle part; and of *Serrodiscus*, *Calodiscus* and *Triangulaspis* in the upper part, as well as endemic faunas such as *Protaldonaia*. Overlying the Herrerías shales, a succession of muscovitic sandstones take place, named as “Rincón beds”, with age assigned to Bilbilian. Middle Cambrian rocks are formed by spilites and shales assigned to “Playon Beds” and conglomerates, feldspathic sandstones and quartzites named as Umbría-Pipeta Formation.

P11: Life on the Edge of a Changing Ocean: Response of shelf ecosystems to climate change at the Eocene-Oligocene Transition

Rebecca Cooper[1]

[1]*University of Bristol*

The Eocene-Oligocene Transition (~34-33.5Mya) comprises a time of gradual climate change with two main phases: a major cooling of global temperatures and the first major glaciation of the Antarctic continent. During this time, extinction is not uniformly felt throughout the biotic realm. Whilst most marine research has focused on open ocean records, relatively little work has examined shelf ecosystem response. In the modern day, shelf ecosystems are known for their exceptional biodiversity. However, this is under threat from climate change. Understanding shelf response to major climate events in the past is therefore exceptionally important to understand how they may respond to future changes. Here we use both global (Palaeobiology Database) and local (Tanzania Drilling Project) data to characterise and compare the response of six shelf-dwelling groups of carbonate producers: large benthic foraminifera, gastropods, bivalves, bryozoans, echinoderms and corals across the Eocene-Oligocene Transition. Taxa within these groups were divided into ecological groups based on motility, life habit, and diet, and analysed using a combination of time series, diversity and principle co-ordinate analyses. Overall, we find that different groups decline or increase in diversity during this time, with variation in the response within these groups dependent on species ecology. This highlights the need to study extinction events across multiple groups, locations and time resolutions to better understand how dynamic changes in the climate influence diversity.

P12: A 3D reconstruction of the extinct giant shark *Otodus megalodon*

Jack Cooper[1], **John Hutchinson**[2], **Matt Dicken**[3,4], **Jan Menzel**[3], **Catalina Pimiento**[1,5]

[1]*Swansea University*

[2]*Royal Veterinary College*

[3]*KwaZulu-Natal Sharks Board, Umhlanga Rocks, South Africa*

[4]*Nelson Mandela Metropolitan University*

[5]*Smithsonian Tropical Research Institution, Panama*

Combining exceptionally preserved fossil specimens with computational modelling has given palaeontologists the unprecedented ability to digitally reconstruct entire bodies of extinct animals. However, cartilaginous skeletons of extinct sharks have particularly poor preservation, often only leaving behind hard teeth and occasional vertebrae. Palaeontologists therefore typically use dental and ecological similarities with extant relatives to infer morphology of extinct sharks. Using exceptional fossils, the morphology of an ecological analogue, and an “octagonal hooping” method previously used in reconstructions of dinosaurs, we create a 3D computational model of the extinct giant shark *Otodus megalodon*. The base model is created from CT scans of a reconstructed jaw and the longest vertebral column of *O. megalodon* known to the fossil record. Vertebrae and teeth are scaled to real size based on direct measurements of the fossils, with tooth crown height being used to calculate total length (TL) of our model based on previously published equations. The rest of the body is constructed using a digitally reconstructed head and a CT scanned full body specimen of the great white shark (*Carcharodon carcharias*), the most commonly used ecological analogue to *O. megalodon*, scaled up to our model TL, in conjunction with our base model. Our final model is of an *O. megalodon* at ~15.93 m TL and a body mass of ~50 metric tons. This study marks the first ever digital reconstruction of an extinct giant shark; a model now being used to calculate a variety of inertial properties.

P13: The Evolution of Eocene Planktonic Foraminifera *Dentoglobigerina*

Florent Fayolle[1], Bridget S. Wade[1]

