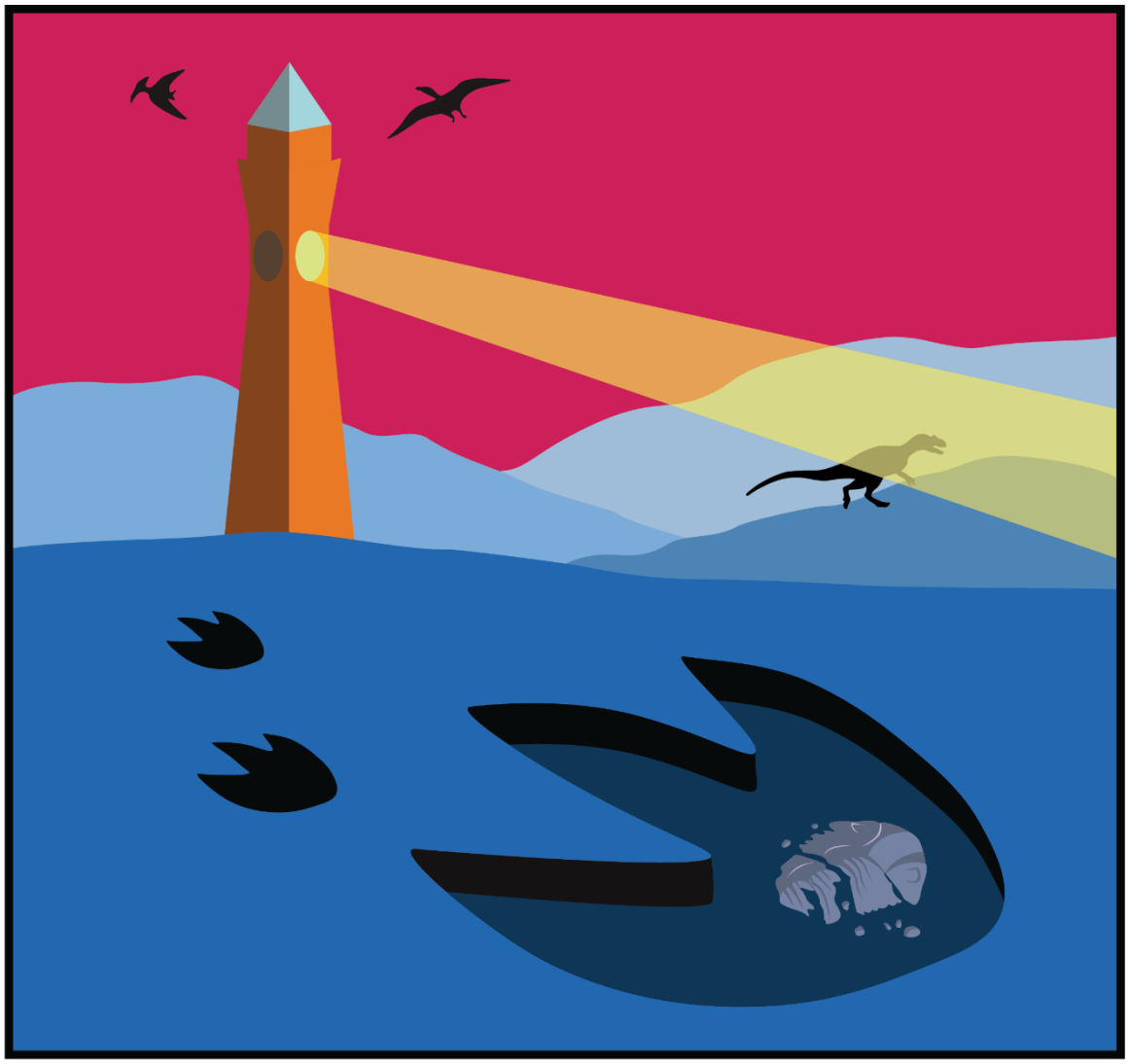


PROGPAL 2019

BIRMINGHAM

Abstract Booklet

The Palaeontological Association

Reg. Charity No. 1168330

Welcome to Progressive Palaeontology, a postgraduate student conference of the Palaeontological Association (PalAss). PalAss is a charity that promotes the study of palaeontology and its allied sciences through publications, sponsorship of meetings and workshops, provision of web resources and a large annual programme of awards and grants.

Membership fees for students are just £20 a year. Members receive many benefits including the Association's newsletter, online access to the PalAss journals *Palaeontology* and *Papers in Palaeontology*, a discount on Field Guides and other books, and eligibility for Association awards and grant schemes including the Postgraduate Travel Fund.

Our flagship Annual Meeting is a major international conference in December with subsidized registration for students, and contributions to travel costs are made to a large percentage of student members who are presenting their work. The President's Prize and Council Poster Prize are awarded to the best presentations from early career researchers at the meeting each year, each with a certificate and cash prize.

The Association has a public engagement group that involves postgraduate student members as volunteers at outreach events. PalAss has members all over the globe and we welcome new members at www.palass.org. You can also find us on Facebook and Twitter (@ThePalAss).

Dr Jo Hellawell

Executive Officer
The Palaeontological Association

e-mail: palass@palass.org
Visit our website at: www.palass.org

Code of Conduct for Palaeontological Association meetings

The Palaeontological Association was founded in 1957 and has become one of the world's leading learned societies in this field. The Association is a registered charity that promotes the study of palaeontology and its allied sciences through publication of original research and field guides, sponsorship of meetings and field excursions, provision of web resources and information and a programme of annual awards.

The Palaeontological Association holds regular meetings and events throughout the year. The two flagship meetings are the Annual Meeting, held at a different location each December, and the annual Progressive Palaeontology meeting, run by students for students with the support of the Palaeontological Association. The Association Code of Conduct relates to the behaviour of all participants and attendees at annual events.

Behavioural expectations: It is the expectation of the Palaeontological Association that meeting attendees behave in a courteous, collegial and respectful fashion to each other, volunteers, exhibitors and meeting facility staff. Attendees should respect common sense rules for professional and personal interactions, public behaviour (including behaviour in public electronic communications), common courtesy, respect for private property and respect for intellectual property of presenters. Demeaning, abusive, discriminatory, harassing or threatening behaviour towards other attendees or towards meeting volunteers, exhibitors or facilities staff and security will not be tolerated, either in personal or electronic interactions.

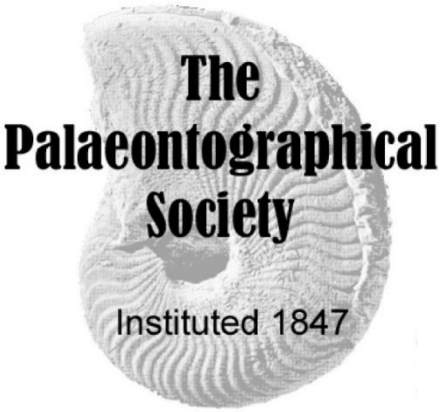
Digital images and social media: Do not photograph a poster or record a talk without the author's express permission. While the default assumption is to allow open discussion of presentations on social media, attendees are expected to respect any request by an author to not disseminate the contents of their talk or poster.

Reporting unacceptable behaviour: If you are the subject of unacceptable behaviour or have witnessed any such behaviour, please notify any member of the organizing committee (see page 7) or a member of the Palaeontological Association Council (Executive Officer Dr Jo Hellawell: executive@palass.org; President Prof Charles Wellman: president@palass.org). Reports can also be made through direct messages to our social media or by emailing progpal2019@gmail.com.

Anyone experiencing or witnessing behaviour that constitutes an immediate or serious threat to public safety, or a criminal act is expected to contact the emergency services by phoning 999. Those witnessing a potential criminal act should also take actions necessary to maintain their own personal safety.

Thank you to our sponsors

CENTA



PeerJ

GEOLOGICAL CURATORS GROUP

transmitting science

Are you interested in the care of rocks, minerals and fossils? Have you considered joining the Geological Curators' Group?

The Geological Curators' Group is dedicated to the better care, maintenance and use of geological collections

We are a Specialist Group of The Geological Society of London. Membership is open to all. Benefits include:

- Regular workshops to gain new skills
- The peer-reviewed journal The Geological Curator
- Regular news updates
- An annual two day themed seminar
- Online resources

www.geocurator.org

GEOLOGICAL CURATORS GROUP GCG

info@geocurator.org

@originalGCG

GeologicalCuratorsGroup

Our membership includes:

- Museums
- Students
- Curators
- Volunteers
- Geoscientists
- Researchers
- Mineralogists
- Educators
- Palaeontologists
- Collectors
- Conservators
- Preparators

and anyone else with an interest in our work!

Front image: Assorted ammonites - how would you arrange this collection? From www.3d-fossils.ac.uk CC BY-NC-SA

Central England NERC Training Alliance - Doctoral Training Partnership

CENTA

The Central England NERC Training Alliance (CENTA) is a consortium of 6 research intensive Universities and 4 research institutes that are working together to provide excellence in doctoral research training.

CENTA encompasses research activities within three broad themes:

Climate & Environmental Sustainablility

Research on the physical environment & related interaction with human activities.

How do we increase our understanding of physical & chemical processes?

How do we best use models & knowledge of potential future climates to increase resilience in

Organisms & Ecosystems

Research into Earth's Life Support System & our place within it.

How ecosystems & biogeochemical cycles change through time & our roles in & our responses to change.

Dynamic Earth

Research theme covering present & past internal workings of our planet & how we interogate geological records.

How are elements of economic importance extracted from the mantle into the crust & then mobilised & then concentrated?

How might we forecast & mitigate future tectonic upheavals such as volcanic & earthquake activity?

A critical mass of researchers in close geographical proximity is one of our great strengths. It facilitates shares access to facilities and training and helps to build a strong cohort identity.

At CENTA we aim to develop well-rounded students confident in a wide range of scientific, research, leadership and entrepreneurial skills. Such individuals will go on to become future sector leaders, equipped not only with specialist and technical expertise in their research fields, but also the ability to translate research into impact and to address the complex environmental challenges facing society.

We recruit graduates who have studies a wide range of subjects including earth sciences, geography, environmental science, chemistry, biology, physics, maths, engineering and computing. Visit www.centa.org.uk for more information.




Henlo hoomans!

Welcome to Birmingham ProgPal 2019! These are all the heckin' hoomans that have worked really hard to make Birmingham ProgPal the best it could be (overseen by me obviously, much work, such time). We all thoroughly hope you have a great time here, learn lots of new things and meet lots of new people!

Many sniffs,
Hugo

ProgPal Pooch
Specialist Squirrel Finder
Master Ball Catcher

Luke Meade
Vertebrate Palaeontologist
& Trying his best

Daniel Cashmore
Vertebrate Palaeobiologist
& Local translator

Lisa Schnetz
Marine (Palaeo)biologist
& Aspiring Shark Whisperer

Struan Henderson
Vertebrate Palaeontologist
& Amateur Parent/Toddler PA

Amy Jones
Micropalaeontologist
& Coffee Connoisseur

Juan Pablo Castañeda
Micropalaeontologist
& Bicycle Enthusiast

Emma Dunne
Vertebrate Palaeobiologist
& Professional Dog Spotter

Emma Hanson
Micropalaeontologist
& Proud Human of Hugo

Nicola Kirby
Micropalaeontologist
& Gravity Defier

Marcelo de Lira Mota
Micropalaeontologist
& World Traveller

Fion Ma
Vertebrate Palaeontologist &
Unprofessional Bird Watcher

General information

Registration

The registration desk will be open early–late each day of the conference (see schedule) at the front inside the Lapworth Museum. Here, delegates can collect their name badge, t-shirt and dinner ticket (if ordered), and travel grant (if awarded). The desk will be available at all times throughout the main periods of the meeting for any inquiries.

Workshops

Please assemble just before 12:00 on 6th June in the Lapworth Museum by the registration desk for the workshops. Workshop 1 Introduction to the Paleobiology Database will take place in the Earth Imaging Lab with Prof. Richard Butler. Workshop 2 An Introduction to Digital Palaeontology with Dr. Stephan Lautenschlager in the Palaeo Lab. Committee members and those staffing the registration desk can direct you to these locations. Please check your emails closer to the date for additional information ahead of the workshops.

Discussion Group

The discussion session will take place at 15:00 in the Earth Imaging Lab. Feel free to assemble by the registration desk in the Lapworth Museum beforehand - committee members and those staffing the registration desk can direct you to this location. Discussion session panel will feature individuals representing different topics relevant to ProgPal delegates: Dr Thomas Halliday (academic careers, early career fellowships), Dr Andy Jones (museums/outreach careers), and Dr Sally Thomas and Dr Barry Lomax (getting published). Each panel member will briefly introduce themselves, say what they do, and give a brief history of how they got there. Then, we'll start the "focus groups" where smaller groups of participants will have approx. 15 mins with each of the presenter before rotating to the next presenter. The session will end with a collective Q&A and a sum-up of the best and most valuable points raised in the discussions.

Icebreaker

The icebreaker social will be kicking off in the Lapworth Museum at 18:00 on the 6th June with a variety of soft and alcoholic drinks, as well as light snacks.

Talks & posters

Full talks need to last 12 minutes, leaving 3 minutes for questions. Lightning talks need to last a maximum of 4 minutes, leaving at least 1 minute for questions. Talks should be uploaded onto the computer in the WG5 lecture theatre *prior to the beginning of the session in which you will be presenting*. Please talk to a session chair or other committee member to arrange this.

Poster boards will accommodate A1 posters in landscape *or* portrait format. Posters may be put up in the morning of 7th June if you would like them to be on display to the public during the day or following the final talk session in preparation for the dedicated poster session in the afternoon.

If you do would prefer your talk or poster to not be recorded, streamed, photographed, or mentioned on social media, please use the signs available at this link: https://www.palass.org/meetings-events/permission-signs-talks-and-poster

Social media

The Twitter hashtag for the meeting will be **#ProgPal19**

You can find our social media at https://www.facebook.com/progressivepalaeontology2019/ and https://twitter.com/ProgPal2019

T-Shirts & other sales

ProgPal 2019 t-shirts ordered through registration will be available to collect at the registration desk. There will also be a limited number on sale at the meeting for £15.

The palaeoartists Julian Kiely and Jack Mayer Wood will be exhibiting art and selling material whilst attending the meeting. Check out their stalls in the Lapworth Museum!

Lunch

Packed lunches will be provided in the Lapworth Museum for all registered delegates following presentation session 2 on 7th June (see schedule). Any dietary requirements provided in your registration will have been catered for.

LGBTQ+ meetup

Following the success at the PalAss annual meeting, there will be an informal LGBTQ+ meetup at ProgPal 2019. Please meet at the entrance to the Lapworth once you have collected your lunch from the tables nearby. All welcome!

Wi-Fi

Wi-Fi connection is available on the University of Birmingham campus through Eduroam or the UoB guest Wi-Fi.

Travel Grants

Successful awardees of travels grants may collect their grant in the form of a cheque from the registration desk at any point during the conference (see schedule for times).

Dinner

The ProgPal2019 dinner will take place at 20:00 7th June at Celebrity Indian Restaurant on Broad Street, Birmingham (B1 2HP). If you have booked a place at the dinner, your ticket can be collected at the registration desk. The dinner will be a buffet style Indian meal with water provided to each table. Additional drinks can be ordered separately at the bar.

Auction

Following the poster session and prize-giving, various items will be auctioned in order to raise money to fund travel grants for ProgPal 2020. We encourage anyone with something worth auctioning to donate it to the auction in order to help support ProgPal remaining accessible in the future. Please email progpal2019@palass.org for postage details!

The auction will be held in the Lapworth Museum – please bring cash if you plan to bid for items (ATMs are available on campus at R23 and O1 on the campus map, page 12).

'Fieldtrip' & museum tours

Those booked onto the Lapworth Tours will be assigned to either the first (10:00) or second (11:00) group to tour the museum's collections, led by museum director Jon Clatworthy, on the morning of the 8th June. Please meet at the museum entrance in good time prior to your assigned time.

The Urban Palaeo Expedition, guided Julie Schroder of the Black Country Geological Society, will begin at 10:30 at the statue of Queen Victoria in Victoria Square (https://goo.gl/maps/vXHdGVoD8VeDSyF79). The expedition will end at approximately 13:00 at Grand Central (New Street train station), and there will be an option to move on to The Stable (specialising in pizza & cider) for lunch.

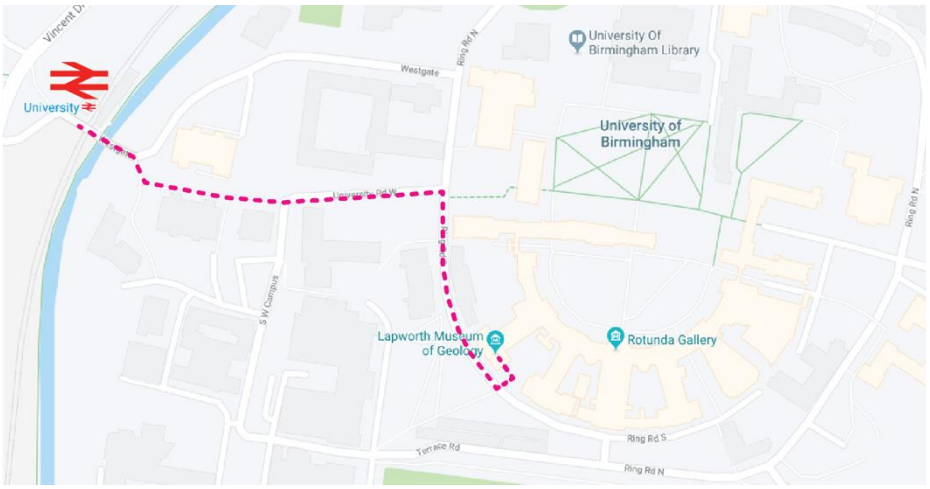
Sustainability

We are endeavouring to make ProgPal 2019 as environmentally friendly and waste-free as possible. To achieve this goal, we will cut down on single-use plastics (e.g. non-compostable disposable coffee cups) and not distribute delegate packs in favour of using digital resources, among other initiatives. **If you have a reusable coffee cup, please bring it along** - we hope you will join us in changing our conference habits for the better!

Facilities

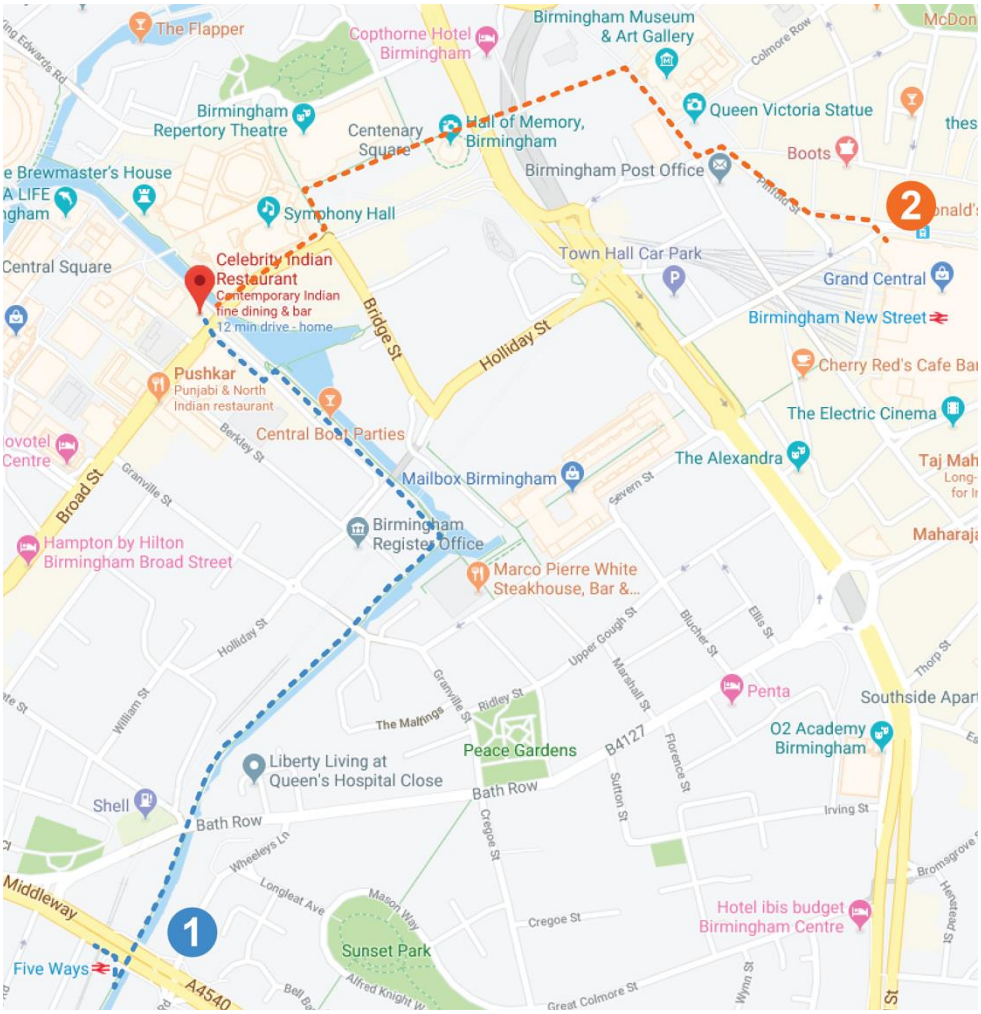
Throughout the conference, there will be a gender neutral bathroom in the Lapworth Musuem and a list with directions to additional gender neutral facilities provided at the registration desk. There will also be a designated quiet space available throughout each day to all delegates close to the main conference venues. Please ask any member of the organising committee for further details.

Getting on campus

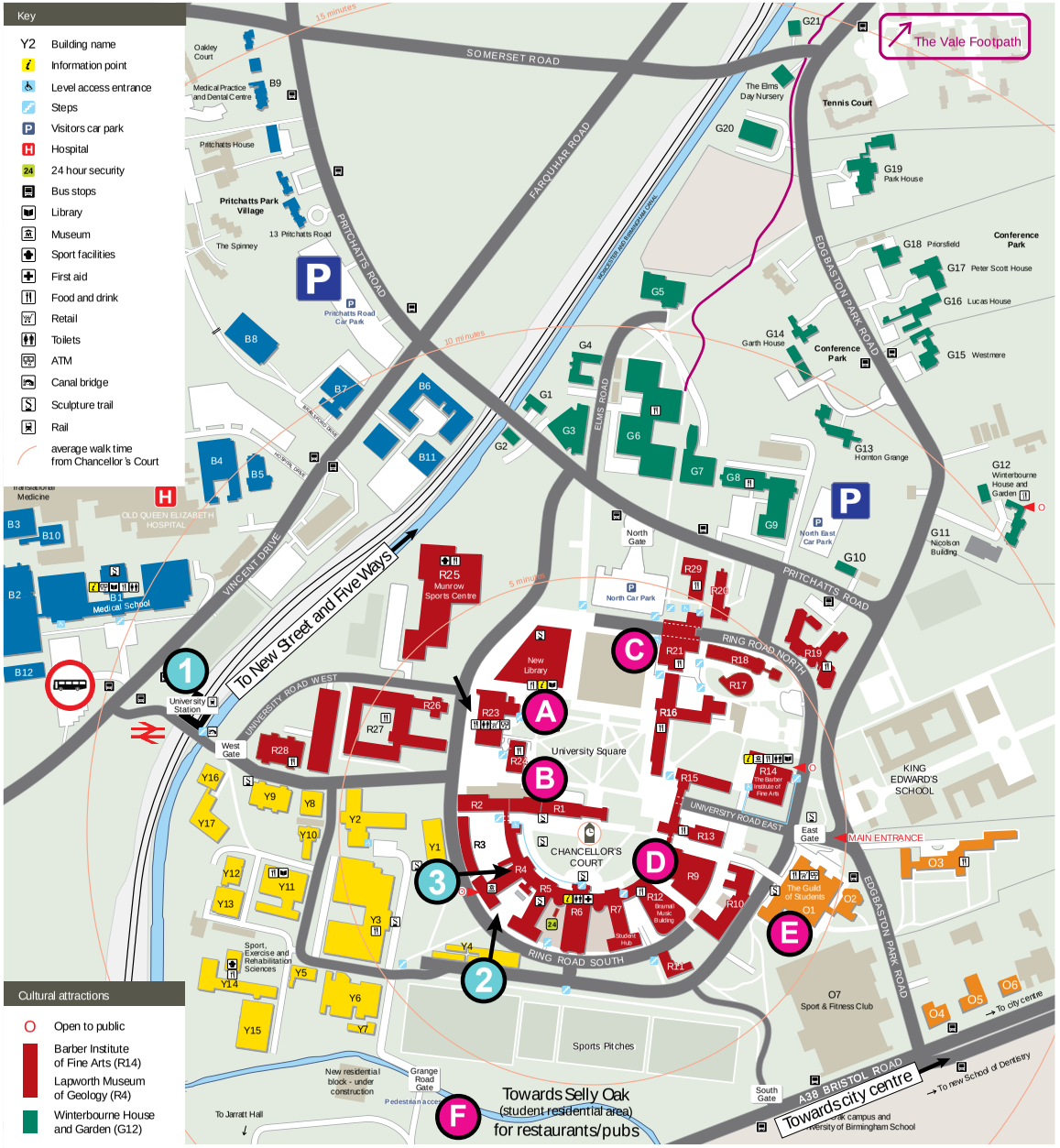


We recommend travelling to the university campus by train (University Station). From there, the Lapworth Museum and Earth Sciences building is only a short 5-minute walk.

Getting to the dinner & auction venue



Celebrity Indian restaurant lies on Broad Street, equidistant from both New Street and Five Ways train stations. From Five Ways (route 1), you can walk along the canal path past the Mailbox area. From New Street station (route 2), you can walk via Victoria Square in the city centre. Both walks take about 13–14 minutes.