[1]University College London

Dentoglobigerina is a diverse genus of planktonic foraminifera ranging from the Eocene to Recent. However, the ancestry of *Dentoglobigerina* has been controversial. A growing body of evidence indicates the genus *Dentoglobigerina* to have been spinose in life and evolved from Eocene Subbotina, whilst others have suggested its origins to rely on Acarinina. To date, researchers have not treated the Eocene phylogeny of *Dentoglobigerina* in detail. Here we explore whether Subbotina or Acarinina is the ancestor of *Dentoglobigerina* by examining specimens, evaluating their morphology and their occurrences through the middle to late Eocene, from worldwide localities. We find that *Dentoglobigerina* evolved ~4 million years earlier than previously documented, with the species *Dentoglobigerina pseudovenezuelana* and *'Dentoglobigerina' eotripartita* recorded in middle Eocene Zone E9. Morphological convergences between Dentoglobigerina and Subbotina were found with *D. galavisi* and D. *pseudovenezuelana*, and between *Dentoglobigerina* and *Acarinina* with *'D.' eotripartita*. Spine holes were observed in *D. galavisi* and *D. pseudovenezuelana*, and not uniformly found in all forms. Our finding suggests that there are two distinct lineages, (1) *Dentoglobigerina* encompassing the species *D. pseudovenezuelana* and *D. galavisi* as a descendant of *Subbotina,* and (2) '*Dentoglobigerina'* (including *'D.' eotripartita*) as descendant of *Acarinina*. Our results contribute to a better understanding of *Dentoglobigerina* biostratigraphy, phylogeny and evolution.

P14: Marine biodiversity and environmental change during the Permian-Triassic mass extinction and recovery in western Utah, USA.

Elise Harris[1,2], Richard Twitchett[2]

[1]Imperial College London *[2]Natural History Museum, London*

The Late Permian mass extinction most notably affected benthic marine organisms in shallow shelf settings due to climate warming and anoxic conditions. This study used quantitative palaeoecological analyses to assess how functional and taxonomic diversity of shallow marine ecosystems changed in response to this event in the Confusion Range of western Utah, USA. A total of 28 horizons spanning the uppermost Gerster and lowermost Thaynes formations yielded 36,586 identifiable fossil bioclasts, representing a minimum of 19,131 individual animals, from 45 species, including bivalves, gastropods, brachiopods, bryozoans, echinoderms, ostracods and microconchids. The Permian subtidal limestones of the Gerster Formation contain high taxonomic and functional diversity assemblages (Simpson's index = 0.85, Shannon's index = 2.28), whereas the Lower Triassic Thaynes Formation limestones have low diversity and complexity (Simpson's index = 0.47, Shannon's index =1.25). Sedimentary facies indicate stressful environments, including hypersaline lagoons with microbialites, after the extinction, which affected taxonomic and functional composition and impacted local recovery rates. Taxonomic and functional diversity correlate with bulk $\delta^{13}C$ and $\delta^{18}O$ values from the same horizons, highlighting the role that environmental changes such as productivity, temperature and salinity had in shaping benthic ecosystems during this important interval in Earth history.

P15: Transition from swimming to walking preserved in tetrapod trackways from the Late Carboniferous of Bjørnøya, Svalbard

Seán Thór Herron[1], Michael Flowerdew[2], Edward Fleming[2]

[1]University of Cambridge *[2]Cambridge Arctic Shelf Programme (CASP)*

The Late Carboniferous was a crucial interval for the establishment of terrestrial ecosystems. A dramatic change in tetrapod distribution and ecology is coupled with an ongoing transition from amphibian to amniote domination. Presented here is a new set of tetrapod discovered on the island of Bjørnøya in the Norwegian High Arctic. A photogrammetric model was constructed to allow analysis of the trackway, and palaeoenvironmental observations were taken to provide context to the ichnological determinations. The slab appears to preserve the transition from swimming to walking. This coincides with a change in the preservation style and an apparent change in the depth of water traversed by the tracemaker. Two trackways can be assigned to the ichnogenus *Limnopus* Marsh 1894 (temnospondyl amphibians). They consist of 36 and 24 prints respectively, and have widths and lengths of 151mm x 2149mm and 166mm x 1226mm. Two other trackways represent the traces of indeterminate tetrapods. Palaeoenvironmental analysis suggests that the trackways were lain in a fluvial floodplain setting in a palaeo-river valley system, in agreement with regional-scale analyses. Locomotion analysis suggests that on moving from submerged walking and swimming to terrestrial walking, large Late Carboniferous temnospondyls increased their pace angulation and lengthened the stride. At ~30°N, these tracks may be the farthest north *Limnopus* trackways yet found in terms of palaeolatitude. They are the first Carboniferous tetrapod traces recovered from Svalbard and the Fennoscandian region, and are probably among the oldest examples of *Limnopus* yet found.