University of Birmingham Edgbaston Campus (B15 2TT)

1. University Train Station
2. Lapworth Museum of Geology (R4)
3. Earth Sciences Department (R4)

Food Outlets on Campus

A University Centre (R23)
- SPAR (ground floor) - serving hot food
- Café GO (ground floor)
- COSTA (access from outside)

B Staf House (R24)
- Bratby Bar (ground floor) - hot food
- Café Aroma (1st floor) - cof ee and sandwiches
- Noble Room (2nd floor) - hot food

C Muirhead Tower (R 21)
- Starbucks

D Bramall Music Building (R 12)
- COSTA

E Guild of Students (O1)
- Subway (to-go)
- SPAR - serving hot food

F Selly Oak area - pubs/ shops
- 5–10 minute walk

Thursday 6th June

11:00–19:00 Registration desk open in Lapworth Museum

12:00–14:00 **Workshop 1. Introduction to the Paleobiology Database**

Palaeolab (meet in Lapworth Museum)

12:00–14:30 **Workshop 2. An Introduction to Digital Palaeontology**

Earth Imaging lab (meet in Lapworth Museum)

15:00–16:30 **Discussion session**

Earth Imaging lab (meet in Lapworth Museum)

18:00–20:00 **Icebreaker social**

Lapworth Museum

Friday 7th June

08:00–17:00 Registration desk open in Lapworth Museum

09:00–09:15 **Welcome address** from ProgPal 2019 and PalAss

SESSION 1 – Chair: Daniel Cashmore

09:15 **Carolina Karoullas**

Using linear and geometric morphometric techniques to determine the utility of using avian bill shape as a proxy for diet and ecological niche

09:30 **Albert Chen**

Total-evidence framework reveals complex morphological evolution in nightbirds (Strisores)

09:45 **Oliver E Demuth**

3D limb biomechanics of the stem-archosaur *Euparkeria capensis*

10:00 **Juan Benito**

New *Ichthyornis* specimens: shedding new light on modern bird origins

10:15 **Emily Brown**

Endocranial anatomy and life habits of the Early Triassic archosauriform *Proterosuchus fergusi*

10:20 **Amy Campbell**

Commitment to the morphological extreme-Revised systematics of the sauropod dinosaur *Dicraeosaurus* from the Late Jurassic of Tendaguru (Tanzania) and 3D articulation and biomechanics of the dicraeosaurid neck and shoulder girdle.

10:25 **Fernando Arnal**

Ecomorphology of the turtle limbs: studying the present to understand the past

10:30 **Coffee break in Lapworth museum**

SESSION 2 – Chair: Amy Jones

11:00 **Carrie Walker**

The morphological diversity of living and fossil ferns

11:15 **Caitlin Lebel**

Larger Benthic Foraminifera of the Eocene-Oligocene of Florida

11:30 **Bridget Warren**

Morphological response of benthic foraminifera to the Early Eocene Climatic Optimum

11:45 **Adam Woodhouse**

To the bitter end: do planktonic foraminifera actively change their niche habit in response to external drivers prior to extinction?

12:00 **Martha Gibson**

Wall ultrastructure and development in the Permian pollen grain *Lueckisporites virkkiae* Potonié and Klaus 1954 emend. Clarke 1965: evidence for botanical affinities

12:05 **Sophie Kendall**

Ontogenetic disparity in early planktic foraminifers

12:10 **Grace Lamyman**

Morphological traits and the importance of their functions in planktic foraminifera

12:15 **Andrew Mair**

Spatial core top variation of planktonic foraminiferal assemblages on the Uruguayan Margin

12:20 Presentation by ProgPal 2020

12:25–13:30 **Lunch in Lapworth Museum**

SESSION 3 – Chair: Emma Dunne

13:30 **Joseph Sutherland**

The Carnian Biotic Crisis: a hidden mass extinction driven by the Carnian Pluvial Episode?

13:45 **João Leite**

Scaling patterns of metacarpus dimensions and body size in non-avian dinosaurs

14:00 **Alfio Alessandro Chiarenza**

Late Cretaceous dinosaur latitudinal biodiversity gradient reaveals the palaeogeographic signature of sauropod thermophysiology

14:15 **Bethany J. Allen**

The latitudinal diversity gradient of tetrapods across the Permo-Triassic mass extinction and recovery interval

14:30 **Lewis Jones**

Spatial bias, hotspots, and the latitudinal biodiversity gradient

14:35 **Struan Henderson**

Trends and sampling bias in the diversity of Palaeozoic ray-finned fishes

14:40 **Emily Green**

Understanding the drivers of the European Perissodactyl turnover at the Eocene-Oligocene boundary

14:45 **Coffee break - Lapworth Museum**

SESSION 4 – Chair: Struan Henderson

15:15 **Morten Lunde Nielsen**

Secondary silicification of soft tissues in the Sirius Passet Lagerstätte, North Greenland implies less variability in pathways to exceptional preservation

15:30 **Barbara Grant**

How are gait and energetics modified in humans when walking over substrates of varying compliance?

15:45 **Richard Howard**

A sessile Cambrian Lobopodian

16:00 **Will Crabbe**

Paraconodonts: a ‘toothy’ Cambrian predicament

16:05 **Hannah Byrne**

Virtual 3D-reconstruction of inclusions from two large coprolites from a Devonian-Carboniferous boundary lake deposit.

16:10 **Kim Chandler**

Determinate growth and diphyodonty of Triassic Mammaliaform *Morganucodon watsoni*.

16:15 **Christopher Stockey**

Let them eat…everything? Dietary proxies for all: homology-independent palaeoecology across all taxa.

16:20–17:30 **Poster session** - Lapworth Museum (main galleries)

17:30–18:30 **Prizes and Auction** - Lapworth Museum (main galleries)

20:00–21:30 **Dinner** at Celebrity Indian Restaurant, Broad Street

Saturday 8th June

10:00 **Lapworth tour** group 1 – meet at museum entrance

11:00 **Lapworth tour** group 2 – meet at museum entrance

10:30 **Urban Palaeo Expedition with Black Country Geological Society**

Meet at statue of Queen Victoria in Victoria Sqaure, city centre (https://goo.gl/maps/vXHdGVoD8VeDSyF79)

Oral Presentations

The latitudinal diversity gradient of tetrapods across the Permo-Triassic mass extinction and recovery interval

Bethany J. Allen[1], Daniel J. Hill[1], Erin E. Saupe[2], Paul B. Wignall[1], Alexander M. Dunhill[1]

[1]University of Leeds
[2]University of Oxford

The modern-day latitudinal diversity gradient (LDG) is a general trend of increasing biodiversity from the poles to the equator. However, our understanding of the underlying processes is limited, and it remains unclear whether this pattern was present throughout the Phanerozoic. One approach to answering these questions is to examine spatial biodiversity patterns in the geologic past, across different global climate regimes and continental configurations.

The Late Permian–Middle Triassic (~250 Ma) represents an ideal time interval, characterized by large-scale volcanic episodes, extreme greenhouse temperatures and mass extinctions and recoveries. Continental configuration was also markedly different from today, with landmasses coalesced into the supercontinent Pangaea. We examined tetrapod spatial biodiversity patterns across this time window by applying established quantitative techniques to a database of global tetrapod occurrences, to investigate the role of climate change and continental distribution in driving LDGs.

Throughout the interval, terrestrial tetrapods exhibited a bimodal richness distribution, with peaks in the northern low latitudes and southern mid latitudes. Marine tetrapods, which first appeared in the late Early Triassic, were only found in the northern mid latitudes. These trends persist through the application of subsampling methods, suggesting they are robust to spatial sampling biases. These results are consistent with the hypothesis that unusual climate patterns, driven by global warming and the assembly of Pangaea, controlled tetrapod extinction and migration throughout the Late Permian to Middle Triassic.

Ecomorphology of the turtle limbs: studying the present to understand the past

Fernando Arnal[1], Roger Benson[2], Mark Puttick[1], Matthew Wills[1]
[1]University of Bath
[2]University of Oxford

Turtles are an enigmatic group of reptiles, mainly characterised by the acquisition of a bony or cartilaginous shell originated by the modification of their ribs. They are an ecologically diverse group, which underwent several water-to-land and land-to-water transitions during their evolutionary history, resulting in the adaptation to a wide array of aquatic and terrestrial habitats. Several attempts to infer the ecology of fossil turtles have been carried out by studying the anatomy of their limbs and carapace (e.g., bone length proportions of the forelimbs and shape of the shell). These methods have proven inefficient to account for the whole scope of morphologies and their potential ecological correlates. For example, some living species feature an ecomorphology that is not consistent with the results of previous works, rendering those measured morphological proxies unfit to assess their ecology. In the first chapter of my doctoral thesis we aim to overcome those limitations by comprehensively studying the morphology of the limbs of extant families including their extinct members, using computed tomographic techniques (micro-CT) combined with 3D morphometric analyses. The use of these modern analytical tools will shed light on the relationship between the limb morphology of living species and their well-known ecologies (i.e., form-function relationships), which will ultimately allow us to design a reliable comparative framework to infer the palaeoecology of fossil turtles.

New *Ichthyornis* specimens: shedding new light on modern bird origins

Juan Benito[1,5], Bhart-Anjan Bhullar[2], David Burnham[3], Laura E. Wilson[4], Daniel J. Field[5]

[1]University of Bath, Bath, UK
[2]Yale Peabody Museum of Natural History, New Haven, USA
[3]University of Kansas Natural History Museum, Lawrence, Kansas, USA
[4]Sternberg Museum of Natural History, Hays, Kansas, USA
[5]University of Cambridge, Cambridge, UK

The skeletal morphology of the Late Cretaceous toothed bird *Ichthyornis dispar* is considered to be more representative of the ancestral condition of crown birds than that of any other known Mesozoic avialan, and its study has crucial implications for understanding the morphological evolution prior to the great radiation of the avian crown group.

Here we present high resolution scans of new, exquisitely preserved three-dimensional specimens of *Ichthyornis* from the Late Cretaceous of Kansas. These correspond to a partial skeleton from a single individual, more complete and in better condition than the classic material, including a complete sternum and shoulder girdle with evidence of extensive pneumatization. This new skeleton shows certain morphological differences from the classic material, including the absence of some previously recognized diagnostic features for *Ichthyornis*. Thus, the new material may represent a previously unknown species, or it could indicate that the morphological disparity within *Ichthyornis* may be larger than previously appreciated.

Phylogenetic analyses incorporating the new morphological data confirm previous results and recover a grade of predominantly marine taxa close to the origin of the crown group. *Ichthyornis dispar* is found stemward of the Hesperornithes and the anatomically similar taxon *Iaceornis marshii*, which is recovered as sister taxon to all crown birds. The in-depth study of *Iaceornis* and other obscure and undescribed taxa in this region of the tree will help confirm these results and establish the measure to which the marine adaptations of crownward stem birds influenced the early evolution of the crown group.

Endocranial anatomy and life habits of the Early Triassic archosauriform *Proterosuchus fergusi*

Emily Brown[1], Richard Butler[1], Martin Ezcurra[2], Bhart-Anjan Bhullar[3], Stephan Lautenschlager[1]

[1]University of Birmingham
[2]Museo Argentino de Ciencias Naturales "Bernardino Rivadavia"
[3]Yale University

Proterosuchids are an important group of carnivorous basal archosauriforms characterised by a bizarre and enigmatic downturned premaxilla that overhangs the lower jaw. They are particularly significant because they radiated in the immediate aftermath of the Permian–Triassic mass extinction, and represent one of the best known 'disaster taxa' following that event. While traditionally considered semi-aquatic, recent histological studies and geological data have suggested that they more likely inhabited terrestrial environments. By utilising computed tomographic (CT) data, we virtually reconstruct the brain endocast and endosseous labyrinths of two adult specimens of *Proterosuchus fergusi* from the earliest Triassic of South Africa, in an attempt to understand its life habits within the context of basal archosauriform evolution. Endocasts reveal that the brain cavity is tubular in shape and the endosseous labyrinths are highly pyramidal. The angle of the lateral semi-circular canal suggests that *P. fergusi* naturally held its head upwards ~17°, while the length of the cochlear duct suggests its auditory abilities were specialised towards low-frequency sounds. Furthermore, beam theory analysis suggests that the rostrum of *P. fergusi* is highly resistant to both bending and torsion when compared to modern crocodilians, although this resistance is neither enhanced or reduced by the overhanging premaxilla. Comparative anatomical analyses suggest *P. fergusi* was likely a semi-aquatic, generalist apex predator capable of surviving the harsh environmental perturbations of the Early Triassic.

Virtual 3D-reconstruction of inclusions from two large coprolites from a Devonian-Carboniferous boundary lake deposit.

Hannah Byrne[1], Henning Blom[1], Grzegorz Niedźwiedzki[1], Benjamin Kear[2], Per Ahlberg[1]

[1]Department of Organismal Biology, Uppsala University
[2]Museum of Evolution, Uppsala University

The Devonian-Carboniferous (D-C) strata from East Greenland form one of the best successions of low latitude sediments from that time. The Obrutschew Bjerg Formation represents a deep permanent lake that straddles the D-C boundary, and this black shale deposit can be linked to the famous Hangenberg extinction event. The deposit contains an abundance of actinopterygian remains believed to belong solely to the species *Cuneognathus gardineri*, along with a smaller number of acanthodian and chondrichthyan specimens. There is also an abundance of coprolites (over 100 collected) of various morphologies. There are large, non-spiral coprolites present which are suspected to be tetrapod in origin, however tetrapod body fossils do not occur in this assemblage; only in the late Devonian Aina Dal and Britta Dal formations. Here we present the modelled inclusions of two large coprolites, which have been imaged using Synchrotron phase-contrast microtomography at the European Synchrotron Radiation Facility (ESRF). The coprolite intrusions were modelled via masking using the imaging software Materialise Mimics 19. Both coprolites contain a similar assemblage of elements; partly articulated fish, multiple cleithra, clavicles and dental elements of actinopterygian origin, and acanthodian spines. The vast abundance of actinopterygian inclusions within the coprolites show that actinopterygians were the preferred choice of prey and could suggest that *C. gardineri* were schooling fish. It also indicates that the coprolite producer was a proficient swimmer. The actinopterygian inclusions have excellent 3D preservation, and so have the potential to aid in furthering our understanding of changes in actinopterygians across the D-C boundary.

Commitment to the morphological extreme-Revised systematics of the sauropod dinosaur *Dicraeosaurus* from the Late Jurassic of Tendaguru (Tanzania) and 3D articulation and biomechanics of the dicraeosaurid neck and shoulder girdle.

Amy Campbell[1], Daniela Schwarz[1]
[1]Museum für Naturkunde, Leibniz

In this talk I aim to give an overview of the work I will be undertaking during my PhD on dicraeosaurid sauropods. This first involves a thorough redescription of the type material for both species *Dicraeosaurus hansemanni* and *Dicraeosaurus sattleri*. Interpretation of the validity of the splitting of the genus will be undertaken as the main criteria for their current separation is their different stratigraphic distribution. Subsequently, a character matrix specifically tailored towards dicraeosaurids will be produced and all relevant taxa (three new species of which have been published on in the past year) coded in so as to gain a better understanding of the evolutionary origins and interrelationships of the group. Some of the vertebra will also be 3D and CT scanned in order to see the changes in pneumaticity that may have occurred with the evolution of the shortened neck of dicraeosaurids. There was a very high diversity of sauropods in Tendaguru, with 5 distinct species being known from the Upper Dinosaur Member. 3D reconstructions of the musculature of the neck and shoulder girdle of *Dicraeosaurus* will be produced and in turn compared with reconstructions of other sauropods in order to determine the potential feeding ecologies present in the locality.

Determinate growth and diphyodonty of Triassic mammaliaform *Morganucodon watsoni.*

Kim Chandler[1], Emily Rayfield[1], Pamela Gill[1]

[1]University of Bristol

The Triassic mammaliaform, *Morganucodon watsoni*, has given us unique insights into the appearance of what we consider mammalian characteristics. Often cited as the first in the mammal lineage to possess the traits of diphyodonty and determinate growth patterns, recent unpublished studies have shown that our simplified understanding of trait appearances in time may be incorrect, and more complicated than originally thought. Suggestions have been made of potential dimorphism in *M. watsoni* based on an unpublished study on diphyodonty (pers. comm Pam Gill). In such a case where dimorphism is shown to exist, there is the potential for our understanding of the growth pattern of *M. watsoni* to be affected. It is therefore my aim to investigate further the body size versus age pattern of *M. watsoni* and the effect this may have on the perceived growth pattern of *M. watsoni*. An extensive dataset of measurements of over 850 jaw specimens has been collected and statistical analysis will show whether our hypothesis of dimorphism is correct. After establishing this, the determinate growth pattern of Morganucodon will be revisited. The same unpublished study suggests, due to new observations into resorption patterns of teeth, that Morganucodon may not be strictly diphyodont, instead having a third wave of replacement teeth. As such, evidence of a non-diphyodont condition will be explored while bearing in mind the potential dimorphism.

Total-evidence framework reveals complex morphological evolution in nightbirds (Strisores)

Albert Chen[1], Daniel Field[2]

[1]University of Bath
[2]University of Cambridge

Strisores is a clade of largely insectivorous neoavian birds that includes specialized fliers such as swifts and hummingbirds, as well as a large diversity of nocturnal species such as nightjars. Despite the use of large-scale molecular datasets, the precise phylogenetic relationships among major strisorean groups remain controversial. Given the lack of consensus among recent phylogenomic datasets, we incorporated anatomical data from living and fossil strisoreans within a Bayesian total-evidence framework. Combined analysis of molecular and morphological data resulted in a phylogenetic topology for Strisores that is congruent with the findings of one recent molecular phylogenomic study of modern birds. However, we found that integration of molecular and morphological data did not yield increased statistical confidence in our topology, highlighting apparent homoplasy in both sequence and anatomical data. We suggest that disparate strisorean lineages have experienced convergent evolution across the skeleton, and that many of the distinctive specializations of strisorean subclades were acquired early in their evolutionary history. Furthermore, the results of applying tip-dating methods to this dataset indicate very rapid diversification of major strisorean lineages shortly following the origin of this clade. These complex patterns have resulted in a challenging phylogenetic problem, which obfuscates the robust inference of ancestral character states.

Late Cretaceous dinosaur latitudinal biodiversity gradient reveals the palaeogeographic signature of sauropod thermophysiology

Alfio Alessandro Chiarenza[1], Philip D. Mannion[2], Alex Farnsworth[3], Dan Lunt[3], Peter A. Allison[1]

[1]Imperial College London
[2]University College London
[3]University of Bristol

The latitudinal biodiversity gradient, characterised by an increase in species richness from the poles to the equator, is the first-order macroecological pattern today. However, evidence from the fossil record suggests that this modern-type pattern has not always been present. Previous work on Mesozoic dinosaurs has suggested a peak in diversity at higher latitudes, with evidence for spatial partitioning between the main subclades (Theropoda, Sauropoda and Ornithischia) during the Late Cretaceous. However, some authors have suggested this might be a sampling artefact. We combined a global occurrence dataset of non-avian dinosaurs for the Late Cretaceous (100.5–66 million years ago) with HadCM3L General Circulation Models, reproducing the climatic conditions of this time interval. We evaluated the effect of physical drivers, such as climate (e.g. temperature and precipitation patterns) and palaeogeography (range size), on dinosaur distribution. Sampling-standardisation approaches indicate a subtropical distribution for sauropods, in contrast to an antitropical distribution for theropods and ornithischians. Multivariate space quantification of palaeogeographic and palaeoclimatic occupation shows that sauropod hypervolumes are more constrained by temperature extremes than the other dinosaur clades. Using generalized least squares regressions to determine the relationships between latitudinal biodiversity patterns and potential explanatory variables (e.g. temperature and sampling proxies), we demonstrate statistical support for sauropod diversity and range sizes being constrained by temperature fluctuations. In contrast, theropod and ornithischian diversity patterns and ranges appear largely independent of climate. These results suggest a different thermophysiological strategy for sauropods, with a possible explanation for the gigantothermic physiology experimented by this dinosaur group.

Paraconodonts: a ‘toothy’ Cambrian predicament

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

[1]University of Leicester

Paraconodonts are a group of phosphatic tooth-like microfossil that ranged from the upper-middle Cambrian to the lower Ordovician and are thought to be directly ancestral to the euconodonts; they are therefore among the earliest vertebrates to possess a mineralized skeleton. This evolutionary scenario relies upon the apparent microstructural continuity among coniform para- and euconodont elements. However, complex paraconodont forms, such as the U-shaped and W-shaped form-species of *Westergaardodina*, display apparently paradoxical growth patterns that diverge from those of coniform elements. Examination of the internal structure and growth patterning of these problematic forms will be crucial in resolving the early history of the vertebrate lineage. To this end, a rich and highly diverse assemblage of paraconodonts has been examined from drillcore samples of the upper Cambrian Deadwood Formation in Saskatchewan, western Canada. The fossils display a unique mode of preservation that renders the internal growth lines of all specimens visible in transmitted light, providing an unparalleled opportunity to describe and interpret element morphogenesis. A total of six morphotypes and six subtypes have been identified and described within *Westergaardodina*, including forms that were previously restricted to Sweden and others that are entirely new to science. Our initial results have indicated that these earliest conodonts were more structurally disparate than expected, with a suite of distinct growth styles observed among superficially similar Deadwood morphotypes. This raises significant questions into the function of these elements and suggests that the earliest vertebrates may have been more ecologically complex than has previously been appreciated.

3D limb biomechanics of the stem-archosaur *Euparkeria capensis*

Oliver E Demuth[1], Emily J Rayfield[1], John R Hutchinson[2]

[1]University of Bristol
[2]Royal Veterinary College

Archosaurs are an extremely diverse group of reptiles, originating shortly before the Triassic period and radiating rapidly after the Permo-Triassic mass extinction. In the Triassic they explored diverse morphologies in the ankle and pelvis, which lead to the different locomotor types and body plans we see throughout their evolutionary history. The diverse skeletal morphologies in Triassic archosauriforms had an undeniable influence on their locomotion, however the implications for specific functions are still poorly understood. Early archosaurs and sister taxa to Archosauria are essential to understand the evolution of the different locomotor adaptations; however, quantitative locomotor biomechanics studies of extinct archosaurs have so far focused mainly on non-avian dinosaurs. We present the first detailed, quantitative and 3D investigation into the locomotory abilities of the stem-archosaur *Euparkeria*. µCT scans of multiple specimens from South Africa enabled the reconstruction of its limbs in unprecedented detail and the characterization of previously unknown morphological features. To test previous qualitative hypotheses regarding posture, gait and stance of *Euparkeria*, the mobility of the complete hindlimb was assessed and the maximal joint ranges of motion quantified. Two sensitivity analyses were performed to account for the unknown amount of epiphyseal cartilage and the restricting influence of soft-tissue. Due to the medially expanded femoral head and the distinct supra-acetabular rim, *Euparkeria* seems to have been capable of adopting a crocodile-like “semi-erect” posture. This is consistent with other evidence suggesting that the common ancestor of archosaurs had a similar ability to adduct the hindlimbs into less sprawling poses

Wall ultrastructure and development in the Permian pollen grain *Lueckisporites virkkiae* Potonié and Klaus 1954 emend. Clarke 1965: evidence for botanical affinities

Martha Gibson[1], Wilson Taylor[2], Charles Wellman[1]

[1]University of Sheffield
[2]University of Wisconsin - Eau Claire

Late Permian spore-pollen assemblages are characterised by striate bisaccate pollen grains that are known to be produced by three distantly related plant groups (glossopterids, peltasperms and conifers). Spore-pollen assemblages from the Zechstein Sea basin are dominated by an example of this pollen type: *Lueckisporites virkkiae* Potonié and Klaus 1954 emend. Clarke 1965. However, as of yet no biological affinity for *L. virkkiae* has been confidently assigned despite its biostratigraphical significance and it being a ‘Bridging Taxon’ across phytogeographical provinces. Individual grains were isolated from a dispersed spore-pollen assemblage from the Late Permian (Lopingian) ‘Lower Marl’ of Kimberley, Nottinghamshire, UK. Here we show that using transmission electron microscopy (TEM) analysis, the wall ultrastructure of *L. virkkiae* is revealed to be protosaccate and alveolate. These bitaeniate bisaccate pollen grains have an exine composed of a three-part ektexine of an outer solid tectum, an alveolar infratectum and a thin basal foot layer; and an electron dense homogenous endexine. The protosaccate sacci are formed by an expansion of the infratectum with endoreticulations spanning the entire width of the sacci. This ultrastructure affiliates *L. virkkiae* with the conifers. The obtained data is compared with published data on the ultrastructure of fossil and modern conifer pollen grains and a botanical affinity to the abundant conifer macrofossil species *Pseudovoltzia liebeana* Geinitz (Majonicaceae) is suggested. This finding improves the accuracy and resolution of Euramerican floral reconstructions for the Late Permian.

How are gait and energetics modified in humans when walking over substrates of varying compliance?

Barbara Grant[1], James Charles[1], Kristiaan D'Août[1], Karl Bates[1]

[1]Institute of Ageing and Chronic Disease, University of Liverpool

The transition to terrestrial bipedalism represents one of the most significant adaptations to occur within the hominin lineage. The most direct evidence we have of the locomotor dynamics of fossil hominins comes from fossilised footprints- the combined result of foot anatomy, gait dynamics and substrate properties. However, we lack an in-depth understanding of how human walking is altered by substrate compliance and which aspects of gait are recorded in footprints.
To better understand how gait mechanics and energetics are altered in response to substrates with different mechanical properties we are comparing energetic costs, muscle activity of the lower limb and trunk and lower limb motion in 30 healthy human subjects walking on three artificial substrates: 2 compliant and 1 non-compliant. Whole-body kinematics are recorded using surface marker motion capture, oxygen consumption measured using a wearable metabolic system and used to calculate cost of transport and muscle activities recorded using surface electromyography (EMG).
As substrate compliancy increases, there is an increase in energetic costs. Participants also display an increased range of motion at the ankle, knee and hip joint and a decrease in step, stance and swing time and mean speed. These gait modifications would suggest the need to consider the potential differences in substrate mechanical properties across fossil footprint sites when drawing conclusions about the evolution of locomotion through time.

Understanding the drivers of the European Perissodactyl turnover at the Eocene-Oligocene boundary

Emily Green[1]

[1]University of Bristol

The Eocene-Oligocene boundary (33.5 ma) represents a period of large-scale faunal overturn resulting from global cooling and glaciation producing increased seasonality and aridity in the Northern Hemisphere. Europe, as well as being influenced by this dramatic climate event, also saw simultaneous large-scale migration of Asian fauna in the 'Grande Coupure', facilitated by the decrease in sea level. Perissodactyls, as hindgut fermenters, possess a strong link to vegetation and the environment. They proved the dominant ungulate clade through the Eocene, though many of their endemic Europeans members became extinct at the EOB and were replaced by incoming migrants. To understand the extrinsic and intrinsic drivers at play in the relationships of ungulates during this period, landmarking techniques were used to assess mandible morphology as a proxy of feeding ecology, to create functional and geomorphometric morphospace. Palaeotheriidae and Rhinocerotoidea represent fundamentally different functional morphologies and show a dominant change in morphospace occupation for Perissodactyls across the EOB. The Equoidae morphospace gap discerned between their EOB extinction and later reintroduction to Europe in the early Miocene is observed to be filled by early Oligocene migrant Artiodactyls, such as *Bachitherium*. Intrinsic factors here are demonstrated to be strongly influencing the change in European Perissodactyl mandible morphology across the late Eocene-early Miocene, with phylogeny inferred to play a large role.