P16: Tracing changes in penguin populations on Ardley Island, Western Antarctic Peninsula using bio-elemental concentrations in guano-influenced lake sediments

Eleanor Maedhbh Honan[1]

[1]University of Bristol

The Western Antarctic Peninsula (WAP) has experienced profound regional warming and changes in sea ice dynamics. The most northerly tip of the continent, the peninsula is one of the most studied regions in Antarctica, but there is still critical work to be done in resolving the area's ice, ocean and ecosystem feedback systems. All three extant species of the penguin genus *Pygoscelis*; *Pygoscelis papua, P. antarctica*, and *P. adeliea* co-exist on the WAP. These penguins are incredibly sensitive to environmental change. Ardley Island in the South Shetland Islands hosts one of the WAP's largest populations of *P. papua*. The presence of a permanent depositional sink on the island, Ardley Lake, records a Holocene sub-fossil and geochemical record of the penguins' occupation, with approximately 139 tonnes of guano discharged onto the island by the penguins every breeding season. This research uses ITRAX scans of sediment cores from Ardley Lake to trace patterns of guano-derived bio-elements from the penguin colonies, to better constrain historical fluctuations of Pygoscelids on the island and identify the primary drivers. Spikes in colony size are recorded in the concentration of guano-derived bio-elements, as is the episodic eradication of colonies by volcanism from nearby Deception Island. Better understanding of how the WAP's penguins have responded to past climatic and environmental changes will inform on the species' response to contemporary and future changes, and help refine understanding of past environmental change on the peninsula.

P17: Diversity of the Lower Devonian conodonts from the Prague Synform (Czech Republic)

Aneta Hušková[1]

[1]*Charles University*

Conodonts, an extinct group of marine animals, are commonly used for the stratigraphic purposes from the Cambrian period to the Triassic. The main aim of our work is focused on the Silurian/Devonian boundary, where we strive for improving the current conodont biostratigraphy. The study of two key sections (Na Požárech and Praha-Radotín) across the Silurian/Devonian boundary in the Prague Synform in Czech Republic provided rich conodont material. The contrasting depositional environment in both localities was expected to show the differences in composition of conodont faunas.
Most common and stratigraphically important are the representatives of the two conodont family - Spathognathodontidae and Icriodontidae. Especially the first mentioned family, the Spathognathodontidae, is the most abundant in the number of genera and species, but also prevails in number of elements in samples from different carbonate environments. A new species *Zieglerodina petrea* of the Spathognathodontidae family was described.
New data from the both mentioned sections will be presented. The potential for the stratigraphical correlation with other worldwide localities will be discussed in the poster.

P18: Limb proportions indicate *Protemnodon*'s locomotion was divergent from modern large macropodines.

Billie Jones[1], **Christine Janis**[1], **Emily Rayfield**[1]

[1]*University of Bristol*

Kangaroos boast a diversity of locomotor modes, from bounding quadrupedally to hopping bipedally. Optimum body mass for hopping is 50 kg; with a limit to hopping locomotion predicted at 160 kg due to tendon strain. Modern kangaroos range in body mass from 500 g to 70 kg, however, in the Pleistocene a variety of "giant" kangaroos existed. Here, we examine the extinct giant kangaroo *Protemnodon*. *Protemnodon* reached far above the optimum body mass for hopping (*P. anak* ~ 166 kg, *P. brehus* ~ 131 kg), yet its primary locomotor mode has undergone little question. To investigate the locomotion employed by *Protemnodon* we assess the association between limb proportions and locomotor mode across Macropodoidea. We apply multivariate analysis to a morphological dataset of 60 different extant and extinct species of macropod across a variety of morphologies and primary locomotor modes. Using 14 "osteological indices" derived from linear measurements of the postcranial skeleton, we assess how primary locomotor mode influences postcranial morphology. We find that kangaroos of different primary locomotor mode (bipedal hopping vs quadrupedal bounding) have predictable morphologies. *Protemnodon* exhibits a variety of postcranial features similar to both hopping and quadrupedal kangaroos, yet occupies a vacant area of morphospace. *Protemnodon*, therefore, represents an ecomorph with no extant analogues. Forelimb anatomy may be indicative that *Protemnodon* employed a significantly greater amount of quadrupedal locomotion than modern large kangaroos.