Trends and sampling bias in the diversity of Palaeozoic ray-finned fishes

Struan Henderson[1], Sam Giles[1]

[1]University of Birmingham

As one of the largest vertebrate groups, with around 32,000 known extant species, the Actinopterygii (ray-finned fishes) are key to our understanding of vertebrate evolution. How they attained this staggering current diversity is uncertain, and there has been very little research to date into the diversity trends of actinopterygians in their evolutionary history. Palaeozoic taxa in particular have received little attention despite their substantial fossil-record and importance in the story of early ray-finned fish evolution. Previous work on all fish groups has suggested major faunal turnover from the Devonian to the Carboniferous, with actinopterygians becoming a more dominant faunal component. The diversity trends within ray-finned fish specifically however, and importantly the impact of biases on the record of the group, have not been closely examined. Here we show with a novel occurrence dataset that the raw diversity of the actinopterygian fossil record is tightly linked with the number of localities and formations in which they are found, indicating a substantial source of sampling bias. Furthermore, comparison of species- and genus-level diversity shows that peaks in species counts are largely due to high species diversity within a small number of poorly-defined 'waste-basket' genera. Further work will attempt to refine these bloated genera and use sampling standardisation to identify whether the peaks and troughs observed in the raw data are robust, valid and biologically meaningful changes in diversity through time.

A sessile Cambrian Lobopodian

Richard Howard[1,2,3], Gregory Edgecombe[1], Xianguang Hou[3], Xiaoya Ma[2,3]

[1]The Natural History Museum
[2]University of Exeter
[3]Yunnan Key Laboratory for Palaeobiology

Cambrian lobopodians represent a non-monophyletic assemblage of panarthropods, typically interpreted as stem lineage members of the extant panarthropod phyla (Euarthropoda, Onychophora and Tardigrada). Most Cambrian lobopodians exhibit appendages (lobopods) of uniform structure, or of limited specialization. However, one group, the luolishaniids, possess highly specialized appendages thought to be associated with suspension feeding ecologies. In this study, we document new material of the enigmatic Chengjiang Biota worm *Facivermis yunnanicus* Hou & Chen, 1989, and hypothesise that it was a secondarily vermiform and sessile luolishaniid. We document new characters using SEM EDX mapping, including a characteristically lobopodian head with paired eyespots, and performed both maximum parsimony and probabilistic (Bayesian and ML) phylogenetic analyses. All methods resolve *Facivermis* within the luolishaniid group with high support. Our trees indicate considerable deviation from the distinctive anterior-posterior luolishaniid tagmosis. This deviation is characterised by loss of the posterior appendages and dorsal sclerotization, coupled with elongation and posterior swelling of the trunk. We interpret these adaptations as consistent with a sessile mode of life – or at least one of reduced motility. *Facivermis* therefore greatly expands the known ecomorphological range of Cambrian lobopodians, and exemplifies the diversity of soft-bodied panarthropods in Cambrian oceans.

Spatial bias, hotspots, and the latitudinal biodiversity gradient

Lewis Jones[1], Christopher Dean[1], Philip Mannion[2], Peter Allison[1]

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

The latitudinal biodiversity gradient (LBG), in which species diversity decreases from tropical to polar regions, is one of the most recognisable macroecological patterns today. Analyses of biogeographic patterns in deep time is impacted by biases arising from incomplete sampling and the fundamental architecture of the fossil record. Whilst a multitude of methods have been developed to standardise sampling to mitigate problems associated with uneven 'raw' occurrence data, these have often been considered within one dimension, typically temporal or latitudinal bins. However, the geographic coverage of sampled and available outcrop also impacts upon our view of deep time macroecological patterns. Whilst the modern LBG is marked by tropical peaks in diversity, a vast amount of this richness can be accredited to a few biodiversity hotspots around the globe. Intuitively, such hotspots also existed in the past, but whether they ever entered the geological record is difficult to determine. As a result, perceived LBG's within the fossil record might simply be the result of absence of data. Using both real and simulated data, we show that observed deep time LBG trends can be impacted by the geographic coverage of sampled outcrop, highlighting the potential significance of data absence. In addition, we test the ability of the commonly applied method of shareholder quorum subsampling to reconstruct spatial diversity patterns in comparison to known simulated data. We show that caution is needed when using such methods to recover relative richness patterns, and highlight the need to consider geographic coverage.

Using linear and geometric morphometric techniques to determine the utility of using avian bill shape as a proxy for diet and ecological niche

Carolina Karoullas[1], Robert Nudds[1]

[1]University of Manchester

The ability to connect fossil bill shape to feeding style (and niche) would contribute greatly to unravelling avian ecology and evolution. Here, linear and geometric morphometrics (elliptical Fourier analyses, EFA) were used to determine how feeding style and phylogeny impact bill shape in extant taxa. Linear discriminant analyses (LDA) on taxa that feed similarly and are close phylogenetically were used to identify whether factors other than diet and phylogeny influenced bill shape. For linear data, no differences between taxa were found. Contrastingly, minor differences between taxa were found for EFA data. LDAs were then conducted on taxa that feed differently but are close phylogenetically and those that feed similarly but are distant phylogenetically. For both datatypes, LDAs suggested that, although mostly determined by feeding style, phylogeny does influence bill shape. Subsequently, phylogenetically-controlled functional discriminant analyses (pFDAs) were conducted on all taxa together to remove the phylogenetic effect. The pFDAs on linear datasets relating to three-dimensional and lateral-only bill morphology correctly predicted feeding style in 92% and 80% of taxa, respectively. Comparatively, pFDAs on EFA data correctly predicted feeding style in 93.5% and 71% of taxa using ventral and lateral bill views, respectively. This suggests that avian bill shape is a reasonable metric for feeding ecology and niche. Furthermore, linear measurements seem able to determine feeding ecology just as effectively as geometric morphometric approaches. This is pertinent to interpreting fossil taxa ecology because fossil bill preservation generally only allows linear measurements to be extracted.

Ontogenetic disparity in early planktic foraminifers

Sophie Kendall[1], Felix Gradstein[2], Christopher Jones[3], Oliver T. Lord[4], Daniela N. Schmidt[4]

[1]Independent
[2]Natural History Museum, University of Oslo
[3]School of Physics, University of Bristol
[4]School of Earth Sciences, University of Bristol

Changes in morphology during ontogeny have profound impacts on the physiology and biology of a species. Studies of ontogenetic disparity through time are rare because of the lack of preservation of developmental stages in the fossil record. This leaves important processes difficult to address. As they grow by incremental chamber accretion, and retain evidence of growth in their shell, planktic foraminifera are an ideal group for the study of this process. Here, we show how different developmental stages in Jurassic foraminifers can be used to decipher the ecology and therefore infer the evolutionary implications of shape of these earliest representatives of the group. Using a Zeiss XRadia micro CT-scanner, the development of *Globuligerina bathoniana* and *Globuligerina oxfordiana* from the Bathonian of Gnaszyn, Poland, and *Globuligerina balakhmatovae* and *Globuligerina tojeiraensis* from the Kimmeridgian Tojeira Formation of Portugal was reconstructed. Disparity is low through the early evolution of planktic foraminifers. The number of chambers and range in surface area per volume is lower than in modern specimens which we interpret as an indication of opportunistic behaviour. Strong ontogenetic constraints indicated by low plasticity during the juvenile stage noted in the modern ocean are already present in Jurassic specimens. The high surface area per unit volume points towards the need to satisfy a higher metabolic demand than is found in the adult specimens. The short life cycles and potentially rapid reproduction may have allowed these species to exploit the warm, shallow and nutrient rich waters of the Jurassic Tethys Ocean.

Morphological traits and the importance of their functions in planktic foraminifera

Grace Lamyman[1], Paul Wignall[1], Juan Cantalapiedra[2], Tracy Aze[1]

[1]University of Leeds
[2]University of Alcalá

Planktic foraminifera possess various measureable morphological traits (e.g. presence or absence of spines, coiling direction, chamber number) and these traits are typically measured in order to investigate micro and macroevolutionary processes and patterns. At present, there is a disparate literature which describes which of these measureable traits have been observed to be related to a biological function, and in turn impact fitness. This project aims to identify the function of all commonly measured planktonic foraminifera morphological traits and arrange the features in order of certainty of function and importance to the organisms' fitness and ecosystem functioning. A review of all previous literature on trait function has been conducted and a hierarchy has been established, for traits with i) known functional affinity, ii) possible functional affinity and iii) unknown functional affinity. Traits with known and possible functional affinity will be mapped onto the Cenozoic macroperforate planktonic foraminifera phylogeny (Aze et al. 2011) in order to assess rates of trait evolution throughout the last 65 million years and to investigate the relationship between the recovery of diversity and disparity of this clade after the end-Cretaceous mass extinction.

Larger Benthic Foraminifera of the Eocene-Oligocene of Florida

Caitlin Lebel[1], Laura Cotton[2]

[1]University of Florida
[2]University of Bristol

The Eocene-Oligocene Transition (EOT) was an interval of dramatic climatic change and significant turnover in both marine and terrestrial organisms, including the larger benthic foraminifera (LBF). LBF are symbiont bearing protists which can reach exceptionally large sizes, and are restricted to warm, oligotrophic waters in the photic zone. Consequently, they are highly sensitive to environmental change. LBF assemblages in the Eocene to Oligocene of the North American bioprovince are distinctly different from those in Europe and Indo-Pacific, making it essential to include their response in studies of global climatic perturbations. For example, lepidocyclinids dominate the Eocene in America but do not appear elsewhere until the upper part of the lower Oligocene. Although work has examined the response of LBF to the EOT in detail within the Tethyan and Indo-Pacific realms, it remains poorly understood in the Americas despite an abundance of LBF-bearing carbonates. This is largely due to an absence of a robust biostratigraphy and detailed taxonomy.
The Florida Geological Survey recently recovered a 230m record from Tallahassee, Florida, spanning the Middle Eocene to Oligocene. The core consists entirely of shallow water limestones, with few facies changes, and exceptionally abundant LBF. Here we present the preliminary ranges of LBF from this record, coupled with bulk carbonate stable isotope data to examine the overturning event in the Americas. This record will help to fill a key knowledge gap in our understanding of the extinction mechanisms of LBF and contribute to a more global understanding of shallow marine response to the EOT.

Scaling patterns of metacarpus dimensions and body size in non-avian dinosaurs

João Leite[1,2], Anjali Goswami[1], Paul Barrett[1]

[1]The Natural History Museum
[2]University College London

Hypotheses on locomotor biomechanics of terrestrial tetrapods are widely based on the scaling relationships between the limbs and body size. Less attention has been given to the hand (or manus), even though being one of the body parts in direct contact with the environment and potentially under more diverse selection pressures. Non-avian dinosaurs provide an excellent opportunity to study manus scaling, due to their wide range of body sizes, ecologies and behaviours. In addition, all early non-avian dinosaurs were bipedal, which allowed diverse manus morphologies to evolve. However, multiple independent reversions to quadrupedality also imposed some shared mechanical constraints. Here, we present the first study to compile an extensive dataset of metacarpus measurements across all major non-avian dinosaur lineages and use these to assess scaling patterns of the manus against overall body size. Data were analysed using phytools in R and Past. Across non-avian dinosaurs the metacarpus scales with positive allometry (close to isometry), with no significant differences between metacarpals, major clades, hand function, or locomotive stance. Multivariate analyses show some degree of clustering between clades, as well as identifying some extreme cases, such as tyrannosaurids. Each major clade occupies distinct areas of morphospace, with overlap between some groups.

Spatial core top variation of planktonic foraminiferal assemblages on the Uruguayan Margin

Andrew Mair[1], Tracy Aze[1], Ruza Ivanovic[1], Robert Newton[1], Jason Harvey[1]

[1]ESSI / University of Leeds

Oceanographic processes offshore Uruguay are exceptionally complex and energetic, with mixing of warm equatorial waters and cold Antarctic waters, bathing the margin. Planktonic foraminifera show ecological affinities for water masses based on temperature and thus within an oceanic mixing environment a transitional assemblage may be expected. Plankton tow transects conducted during the 1990s provide a regional picture of the relationship between planktonic foraminiferal communities and associated oceanic water masses along the South American margin. This project aims to relate surface sediment planktonic foraminifera distributions and assemblages to overlying water masses, in order to assess any population heterogeneity present in the core tops, across a margin portion associated with oceanic mixing. The dataset covers a region of 7400 km^2, within which a series of 200 piston cores were collected. A subset of this collection has been sampled, ranging from one to three kilometres water depth and covering the margin breadth. Sampling aims to assess the spatial difference in planktonic foraminiferal assemblages and whether potential differences reflect expected ecological affinities of taxa based on the oceanographic setting, or if ocean current transport and sedimentary affinity influence assemblage compositions.Presentation of initial findings regarding planktonic foraminiferal assemblage heterogeneity obtained from core top samples. Results focus on margin-wide assemblage signal variability and correlation to the modern oceanic setting using species ecological preferences, and whether transport effects explain assemblage variation and species distributions. Regional ecological mapping lays the project groundwork, enabling assessment of assemblage variability in a geographically dense region coinciding with complex oceanographic boundaries.

Secondary silicification of soft tissues in the Sirius Passet Lagerstätte, North Greenland implies less variability in pathways to exceptional preservation

Morten Lunde Nielsen[1], Mirinae Lee[2], Philip R. Wilby[3], Hong Chin Ng[1], Katharine R. Hendry[1], Tae-Yoon Park[2], Arne T. Nielsen[4], Jakob Vinther[1]

[1]University of Bristol
[2]Korea Polar Research Institute
[3]British Geological Survey
[4]University of Copenhagen

Exceptional preservation is crucial for our understanding of the evolution and ecology of animals. Especially the so-called ‘Burgess Shale-type’ preservation of soft-bodied organisms has given a window into life during the Cambrian radiation. Despite the immense attention, there is currently no consensus on the processes leading to ‘Burgess Shale-type’ preservation and especially the roles of primary (early diagenetic) versus secondary (metamorphic) processes. These processes impact how we interpret the palaeoenvironmental conditions, and how they may have varied between 'Burgess Shale-type' localities, and are thus important to identify. Here, we present a new taphonomic model for the Sirius Passet Lagerstätte where the silicified muscles were primarily phosphatized during early diagenesis and secondarily silicified during or after metamorphism using scanning electron microscope (SEM) and Si isotope data. Minute but abundant calcium phosphate (apatite) inclusions in the silicified muscle fibres suggest that apatite was present prior to silicification. Partially silicified metamorphic minerals indicate that silicification occurred during or after metamorphism. Si isotopes are similar to that of the sediment matrix indicating that the silica source must have been the same. This implies that secondary overprinting may constitute an essential role in the geochemical signals of ‘Burgess Shale-type’ preservation. This preservation is often found in metamorphic greenschist slates (Burgess Shale) or highly weathered (Chengjiang) rocks where secondary overprinting is expected. The replacement of a unique taphonomic pathway of soft-tissues (silicification) with a common pathway (phosphatisation) suggests that the taphonomic pathways to exceptional preservation may be overestimated.