P19: Evolution of reticulate *Nummulites* across the Eocene-Oligocene transition: comparisons from 2D sections and 3D reconstructions

Ravi Kiran Koorapati[1], Laura Cotton[2]

[1]Friedrich-Alexander University-Erlangen *[2]University of Portsmouth*

The Eocene-Oligocene boundary was a time of climatic cooling and oceanographic change associated with sea-level fall and the first major continental-scale glaciation of Antarctica. This boundary has been marked by the extinction of the planktonic foraminifera of the family Hantkeninidae, and events here have been studied to have a biotic turnover/extinction effect on many Large Benthic Foraminifera (LBF). The reticulate large benthic forams *Nummulites* pass through this transition apparently unscathed. Preliminary work on material from the Tanzania Drilling Project has shown reticulate *Nummulites* are present throughout the transition, however they show increasing variation intheir morphology. Work on planktonic foraminifera such as *Turborotalia* has shown that this kind of variation and expansion of morphology often precedes speciation. We therefore apply similar methods to a high-resolution dataset of reticulate *Nummulites* spanning approximately 2 My across the EOT. This is then coupled with climate data from the same samples and physiological data from modern foraminifera to investigate drivers of any possible morphological change. Analyses have been carried out both using traditional two- dimensional measurements and three-dimensional measurements to assess the importance of information loss using 2D analyses /relative benefits of using each approach.

P20: Elevated evolutionary rates in dinosaur skulls are associated with specialist adaptations for herbivory

Callum Kunz[1], Manabu Sakamoto[2]

[1]Independent *[2]University of Lincoln*

The acquisition of herbivory is a key innovation that has contributed to the evolutionary success of many vertebrate clades, resulting in numerous specialist adaptations. Dinosaurs, which dominated Mesozoic terrestrial faunas, acquired herbivory multiple times; including in clades historically regarded as predominantly carnivorous. The appearance of herbivory in theropods is linked to drastic changes in dental and craniomandibular functional morphology. Yet, whether changes in functionally relevant phenotypic traits occurred more rapidly in herbivorous lineages compared to in carnivorous lineages remains untested in a statistical phylogenetic framework. Here, we infer rates of phenotypic evolution in relative biting edge (tooth row) lengths of dinosaurs to test the hypothesis that herbivory is associated with rapid changes in the biomechanics of jaw movement. We find elevated evolutionary rates to be present in theropod clades with foreshortened and beaked skulls (Oviraptorosauria, *Limusaurus*), as well as in ceratopsians and *Diplodocus*. The presence and position of a reduced tooth row and increased jaw efficiency unites these high-rate lineages, alongside possible adaptation for masticating tough, fibrous plant material. These mandibular characteristics help explain the high evolutionary rates found in these clades, along with the lack of increased evolutionary rates in similar herbivorous clades (Therizinosauria, Ornithomimosauria, Ornithopoda). Thus, we demonstrate that rapid morphological changes in herbivorous dinosaurs are partly associated with elevated rates of evolution in a functionally relevant trait.

P21: Geometric evolution of the avian quadrate

Pei-Chen Kuo[1], Daniel Field[1]

[1]University of Cambridge

In birds and other reptiles, the quadrate acts as a hinge connecting the lower jaw and the skull, and plays an important role in avian cranial kinesis. Previous studies have qualitatively described its substantial morphological variability, but none have tried to quantify evolutionary changes in its shape. Here, we focus on shape changes of the quadrate in Galloanserae, a major clade of living birds uniting relatives of living chickens and ducks. We are in the process of quantifying quadrate shape variation in three dimensions, and will perform ancestral shape reconstructions in the context of an up-to-date picture of avian phylogeny. This will allow us to explore (i) what the quadrate of ancestral Galloanserae looked like, and (ii) compare differences between these results and the fossil record, because recent fossil discoveries such as *Asteriornis maastrichtensis*, and classic fossil taxa like *Presbyornis* provide direct insight into the ancestral form of the galloanseran quadrate. This will help elucidate the morphological and ecological evolution of extant birds, and provide more information into how the ancestors of modern birds survived the end-Cretaceous mass extinction event.

P22: *Globigerinoides rublobatus* – a new species of planktonic foraminifera

Marcin Latas[1], Bridget Wade[1], Paul Pearson[2], Christopher Poole[1]

[1]University College London *[2]Cardiff University*

The evolution and extinction of fossil species of planktonic foraminifera are used extensively to date and correlate Cenozoic marine sediments. Scientists of the IODP Expedition 363 reported presence of an unusual pink coloured planktonic foraminifers, whose morphology does not fit within description of any widely recognised species. Distinctive pigmentation of this foraminifera resembles that of *Globoturborotalia rubescens* and a pink variant of *Globigerinoides ruber*, which are the only pink species recognised to date. This new foraminifer exhibits “mosaic morphology” combining characteristics typical for *Globigerinoides conglobatus* and *Globigerinoides ruber*, which would suggest potential evolutionary relationship with both. Our high-resolution lab analysis, carried out on multiple specimens from the Indian Ocean Site U1483, revealed that discovered foraminifer occurs in two variants of colouration (pink and white forms). The results of morphometric analysis confirm that this new foraminifer is morphologically distinct from both potential sister taxa with which it co-occurs, indicating that it should be regarded as a separate species.

P23: Phylogenetic and ontogenetic changes of the anatomical organization and modularity in the skull of archosaurs

Hiu Wai Lee[1,2], Borja Esteve-Altava[3], Arkhat Abzhanov[1,2]

[1]Natural History Museum, London *[3]Pompeu Fabra University*

[2]Imperial College London

Comparative studies of the skull of archosaurs provide insights on the mechanisms of evolution for morphologically diverse species of crocodiles and birds. One of the key attributes of skull evolution is the anatomical changes associated with the physical arrangement of cranial bones. Here, we compare the changes in anatomical organization and modularity of the skull of extinct and extant archosaurs using Anatomical Network Analysis. We show that the number of bones, their topological arrangement, and modular organization can discriminate between birds, non-avian dinosaurs, and crurotarsans, and between extant and extinct species. By comparing the same framework in juveniles and adults for crown birds and alligator (*Alligator mississippiensis*), we found that adult and juvenile alligator skulls are topologically similar, whereas juvenile bird skulls have a morphological complexity and anisomerism more similar to non-avian dinosaurs and crurotarsans than their adult forms. This pattern may be explained by clade-specific ontogenetic differences in skull organization, such as extensive postnatal fusion of cranial bones in crown birds. Moreover, we found that juvenile and adult skulls in birds share a similar anatomical integration, which suggests the presence of specific constraint in their ontogenetic growth.

P24: Reconstruction and functional morphology of the oviraptorosaurian theropod cranium

Luke Meade[1], Richard J. Butler[1], Michael Pittman[2], Stephan Lautenschlager[1]

[1]University of Birmingham *[2]University of Hong Kong*

Oviraptorosaurians were theropod dinosaurs from the Cretaceous of North America and Asia that evolved robust toothless beaks and highly modified skulls, leaving their skull function, diet, and ecosystem position uncertain. Biomechanical analyses on digital 3D models of crania representing species throughout the Oviraptorosauria may inform how cranial shape affected function, what they may have eaten, and how the group evolved.

3D models created from CT scanned oviraptorosaurian crania have been retrodeformed to in-life condition by removing the effects of taphonomic damage – digitally repairing cracks and breaks, replacing missing elements, and reversing plastic deformation using the specialist software packages Avizo and Landmark. The oviraptorid oviraptorosaurian *Citipati* and the earliest-diverging oviraptorosaurian *Incisivosaurus* are key taxa that were subjected to finite element analysis (FEA) to assess how the application of force resulted in patterns of stress and strain within the cranium.

The more derived *Citipati* cranium appears adapted for a strong symmetrical bite in multiple positions as greater stress is produced when force is applied asymmetrically. In contrast, *Incisivosaurus* exhibits higher, more generalised stress patterns, and its prominent incisor-like teeth appear adaptive for feeding. These initial results hint at a transition from a generalised feeding style in early oviraptorosaurians, towards a more specialised condition favouring stronger bite forces in later-diverging forms.

Additional FEA models based on reconstructions of cranial musculature and different feeding scenarios, and the addition of further taxa, may reveal how complex functional patterns were throughout the Oviraptorosauria and more broadly elucidate the evolution of dietary diversity in theropod dinosaurs.

P25: Preserved disassociated rhamphotheca of the Cretaceous early bird *Confuciusornis* and its implications in beak evolution

Case Miller[1], Michael Pittman[1], Thomas Kaye[2], Xiaoli Wang[3], Xiaoting Zheng[4]

[1]University of Hong Kong

[2]Foundation for Scientific Advancement, Arizona, U.S.A.

[3]Linyi University

[4]Shandong Tianyu Museum of Nature

Confuciusornis is the earliest known avialan to have a fully edentulous beak which evolved convergently to crown birds. We report a new specimen of *Confuciusornis sanctus* whose rhamphotheca (the horny covering of the beak) is visibly disassociated from the skull when visualized using Laser-Stimulated Fluorescence (LSF) imaging. Together with an undescribed specimen previously imaged under UV, two of the five known confuciusornithid rhamphothecae are disassociated from the skull while the skull remains attached to the body. This state is not reported in any decay studies of crown bird corpses. This suggests that confuciusornithid rhamphothecae were anchored less firmly to the underlying bone than in crown birds. Reconstructing the rhamphotheca allows us to confirm in vivo preservation of at least two other confuciusornithid rhamphothecae and comment on broad in their extent and shape. Cranial extent of the rhamphotheca is consistent with most crown birds, but the confuciusornithid rhamphotheca projects much less post-rostrally than any crown bird with the same amount of rostral vascularity. Rhamphotheca curvature relative to the bone is similar to that of crown birds in *C. sanctus* and *Eopengornis zhengi*, but more similar to that of some turtles in *Confuciusornis dui*. Together, this evidence paints a picture of the confuciusornithid beak as a structure reminiscent of that in crown birds, but distinct in several ways likely related to differing developmental pathways as relics of the groups' distinct evolutionary histories.