Let them eat…everything? Dietary proxies for all: homology-independent palaeoecology across all taxa.

Christopher Stockey[1], Tom Harvey[1], Philip Donoghue[2], Mark Purnell[1]

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

Inferences of feeding ecology in fossil vertebrates have focused on morphological variation in dentition. In addition to the overall jaw morphology, the complexity of individual teeth has been shown to correlate to diet. However, this relationship is usually only described qualitatively, and when analysed quantitatively, most studies have been unidimensional; i.e., focussed on a single aspect of morphology to infer diet and trophic niche. Here, we test the effectiveness of an emerging technique: multi-proxy dental morphology analysis (MPDMA); in reconstructing trophic guilds using measurements of dental complexity. MPDMA combines unidimensional metrics, each analysing a different aspect of morphology, to generate a holistic measurement of complexity comparable between distantly related taxa, but has previously been tested only in crown-mammals. Here, we apply MPDMA to investigate the relationship between dentition morphology and diet in invertebrates, testing whether the method can be extended to non-homologous dental tools in other groups. Specifically, we analysed the bilaterally occluding mandibles of extant orthopterans (grasshoppers and crickets), for which diet is well-constrained by gut content analysis and feeding experiments. We analysed c.50 species to test the robustness of this method, correcting results for phylogenetic signal. Preliminary results indicate that MPDMA is able to predict dietary properties effectively in orthopterans. This indicates MPDMA is not restricted to teeth in vertebrates, but can be extended to dental tools in other groups and therefore to non-homologous dental tools in extinct groups. This is crucial in moving forward to research trophic- and ecosystem-level responses to perturbation events in deep time.

The Carnian Biotic Crisis: a hidden mass extinction driven by the Carnian Pluvial Episode?

Joseph Sutherland[1], Michael Benton[1]

[1]University of Bristol

The Carnian Pluvial Episode (CPE), a globally pervasive phase of volcanically-driven climate change, is associated with major Triassic biotic events. These include the rise of archosaurs to ecological dominance, radiations of the corals and nannoplankton that form the basis of modern marine ecosystems, and turnover across animal and plant clades. Given its profound biotic effects and classic geological trigger, the CPE is increasingly characterised as a lost mass extinction event hidden within a geological stage by poor stratigraphic control, yet it has received little palaeobiological assessment. I investigate the taxonomic and ecological effects of the CPE within the context of the Triassic, using an exhaustively re-dated dataset of 55,140 fossil occurrences downloaded from the Palaeobiology Database. Diversity is calculated using traditional methodologies (shareholder quorum subsampling and squares extrapolation) and a probabilistic Bayesian approach that explicitly accounts for uneven geological sampling (PyRate). Extinction and speciation rates are calculated, along with their taxonomic and geographical distributions, to elucidate macroevolutionary dynamics across the CPE. Changes in faunal composition and community structure are tracked using network analysis and ecological similarity indices. I demonstrate the prominence of Carnian-aged extinctions, termed herein the Carnian Biotic Crisis. The event is asynchronous, with distinct but transient effects on marine taxonomic diversity and ecological structuring during the early Carnian, and profound, lasting impacts in the terrestrial realm during the late Carnian and early Norian, particularly amongst tetrapods. This work contributes to our understanding of how the Carnian Biotic Crisis affected the macroevolutionary trajectory of the biosphere during the Triassic.

The morphological diversity of living and fossil ferns

Carrie Walker[1], Luke Mander[1], Angela Coe[1], Paula Rudall[2]

[1]The Open University
[2]Royal Botanic Gardens, Kew

Studies of the diversification history of life using the fossil record involve quantifying patterns of taxonomic diversity and morphological diversity (disparity) through time.
For animals, the comparative history of taxonomic and morphological diversity through the Phanerozoic is well known, and these two measures of diversity are often decoupled.
However, there is comparatively little data on the patterns of the morphological disparity of plants throughout the Phanerozoic.
To address this, we have investigated the morphological diversity of ferns. We have focussed initially on living plants to provide a present-day baseline for fossil data, and in this talk we aim to: (1) describe the morphology of living ferns using discrete characters; (2) examine patterns of morphospace occupation; and (3) measure the morphological diversity of the clades represented in our dataset.
Spores from 22 leptosporangiate families were collected from living specimens at Royal Botanic Gardens, Kew herbarium and were scored for discrete characters.
Our results indicate that there is no evidence that taxa group within morphospace according to their taxonomic affinity. Instead the nature of spore surface ornamentation exerts the strongest control on the distribution of taxa in morphological space.
A wide variety of functions have been proposed for spore surface ornamantation and our results indicate that further work is needed to understand why this character varies so widely among plants that occupy essentailly the same ecological niche. It is likely that the patterns of morphospace occupation among living ferns will be clarified by the addition of more taxa to our dataset.

Morphological response of benthic foraminifera to the Early Eocene Climatic Optimum

Bridget Warren[1], Daniela Schmidt[2], Vittoria Lauretano[2], Lucas Lourens[3]

[1]University of Birmingham
[2]University of Bristol
[3]University of Utrecht

To understand possible biotic responses to climate change, efforts to date have focussed on laboratory studies. These studies are limited in the complexity and duration in which they can expose species to climate change. Using the geologic record to investigate responses to past climate change events provides evidence on long-term biotic responses in the real world. This study investigates the response of the benthic foraminifera *Oridorsalis umbonatus* and *Nuttallides truempyi* to climate change in the geologic record during the hottest the interval of the Cenozoic, the Early Eocene Climatic Optimum (EECO; 49-54 Ma) at ODP Site 1263, in the south-eastern Atlantic. The time interval not only experienced long-term high ocean temperatures, but these are superimposed by rapid perturbations termed “hyperthermal” events. Specimens were imaged via Computer Tomography and reconstructed in the 3D imaging software AVIZO. We determined changes in morphology representing responses in physiology and reproductive mode such as size, number of chambers and size of the first chambers. Both species showed similar responses, suggesting different microhabitats are affected equally by climate change events. Morphological evidence of stress was correlated to high temperatures and was associated with a shift from asexual to sexual reproduction. We can use these responses to suggest potential mechanisms by which ocean species may adapt to the challenges of modern climate change.

To the bitter end: do planktonic foraminifera actively change their niche habit in response to external drivers prior to extinction?

Adam Woodhouse[1], Sophie Jackson[1], Alexander Dunhill[1], Paul Wignall[1], Tracy Aze[1]

[1]University of Leeds

Extinction rates are currently at their highest for 66 million years and are rising at an unprecedented rate. Oceanic ecosystems are particularly vulnerable to rapid environmental change, compounded by our lack of knowledge regarding the evolutionary history of many marine groups. The completeness of the macroperforate planktonic foraminiferal (PF) fossil record permits a unique opportunity for assessing the ecological and biological effects associated with extinction risk in ancient oceanic basins through single-specimen analysis on large quantities of individuals at high-resolution. By employing a multidisciplinary approach to PF shell geochemistry ($\delta^{18}O$ and $\delta^{13}C$, Mg/Ca), morphometry, and biogeographical modelling, the planktonic foraminiferal fossil record may be selectively analysed for variations in ecology as potential looming-extinction indicators.

This study focusses on the PF species *Dentoglobigerina altispira*, which exhibits an extinction horizon at 3.032 Ma within equatorial regions. Sediment cores from International Ocean Discovery Program Expedition 321 provided extremely good age-control, allowing for sampling at a 3 kyr resolution during the final phases of the *D. altispira* lineage. We present core data representing an interval from 3-3.5 Ma, covering not only the extinction horizon of *D. altispira*, but also the entirety of the mid-Pliocene warm period (mPWP). This interval represents a period in time in which global temperatures were analogous to those expected by 2100 through anthropogenically-induced climate forcing. The extinction indicators exhibited by *D. altispira* may therefore shed potential light on marine extinction patterns in future warmer worlds.

Poster Presentations

A new ostracoderm locality from the early Devonian (Lochkovian) of Shropshire provides insight into the biodiversity, geochemistry and palaeoecology of early jawless vertebrates.

Jake Atterby[1], Joseph Keating[1], Emma Randle[2], Peter Tarrant[3], Roy Wogelius[1], Victoria Edgerton[1], Phillip Manning[1], Robert Sansom[1]

[1]University of Manchester
[2]Imperial College London
[3]Independent

Ostracoderms are an extinct, paraphyletic assemblage of armoured, jawless vertebrates that dominated aquatic environments in the early Palaeozoic. Osteostracans and heterostracans are among the most diverse clades and are highly significant in the history of vertebrate evolution; they shed light on the acquisition of jawed vertebrate characters on the stem-gnathostome lineage. Though their anatomy and evolution has been well described for over 150 years, there is still limited understanding surrounding their growth, ecology and associated bio-geochemistry.
Here we describe material from a new site in the Devonian of Shropshire and identify a diverse fauna consisting of osteostracan taxa (*Pattenaspis whitei*) and juvenile pteraspid heterostracan taxa (*Pteraspis rostrata, Mitraspis cracens* and *gen. et sp. nov.*). The new collection also provided the opportunity to apply geochemical analyses to elucidate the composition and growth of the ostracoderm dermoskeleton. For the first time, preserved dermal armour was surveyed under non-destructive synchrotron rapid scanning X-ray fluorescence (SRS-XRF) and we discuss the possible biological and taphonomic factors responsible for the distribution of trace elements that have never before been recorded in these organisms (e.g. Cr, Ni, Mn and Zn). Furthermore, we examine their association with lines of arrested growth in the heterostracan dermoskeleton and their potential implications for growth and ecology.

Biotic response to a breathless ocean

Kk Aye[1]

[1]University of Bristol

CO_2 concentrations have risen from 280ppm to 408ppm since the industrial revolution. Ocean warming increases thermal stratification in the upper ocean, reducing the export of oxygen to the deep ocean. This has resulted in a 2% loss in oxygen in the deep oceans over the last century, with a further 2-4% decrease projected at bathyal depths in the Arabian Sea and South Atlantic by 2100. Deoxygenation produces considerable threats to benthic foraminifera as oxygen is utilised for respiration and nutrient remineralisation; there is limited understanding of species-specific response to low oxygen in the deep ocean. This research aims to assess the impact of different oxygen gradients on the growth, calcification, and reproduction of two dominant species of benthic foraminifera, *Nutallides umbonifer* and *Oridorsalis umbonatus* in the Arabian Sea and the South Atlantic Polar region. Both past and modern specimens of *Nutallides umbonifer* and *Oridorsalis umbonatus* were picked from numerous sites of the South Atlantic and the Arabian Sea, and CT scanned so 3D morphological reconstructions can determine their test diameter, proloculus size, and calcite volume. Species facilitating thin calcite tests and sizes below 250µm will show increased oxygen uptake, but extreme dwarfing reduces the reproductive maturity of both species. Overall a reduced test diameter, proloculus size and calcite volume of both species are expected at sites of the Arabian Sea and the South Atlantic Polar Region. Establishing the morphological response of benthic foraminifera under modern and past oxygen environments can allow predictions of future impacts deoxygenation poses to benthic ecosystems.

Brain morphology and intraspecific variation in the Triassic cynodont *Thrinaxodon liorhinus*

Charlotte Bird[1], Stephan Lautenschlager[1], Emily Rayfield[2]

[1]University of Birmingham
[2]University of Bristol

Modern studies within palaeoneurology rely upon non-destructive techniques to augment knowledge of the structures that resided within fossil skulls. Such research in mammals provides valuable information on mammalian brain development through the transition from non-mammalian cynodonts to Mammalia, and the impact that improvements in sensory capabilities had upon the size and shape of various brain regions. However, palaeoneurological studies are commonly limited to single specimens, making it difficult to decipher the effects of ontogeny, sexual dimorphism and intraspecific variation. Here, three specimens of the basal cynodont *Thrinaxodon liorhinus* were CT-scanned and digital cranial endocasts were reconstructed, permitting the first description of brain and inner ear anatomy for this species. Quantitative analyses (including calculation of encephalisation quotients and hearing capabilities) shed light upon the sensory capabilities and possibilities for intraspecific and ontogenetic variation within *Thrinaxodon*. The reconstructed brains display millimetre-scale size variations in the olfactory bulbs, cerebral hemispheres, cerebellum and cerebral paraflocculi, whilst shape changes are confined to the forebrain. Intraspecific variation (between individuals of a similar age) thus occurs in the size rather than shape of the reconstructed brain and inner ear anatomy. Results further demonstrate that the sense of olfaction was most profound in *Thrinaxodon*, with inferior auditory and visual acuity when compared to extant equivalents (for example, *Monodelphis domestica*). This is consistent with other nocturnal, burrowing organisms, where a keen sense of olfaction enables efficient tracking of prey and highlights the scope for fossils to augment understanding of the development of sensory capabilities through the mammalian lineage.