P26: Evolution of biotically dispersed seed plants and vertebrate seed dispersers from Middle Jurassic to early Paleogene

Duhita Naware[1]

[1]University of Oxford

Movement of plant propagules away from their place of origin (dispersal), is an important ecosystem service provided by frugivores and herbivores. Although angiosperms have higher proportions and diversity of fleshy diaspores, primitive fleshy seed coats are also seen in some modern gymnosperms. A review of literature shows that first berry-like fleshy fruits appeared in the Early Cretaceous and that by the Late Cretaceous, drupaceous fleshy fruits were almost ten times larger in size. Both morphological diversity and fleshy to dry fruit ratio also increased considerably in Late Cretaceous fruits. Sabiaceae and Cornaceae, represented by large fleshy fruits in the Paleocene, had much smaller but morphologically identical fruits in the latest Cretaceous. This suggests a trend towards higher proportions of animal dispersal in the Late Cretaceous coinciding with an increase in mammalian ecological diversity (characterized by dietary adaptations for frugivory and other specialized diets), which could be related to their survival through the K-Pg extinction. Although trends in plant diaspore size have been analysed previously, there hasn't been a focused study on fleshy seed plant diaspores against the backdrop of major ecomorphological diversifications in Mesozoic and early Tertiary vertebrates. Here, I examine the changes in size and proportion of fleshy seed plant diaspores from the Middle Jurassic to Eocene and propose to compare the peaks with the ecomorphological diversity of coeval vertebrate seed dispersers. I expect to unearth patterns of co-evolution between biotically dispersed seed plants and vertebrate seed dispersers.

P27: Macropus titan, pushing the limits of hopping? Gear ratios and resistance to load in Macropodoidea

Adrian Muirgheas O'Driscoll[1], Christine Janis[1], Emily Rayfield[1]

[1]University of Bristol

Members of the Macropodinae and the Sthenurinae, sister-taxa within Macropodidea, convergently attained giant size in the past. However, it is unknown if both groups adopted similar musculoskeletal and locomotory mechanisms to adapt to the size constraints on locomotory ability. We aimed to assess the biomechanical evidence for different modes of locomotion as indicated by the resistances to bending and torsion in the pedal bones of giant extinct kangaroos. Prior comparisons of *M. giganteus* with both a comparably sized and giant sthenurine observed different resistances but how significant a role allometry, phylogeny, or locomotory mode, play is unknown. By adding the giant *Macropus titan* (NHM London) to that dataset we minimise the effect of allometry and test if mode of locomotion and phylogenetic constraints played significant roles. These analyses indicate *M. titan* was capable of hopping despite its giant size. Additionally, calcaneal gear ratios inform on a variety of extant and extinct taxa. Indications of the locomotory mode of the basal Miocene sthenurine *Hadronomas puckridgi* provide insight into evolutionary trends in the sthenurines. *H. puckridgi* shares traits with derived striding sthenurines despite an anatomy intermediate between a macropodine and a sthenurine, which implies the adoption of striding preceded significant anatomical adaptation.

P28: Burnin' for you: Determining the formation temperature of charcoals using low-cost Fourier Transform Infrared Spectroscopy (FTIR-ATR)

Roy Payne[1], Mark Hardiman[1], Laura Cotton[1]

[1]University of Portsmouth

Fire and charcoal are intrinsically linked, with charcoal being direct evidence of burning as a product of incomplete combustion of the fuel source. Charcoal forms a significant component of many archaeological and palaeontological contexts and can be a product of both natural and human processes. Current research on charcoal from these archives is largely focused on understanding 1) what species of wood were utilised in past burning activities and therefore present on the landscape and 2) understanding wildfire trends and events (charcoal peaks) in order to reconstruct local and regional fire histories.

Much less investigated is charcoal formation temperature, which if more fully understood would provide invaluable information regarding wildfire intensity potentially allowing insights into length of combustion and temperature of combustion.

In this study a FTIR-ATR reference dataset of charcoals formed at a wide range of temperatures found in natural wildfire (300-900°C) has been developed for arboreal taxa commonly found in temperate regions for the first time (including Quercus, Pinus, Betula). Differences in FTIR-ATR spectral output is compared and assessed in terms of their ability to identify the temperature of formation from controlled burns and comparisons are made with natural prehistoric charcoals samples.

P29: The evolution of maximum body size of flying and flightless birds

Garance Robin[1,2], Abigael Parker[1], Jason J. Head[1], Daniel J. Field[1]

[1]University of Cambridge

[2]Université de Rennes

Evolutionary changes in body mass are of great interest, as body mass is linked with important biological and ecological parameters. As such, studying body size variation over long periods of time may help clarify important clade-level changes. Here, we investigate the evolution of maximum body size in birds through time. We surveyed the fossil record across avian evolutionary history, from the Late Cretaceous to the Holocene, by identifying the largest birds known from each sub-epoch on each continent, and applying appropriate body mass reconstruction methods. As expected, maximal body masses were generally higher in the Cenozoic than in the Mesozoic, and idiosyncratic trends in body size change in both flying and flightless birds were noted through time on each continent. This work also highlights the land masses and time intervals in particular need of focused prospecting in order to flesh out our understanding of the avian fossil record. This work emphasizes that the African and Australian records of Mesozoic birds are almost non-existent, and poor in South America. Overall, the avian record is most sparse in Australia, closely followed by Africa. The fossil record in South America is moderately well known, whereas the record in Europe and Asia is substantially more complete. Finally, the most thoroughly sampled avian fossil record is that from North America. Hence, future research effort should focus on Australia and Africa, and additional research should be made in South America. On all three of these undersampled landmasses, the Mesozoic record is in need of particular attention.

P30: Topological and algebraic expressions for the microstructure and septal growth styles of the *Zaphrentis delanouei* species group

William Rutter[1], Marios Miliorizos[1]

[1]University of South Wales

The internal structure of a Tournaisian-Viséan Zaphrentid coral is expressed in topological and algebraic forms. Study of ontogeny and phylogeny encourages further analysis of the evolutionary trends and mechanisms which govern morphological variability. Samples from the Vale of Glamorgan are examined petrographically to investigate growth styles of septae, to discern the growth factor from rates and trajectories.

We use a free-lay composite of microscope images to show the structure of a complete septa within the coral. Growth lines mapped onto the micro-fibrous structure are modelled as homotopic paths within a topological space and using a regular grid over the composite, the growth structure is quantified algebraically using different best fit lines. This mathematical expression of growth styles enables calculation of the growth factor.

Growth factor affects septal shape and microstructure; particularly, results show a range in growth rate and trajectory along the septal length and differences between growth styles along inner and outer path lines. The complexity and sinuosity of the micro-fibrous structure reflects this. By comparing trajectories, septal thickness, and sinuosity, with the shortest distance across the homotopic space, we normalise quantities to calculate variations in growth factor.

The results align with prior work in exoskeletal formation. High growth factor produces high sinuosity and widely separated path lines. We conclude the topology and algebra of septal growth and structure will be effective in quantifying growth in many coral types and it will reveal more about interactions between an exoskeleton and the zooid soft-body and its infolds.

P31: Morphological variation in the passerine carpometacarpus

Lizzy Steell[1], Jacqueline Nguyen[2], Roger Benson[3], Daniel Field[1]

[1]University of Cambridge *[3]University of Oxford*

[2]Australian Museum

Passeriformes is the most diverse extant avian clade, comprising >6,000 living species. Despite constituting over half of modern bird diversity, morphological variation across crown Passeriformes has not been adequately characterised to date. Comprehensive phylogenies of birds were only recently published, and the phylogenetic placement of passerines was previously unresolved through morphology alone. This lack of a comparative framework has hindered progress on understanding patterns of morphological variation across the clade. In particular, the phylogenetic affinities of crown and stem passerine fossils remain ambiguous, limiting our ability to interpret the passerine fossil record. The carpometacarpus (hand bone) is an important element in passerine comparative morphology. It exhibits characters that have been described as diagnostic for passerines, although some of these are convergently present in other bird clades. Carpometacarpi also fossilise readily with respect to several other passerine skeletal elements, and are among the most numerous elements in passerine fossil collections. Here, we present the passerine carpometacarpus as a case study to highlight previously uncharacterised morphological variation across Passeriformes. We present high-resolution 3D images of passerine carpometacarpi from a broad sample of taxa, many having never been studied in an anatomical context before, and identify potential new characters of the passerine carpometacarpus, such as the position of the cranial process. This work will ultimately enable the incorporation of additional passerine fossils into a phylogenetic framework, shedding new light on the evolutionary history of passerines.