A comprehensive review of tetrapod footprints from the late Carboniferous and early Permian of Great Britain

Hannah Bird[1], Richard Butler[1]

[1]University of Birmingham

During the Carboniferous, Britain was part of a large landmass including North America and Europe, enabling terrestrial tetrapods (amphibians and reptiles) to achieve widespread distribution. Development of the Variscan Orogeny produced a rain shadow, leading to aridity and the deposition of classic 'red beds' sequences within which tetrapod footprints are preserved. This environmental change has been linked to faunal turnover from amphibian to reptile dominated systems, as the former were more closely linked ecologically to declining water sources. Ichnology (the study of trace fossils, including footprints) supplements the relatively limited tetrapod body fossil record of Britain by providing *in situ* insights into organisms present and their abundances at a particular point in time, in a given environment. Here we present the first comprehensive review of tetrapod footprints housed within British museums from the late Carboniferous and early Permian of Britain, revealing a cosmopolitan ichnofauna comparable to other global tetrapod localities. Quantitative studies of footprint specimens to determine tetrapod locomotion (body length and trackmaker speed) and photogrammetry techniques to produce 3D models were used to enhance ichnotaxonomic and trackmaker identifications. The hypothesis that amphibians declined whilst reptiles radiated during this interval is not well-represented within the British ichnofauna. Primarily, the relative scarcity of footprint material limits insights into evolutionary transitions, as does West Midlands bias regarding preservational localities. Future exploration of suitable locations is paramount to enhancing this database of footprint material, to elucidate patterns of faunal turnover and supplement the poor body fossil record.

The taxonomy and phylogeny of the Wealden iguanodontian dinosaurs

Joseph Bonsor[1,2], Matthew Wills[1], Paul Barrett[2], Susannah Maidment[2]

[1]University of Bath
[2]The Natural History Museum

Iguanodon (iguana-tooth) originally described by Gideon Mantell in 1825 was the second non-avian dinosaur to be identified. The main deposits containing iguanodontian remains are found in the Lower Cretaceous Wealden group of Southern England and in Bernissart, Belgium (in a now abandoned and filled mine). Many other iguanodontian fossils have been found around the world including China, Russia, Australia and North America. An accurate phylogeny of Iguanodontia has been difficult to decipher due to many of the original holotypes not being suitable specimens for the Linnaean naming system, e.g. isolated teeth, and some type specimens not being assigned in their original descriptions first published by Mantell and others. Subsequently, "*Iguanodon*" became something of a dustbin taxon during the 19th century with many newly named species being assigned to it. In the 20th century and more recently these taxa were frequently re-described and renamed, creating a lot of confusing synonyms and apparent nomina dubia. Work has begun to re-examine the group and to try and make sense of the inter-relationships of these iconic dinosaurs. This project aims to continue this work by extensively re-appraising material originally assigned to *Iguanodon*, producing an up to date phylogeny of the group and studying its macroevolutionary patterns through time.

External anatomy of the extinct Megalodon

Jack Cooper[1], Michael Benton[1], Catalina Pimiento[2]

[1]University of Bristol
[2]Swansea University

The enormous body size of the extinct *Otodus megalodon*, the largest shark ever to exist (~18 m), has long captivated palaeontologists and the public. With few fossils other than teeth and vertebral centra, this giant shark's ecology and anatomy have been inferred from comparison with the modern great white shark (*Carcharodon carcharias*). These comparisons, mostly based on dental similarities, have led to suggestions that the Megalodon resembled a stockier, more robust great white shark. However, different lines of evidence have suggested that the great white did not directly evolve from Megalodon. This suggests that while these two species likely shared ecological functions, they may have been anatomically different. Here, we collect from online sources a series of anatomical measurements and morphometric proportions from five species of extant sharks ecologically and phylogenetically similar to Megalodon. Analyses of variance show no significant differences between these species in the linear relationships between anatomical measurements and total length. We further found similar regressions between these species for all measurements. We therefore use all five species as analogues to estimate Megalodon external anatomy. Preliminary results show that an 18 m Megalodon could have a head of ~6 m in length and a dorsal fin ~2.16 m in height and ~1.87 m in width. These and more anatomical extrapolations will be used to create a 2D model of an 18 m Megalodon, allowing us to provide the first description of the giant shark's external anatomy.

Investigating the gait capabilities of a Lower Cretaceous ornithopod dinosaur (*Tenontosaurus tilletti*) via a multi-body dynamic approach

Matthew Dempsey[1], William Sellers[1]

[1]The University of Manchester

Tenontosaurus tilletti is an ornithischian dinosaur of the clade Ornithopoda, one of several dinosaurian clades to experience a secondary reversion to quadrupedality. *Tenontosaurus* displays a number of skeletal characters generally associated with robust quadrupedality in derived ornithischians, but lacks others. Most notably, it possesses an antero-lateral process upon the ulna and a femur longer than or equal in length to the tibia, but lacks a reduced fourth trochanter and a transversely broad ilium. An improved understanding of the biomechanics of *Tenontosaurus* and dinosaurs with analogous anatomy may allow the characters associated with the early onset of quadrupedality in ornithopods and other ornithischians to be constrained. An investigation into the gait capabilities of *Tenontosaurus* via a multi-body dynamic approach is presented here. Volumetric modelling and a simplified 3D armature were used to determine the joint ranges of motion, the body segment mass properties and the appendicular muscle properties of a scanned subadult specimen (LL.12275). Simulations carried out in the GaitSym software package suggest that *Tenontosaurus* was at least capable of exhibiting stable symmetrical quadrupedal gait patterns.

The systematic differences of primate bone remodelling and moving from destructive to non destructive CT methods of studying bone microstructure.

Amun Dubro[1], Russell Garwood[1], Andrew Chamberlain[1]

[1]University of Manchester

Secondary osteons result from bone remodelling. They develop when osteoclasts resorb bone and osteoblasts deposit concentric cylindrical support structures around Haversian canals (tube networks containing blood vessels). Secondary osteons accumulate after skeletal maturity, and their growth is linked to life history parameters. Secondary osteons within humans have been studied extensively for over 300 years, but studies within other animals groups are limited. The largest of these studies shows a correlation exists between body mass and osteon area, and suggested that primates have larger osteons relative to body size than other mammals.
The aims of this study are to examine a representative sample of species across the primate order to corroborate differences between primates and other mammals, as well as to demonstrate the suitability of tomography for measuring osteon properties. Our results show (1) that non-destructive tomographic approaches can be used to measure osteon size, (2) CT and published microscopic measurements are comparable, and (3) primates tend to have larger osteons relative to body size than other mammals. The results of this study further our knowledge of mammalian bone microstructure, and show how systematic differences between mammal groups can be linked to variation in life histories. The reason for the distinctive microstructural properties of primates could be due to their prolonged growth rates or relatively long lifespans. Non-destructive CT techniques will allow future studies of microstructure to avoid destructive sampling.

Indirect evidence of predation by squid in the fossil record

Sarah Gale[1]

[1]*University of Portsmouth*

Soft-bodied cephalopods don't preserve often in the fossil record, but the Jurassic Kimmeridge Clay Formation of Dorset has yielded a number of three-dimensionally preserved coleoid squids. Their ecology, their prey and their mode of feeding remains unclear.
The unusual preservation of small teleost fish within the same formation may shed some light on the feeding behaviour of Jurassic squids.

Modern day squid hunt using a wide variety of methods but lack the ability to swallow prey whole due to their small mouths and narrow oesophagus. Nevertheless, many squid are recorded actively hunting prey larger than themselves.

During a study of the preservation and taphonomy of a large number of fishes (n = >150) from the Etches Collection, 17 examples comprised a fully articulated skull, but lacked the body. Several specimens comprised isolated, but fully articulated caudal skeletons. These isolated components compare remarkably well with the remnants of feeding by teuthoids in modern seas where squids carefully excise the skull and caudal skeleton prior to ingesting the body.

The anatomical and molecular preservation of exceptional Cambrian and Ediacaran microfossils

Thomas Gray[1]**, Tom Harvey**[1]**, Arnoud Boom**[1]

[1]*University of Leicester*

Small Carbonaceous Fossil (SCFs) are a type of organic walled microfossil commonly occuring in the Cambrian and Ediacaran. They occur in a wide range of depositional environments and reveal greater insight ino faunal assemblages. Here we investigate the geochemistry of two SCF groups: trilobites from the Forteau Formation, Canada (Cambrian) and organic mat material from the Ediacaran. Pyrolysis gas chromatography (GC/MS) on the Ediacaran material revealed that the fossils are composed of aliphatic (alkanes & alkenes) compounds, including C16 and C18 fatty acids, and aromatic compounds. The matrix surrounding these fossils preserves biomarkers including phytane, pristane and hopanes. Fourier Transform Infrared (FTIR) spectroscopy confirms the dominance of aliphatic and aromatic compounds within the fossils and was able to map their distribution spatially. The localisation of different bond types across the mat provides evidence for biomolecular and possibly taxonomic hetergeneity in the mat structure. Trilobites were analysed by BSEM element mapping, both before and after treatment with hydrofluoric acid. Matrix-hosted, pre-treatment trilobites showed concentrations of both carbon and calcium, whereas acid-isolated cuticle fragments were wholly carbonaceous, demonstrating a combined calcite/ organic composition in life. Pyrolysis GC/MS of the isolated trilobite cuticle revealed a composition dominated by aliphatic and aromatic compounds, though with different alkane/ alkene ratios to the Ediacaran mats. Overall the chemical signals preserved in both SCF groups are highly degraded, but with the potential for taxonomic discrimination, if the disparate preserved signals can be reliably linked to the original biomolecular composition.

Ontogenetic brain development in birds and crocodilians with applications to non-avian dinosaurs

Krishna Hu[1], Logan King[1], Michael Benton[1], Emily Rayfield[1]

[1]University of Bristol

Paleoneurology and ontogenetic studies—particularly when dinosaurs are involved—are becoming an increasingly big topic of interest with advancements in 3D modeling techniques and CT scanning. However, they are beginning to outpace our current understanding of the modern taxa most closely related to them: a crucial aspect to analyzing life history of their extinct relatives. To create a baseline case for future archosaur-related studies in this field, we aimed to determine not only the differences in endocast shape and size between extant members—avians and crocodilians—but also how they change through ontogenetic sequence. Here we present the endocast reconstructions of ostriches and alligators: common outgroups for discussing morphological changes in dinosaurs, and each in 5 different life stages. To measure endocranial change, we used 3D programming to generate the endocast models, and will utilize R to measure flexure angles and shape change along the x- and y- plane. Preliminary results show that there was little difference in the general brain shape and flexure angles of the ostrich specimens throughout ontogenetic sequence. We will measure the same components in alligators and compare/contrast the morphological changes, as well as at what life stage each taxa experiences the most endocranial change. We expect our final results to show a greater range in shape change within alligators vs. ostriches. The understanding of changes in the endocast of modern archosaurs will shed light to the patterns of brain growth in dinosaurs.

A new notosuchian crocodylomorph from the Cenomanian Kem Kem beds of southeastern Morocco

Eloise Hunt[1], Cecily Nicholl[2], Philip Mannion[2]

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

Notosuchians were an extinct clade of terrestrial crocodylomorphs that were abundant and diverse during the middle to Late Cretaceous of Gondwana. Unusually for crocodylomorphs, notosuchians exhibit considerable morphological and ecological diversity. Most of this diversity is found in South America, where over 70% of known notosuchian taxa have been discovered. However, the Cretaceous crocodylomorph record of Africa is still poorly sampled, hampering our understanding of large scale biogeographic patterns, especially pertaining to Gondwanan fragmentation, vicariance, and dispersal. Here, we describe two new notosuchian specimens, NHMUK PV R36829 and NHMUK PV R36874, from the early Late Cretaceous (~100–94 Ma) Kem Kem beds of Morocco. NHMUK PV R36829 is generally well preserved and comprises the whole dentary, left splenial and left angular. NHMUK PV R36874 consists of only the partial right dentary ramus and anterior surangular ramus. The possession of heterodont teeth with procumbent incisiviforms on the anterior region of the mandible, and broader molar teeth at the posterior end of the mandible, supports the position of both specimens within Notosuchia. Detailed comparisons and phylogenetic analysis, based on a data matrix comprising 110 taxa scored for 412 characters, indicates that these specimens represent a distinct notosuchian taxon. This new taxon demonstrates a greater diversity in the mid-Cretaceous of Africa than previously realised, adding an important new data point to our understanding of Mesozoic crocodylomorph evolution and Gondwanan palaeobiogeography.

The small theropods of the Early Cretaceous Kem Kem beds of Morocco, North Africa

Megan Jacobs[1], David Martill[1], Nizar Ibrahim[2]

[1]University of Portsmouth
[2]University of Detroit

The Kem Kem beds of Early Cretaceous age, South East Morocco, are renowned for yielding in abundance, very large vertebrates, leading to the nickname 'River of Giants'. Previous work has focused on the palaeoecology, palaeoenvironment and taxonomy of the larger vertebrates found mainly by local fossil collectors. Much work has centred on the very large theropod dinosaurs, especially the sail-backed *Spinosaurus*. The smaller vertebrates, represented mostly by teeth, have been largely overlooked, resulting in an unbalanced view of the ecosystem.
This study focuses on samples of teeth of 10 mm or less in overall size, sieved from mine spoil by the fossil diggers. The teeth were identified using standard comparative anatomical and morphometric methods and using the macro fauna for comparison.
A part of the analysis utilised dental serrations and shape morphometrics to assess theropod diversity. Juveniles of each known taxa were recorded, but examples not fitting any so far described morphology are also present in the sample. The preliminary results suggest that the dinosaurs were most likely nesting and raising their young in close proximity to the river and that the dominance of large carnivores is likely an artefact of sampling by commercial collectors.