P32: First record of fish trace fossils (*Undichna* isp.) from the Middle Devonian Achanarras Limestone Member, Caithness, Scotland

Ben Tindal[1], Anthony Shillito[2], Neil Davies[1]

[1]University of Cambridge *[2]University of Oxford*

Achanarras Quarry, in Caithness, NE Scotland, is a key fossil site for our understanding of Devonian fish communities. The quarry exposes strata of the Middle Devonian Achanarras Limestone Member (Lybster Flagstone Formation, Caithness Flagstone Group), which were deposited in an intramontane rift lake, within the Orcadian Basin. While the site has previously yielded 13 genera of fossil fish, in addition to an invertebrate fauna, trace fossils are so far unreported from the quarry strata. Here we describe newly-discovered specimens of the fish trace fossil *Undichna* isp. from Achanarras Quarry. The traces comprise continuous and discontinuous sinusoidal grooves created by the fins of an Acanthodian fish swimming close to the substrate. This is the first evidence for vertebrate-sediment interactions in deep lake environments from before the Carboniferous, when complex deep lacustrine ichnofacies developed.

P33: Three-dimensional atlas of pectoral musculoskeletal anatomy in the extant tinamou *Nothoprocta pentlandii* (Palaeognathae: Tinamidae)

Klara Widrig[1], Junya Watanabe[1,2], Bhart-Anjan S. Bhullar[3], Daniel J. Field[1]

[1]University of Cambridge *[3]Yale University*

[2]Kyoto University

Palaeognaths (ratites and tinamous) are the sister group of all other modern birds. Recent genetic and developmental studies have illustrated that extant ratites (e.g., ostriches, emus, kiwis) are paraphyletic with respect to tinamous. Tinamous are notable among extant palaeognaths for being the only group that has retained the ability to fly, and may therefore provide key insight into the nature of ancestral crown palaeognaths, and, in turn, crown birds. To reveal new information about the musculoskeletal anatomy of tinamous, we imaged an Andean tinamou (*Nothoprocta pendlandii*) using diffusible iodine-based contrast-enhanced computed tomography (diceCT). Visible components of the musculoskeletal system in the resultant high-resolution scans were segmented in order to create a three-dimensional anatomical atlas of tinamou forelimb musculature. Origins and insertions of the pectoral flight musculature are generally consistent with those in other volant birds specialized for burst flight. We therefore reject the notion that tinamous may be secondarily flighted, a hypothesis that has been advanced to reconcile the emerging phylogenetic position of tinamous as nested within extant flightless ratites. The pectoralis and supracoracoideus are robust, similar to the condition in other extant clades such as Galliformes. The pronator superficialis is larger than the pronator profundus, which is the reverse of the condition in most extant neognaths. This work will form an important basis for future comparative work on the musculoskeletal system of extant birds in light of ongoing advances in soft tissue imaging.

P34: Belemnite δ13C record across the Bajocian–Bathonian boundary, Cabo Mondego (Middle Jurassic, Portugal)

Jack Wilkin[1], Stephen Hesselbo[1], Clemens Ullmann[1], Micha Ruhl[2], Maria Helena Henriques[3]

[1]University of Exeter *[3]University of Coimbra*

[2]Trinity College Dublin

Here we report on recent developments on geochemical proxies derived from belemnite rostra from Cabo Mondego section in Portugal. Cabo Mondego is stratigraphically significant outcrop as the location of the GSSP and Point for the Bajocian and the ASSP for the Bathonian.

Belemnite rostra of 118 individuals from across the Bajocian–Bathonian boundary at Cabo Mondego were studied for the geochemical composition. Two separate analytical procedures were conducted: firstly, for stable isotopes and secondly for minor elements. The samples were screened for diagenetic alteration using trace elements. Samples with Mn/Ca > 0.2 mmol/mol were omitted, further reducing the number of useable samples to 90.

One possible cause of this shift in carbon-isotope ratios is a faunal turnover. Different belemnite taxa are known to have fractionated carbon in different ways, which would explain the change in δ13C values. Faunal turnovers of ammonites and belemnites are observed elsewhere in Europe during the bomfordi subzone, which coincides with the positive δ13C shift in the Lusitanian Basin. This explains the lack of positive excursion in associated brachiopod data.