A description of the Late Jurassic (Kimmeridgian) marine reptile fauna of Helmsdale, Scotland, and new Middle Jurassic crocodylomorph and ornithischian specimens from the Isle of Skye

Kim Kean[1]

[1]University of Edinburgh

Scotland is a largely untapped source for exciting and important research in Jurassic reptile fauna. The Isle of Skye on the West Coast has already revealed evidence of Middle Jurassic dinosaurs and crocodiles, whilst the Late Jurassic (Kimmeridgian; 157-152 Ma) marine reptiles of Helmsdale on the East Coast have not been formally studied. My objective is to identify and describe two new specimens from Skye collected by researchers at the University of Edinburgh, as well as the marine reptile specimens from the Helmsdale and Kintradwell Boulder Beds currently being held at museums across the UK. The marine reptile specimens from Helmsdale include material from plesiosaurs, pliosaurs and ichthyosaurs, however no crocodylomorph material has been discovered yet. One of the specimens from Skye is an ornithischian vertebra, whilst the second specimen is a small boulder containing vertebrae and osteoderms from a crocodylomorph. A number of Helmsdale specimens held at the National Museum of Scotland, and the Skye crocodylomorph have been CT scanned and segmented using Mimics 18.0. This study will provide details currently unknown to the scientific community of the marine reptile fauna from the Kimmeridgian in Scotland. It will also contribute to the growing knowledge of the Middle Jurassic fauna on Skye.

A new look at animal phylogeny: Can total-evidence methods solve the comb jelly mystery?

Fionn Keeley[1], Davide Pisani[1]

[1]University of Bristol

Our understanding of early animal evolution is largely informed by the phylogenetic placement of the earliest diverging animal lineages. However, the placement of these groups has recently been the subject of much debate, with authors variously pointing to either the sponges or the comb jellies as the earliest-diverging lineage. Recently, a number of Cambrian “weird wonders”, potentially representing the earliest members of these lineages, have been put forward as possible solutions to this problem. Our study therefore aims to use a combined molecular and morphological dataset to investigate the placements of these fossil taxa along with existing species. Through a total evidence analysis, we expect to find a new metazoan tree supported by multiple lines of data, and build a stronger understanding of the origins of animal groups.

Climatic constraints on the distribution of terrestrial Neogene eutherian mammal diversity

Miranta Kouvari[1,2], Philip D. Mannion[1], Anjali Goswami[2]

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

The Earth is currently experiencing rapid climatic change that affects biodiversity worldwide. One of the most fundamental macroecological patterns that describes today’s diversity distribution is the latitudinal biodiversity gradient (LBG), in which diversity increases towards the tropics. This pattern is thought to have first appeared during the Paleogene–Neogene transition, but its formation and causes remain unclear. In order to predict future biodiversity loss, it is critical to understand its drivers and how past diversity reacted to climatic changes. This study focuses on spatiotemporal diversity patterns in Neogene terrestrial eutherian mammals, as well as the drivers that shape them. We will test whether the timing of diversity fluctuations where globally synchronous, whether the modern day LBG was a consistent pattern during the Neogene, and whether climate was a primary factor shaping these diversity patterns. For this, we are compiling data into the Paleobiology Database (PBDB), before reconstructing palaeodiversity curves that take into account fossil bias using subsampling methods and a Bayesian approach. We will then test the effect of different paleoclimatic proxies on diversity with regressions. Additionally, ecological niche modelling will be used to study habitat suitability of key eutherian groups through time and space. A preliminary study focuses on South America: sample-standardised Cenozoic palaeodiversity curves show different diversity patterns compared to raw diversity curves. This underlines the importance of considering fossil bias in analyses. However, while the Paleogene record in the PBDB is essentially complete, the Neogene still remains fragmentary.

Biomechanical assessment of locomotor modes in large and small sthenurine kangaroos

Callum Kunz[1], Emily Rayfield[1], Christine Janis[1], Amber Wagstaffe[1]

[1]University of Bristol

The primary mode of locomotion in kangaroos (Macropodinae) is bipedal hopping. This enables rapid movement, and in large macropodines is energetically efficient at high speeds, yet it has been calculated to exceed tendon safety factors in animals above 140 kg. Giant sthenurine kangaroos, such as the 150 kg *Sthenurus stirlingi*, were significantly larger than this limit. Previous work has demonstrated that the dorsoplantar and mediolateral resistances of *S. stirlingi* were considerably higher than those of *Macropus giganteus*, suggesting an alternative mode of locomotion. I have investigated the dorsoplantar and mediolateral resistances in the metatarsals of *Procoptodon browneorum*, a sthenurine kangaroo the same size as *M. giganteus*, using second moment of area analysis in the programme BoneJ. This has shown that *P. browneorum* had resistances higher than that *of M. giganteus* but also significantly lower than those of *S. stirlingi*, thus suggesting that the high resistances of *S. stirlingi* were the result of its larger size. It is difficult to determine the mode of locomotion of *P. browneorum*, but it may have been capable of similar modes to those employed by macropodines. While it is possible the giant sthenurines used a different means of locomotion, this may not be the case for all sthenurines. The results of this second moment of area analysis show that biomechanical characteristics may relate more to scaling properties rather than phylogenetic lineages. This contributes to the understanding of locomotion in giant sthenurines, shedding further light on a highly debated topic concerning this subfamily of extinct kangaroos.

Jaw morphological and biomechanical disparity of archosaurs during Middle Triassic to Middle Jurassic

Pei-Chen Kuo[1], Stephen Brusatte[1]

[1]University of Edinburgh

Mass extinctions not only dramatically change the faunas but also play an important role in evolution. In the Triassic, archosaurs evolved into two large clades: avemetatarsalians (the dinosaur-bird lineage) and pseudosuchians (the crocodile lineage). In the Late Triassic, pseudosuchians were more disparate, diverse, and abundant than dinosaurs, but this situation changed after Triassic-Jurassic mass extinction. There are two main general hypotheses for explaining early dinosaur diversification: the competitive hypothesis and opportunistic hypothesis. Here, to help test between these hypotheses, we examine jaw changes in Middle Triassic-Middle Jurassic archosaurs by geometric morphometrics and biomechanical analysis. We find that (1) Dinosaurs occupied a different area in morphospace and biomechanical morphospace than pseudosuchians. (2) It is not until the Early Jurassic (Pliensbachian-Toarcian) that dinosaurs occupied different morphospace than pseudosuchians. However, in biomechanical morphospace, dinosaurs were in a different area than pseudosuchians during Late Triassic (late Norian-Rhaetian) to Middle Jurassic, but only not in the Early Jurassic (Pliensbachian-Toarcian). (3) In morphological disparity, there were three main turnovers between dinosaurs and pseudosuchians during Late Triassic (late Norian-Rhaetian) to Middle Jurassic. The first was caused by the decrease of pseudosuchians and the other two were due to changes in dinosaurs. (4) In biomechanical disparity, however, there was only one turnover from the Early Jurassic (Pliensbachian-Toarcian) to Middle Jurassic, due to an increase in dinosaurs. In summary, our results are more consistent with the opportunistic hypothesis, and show that morphological disparity is decoupled from biomechanical among archosaurs.

The origins of the eumetazoan body axes: what can we learn from *Dickinsonia*?

Arsham Nejad Kourki[1], Jakob Vinther[1], Philip C. J. Donoghue[1]

[1]University of Bristol

The evolution of eumetazoan body axes is a long-standing problem that has attracted people working in fields as diverse as palaeontology, comparative morphology, and developmental genetics. A consensus has recently emerged that the last common eumetazoan ancestor was bilaterally symmetric, as opposed to radially symmetric. Moreover, it has recently been shown that Trichoplax, representing the phylum Placozoa, likely possesses one of the two axes; and they either ancestrally lack or have secondarily lost a gastric cavity. Given these and the phylogenetic position of Placozoa as sister to Eumetazoa, two questions arise: (1) whether one of the axes evolved as a result of the evolution of the gastric cavity, or independently of it; and (2) which axis evolved first. Here, we bring attention to *Dickinsonia*, an iconic Ediacaran organism recently shown to be of metazoan origins. We show that *Dickinsonia* is most likely a stem-eumetazoan, which strongly suggests that both axes were present before the gastric cavity (the first question); and paves the way for answering the second question—we show that this requires an animal phylogeny incorporating other putative Ediacaran metazoans.

The problematic spinosaurs of North Africa: New specimens with notes on ontogeny and behaviour

Rebecca Lakin[1]

[1]University of Bath

Spinosaurs are a diverse and widespread taxon of dinosaurs that are found on every continent except Antarctica and North America, and lived from the Upper Jurassic to the Middle Cretaceous. As a member of the ecologically diverse theropod suborder, spinosaurs were unique in occupying a piscivorous niche within riverine habitats. The largest species, *Spinosaurus*, is known from the Kem Kem beds of Morocco, along with another massive spinosaur, *Sigilmassasaurus*. Spinosaur phylogeny in the Kem Kem is fraught – both holotypes are highly problematic and there is currently much debate surrounding the morphology, phylogeny and life histories of these species. In addition, good-quality juvenile material from these species is almost unknown, and nothing is known about the ontogeny of Kem Kem spinosaurs.

We report the first collection of juvenile spinosaur material from the Kem Kem beds of Morocco, representing both spinosaur species known from the region – *Spinosaurus* and *Sigilamssasaurus*. We also explore the difficulties of studying whole organism remains from the Kem Kem, and suggest avenues for future work.

‘The evolution of body shape, locomotion and ecology in terrestrial vertebrates’

Alice Maher[1], Dr Susannah Maidment[2] , Dr Phillip Cox[3], Dr Tom Maddox[1], Dr Karl Bates[1]

[1]University of Liverpool
2Natural history museum, London
3University of York

Body shape has a fundamental impact on organismal function. Most studies on body shape in vertebrates are focused on research into squamates (mostly fossorial species) and aquatic or semi-aquatic vertebrates, but it is largely unknown (in a quantitative way) how body shape has evolved more widely in concert with changes in behavior, locomotor style and ecological niche. Here we combine three-dimensional computer models of vertebrate skeletons with phylogenetic reconstructions to quantify the evolution of body segments and whole body shape across terrestrial vertebrates. Measures of whole-body shape include a range of linear measurements, including limb bones lengths (used to calculate whole limb lengths) and gleno-acetabular distance, along with skeletal volumes (generated by automated convex hulling) for major body segments. This data is then used to generate a range of measures to describe various aspects of body shape, such as relative body length, relative limb length and proportion of total skeletal volume made up by individual body segments. We derived this data from 3D skeletal models spanning 410 taxa across all major extinct and extant terrestrial vertebrate groups. In order to test for correlations between body shape and locomotion, behavior and ecology we assigned each taxa to a range of morpho-functional groups. To consider phylogeny in our analysis we constructed a phylogenetic tree of our sample taxa by merging the most recent consensus trees in the published literature. Statistical analysis of this data set so far reveals strong correlations between multiple body shape metrics and both locomotor style and ecological niche.

The evolution and biogeographic history of notosuchian crocodylomorphs

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)

Notosuchians comprise a clade of largely terrestrial crocodylomorphs that were most diverse in the middle–Late Cretaceous (~120–66 Ma) of Gondwana (South America, Africa, Indo-Madagascar). Members of this group are often noted for their “bizarre” morphologies and modes of life; they range from large hypercarnivorous predators to omnivorous/herbivorous species, with heterodont dental morphology convergent with that of mammals and squamates. Moreover, unlike other crocodylomorph groups, notosuchians predominantly lived in hot and arid environments. Since the group’s initial discovery, phylogenetic relationships within the clade have been disputed, especially concerning the taxa that survived the Cretaceous/Palaeogene (K/Pg) mass extinction (66 Ma). Furthermore, these previous analyses often exclude several biogeographically-interesting, though fragmentary, Eurasian remains. Many of these issues can be resolved through improved taxon and character sampling by construction of a revised morphological character dataset based on first-hand study of specimens. Current focus is placed on developing and illustrating novel character data, including via CT-scanning, especially for neglected regions of the notosuchian skeleton, such as the braincase and postcrania. Phylogenetic analyses will be implemented within both Parsimony and Bayesian frameworks, and the resultant trees will be used to analyse macroevolutionary patterns in notosuchians. The biogeographic history of the group will be investigated using BioGeoBEARS, and will incorporate possible geographic and climatic barriers to dispersal. Correlates of survival versus extinction in species will also be tested, to elucidate why only one notosuchian clade crossed the K/Pg boundary.

Oceanic Anoxic Event conundrums: reconciling palaeontology and geochemistry

Connor O'Keeffe[1], Crispin Little[1], Christian März[1], Simon Poulton[1], Fiona Gill[1]
[1]University of Leeds

The early Jurassic Toarcian Oceanic Anoxic Event (T-OAE), was a period of intense carbon cycle perturbation, which is associated with a mass extinction of marine organisms ca. 183 Ma. Temperature rises during the event are comparable to those predicted for the end of the 21st century. The response of the benthic community to oxygen depletion in the Cleveland Basin, Yorkshire, during the T-OAE is well documented: Profound changes in community diversity occurred, with the macrofossil assemblage becoming dominated by opportunistic paper pectens. The presence of vast numbers of these fauna in specific strata, however, appears incompatible with geochemical evidence of persistent anoxia/euxinia through the interval. In this ongoing study, I aim to obtain high resolution palaeoecological and geochemical proxy records of redox state through these cm scale intervals. I expect that iron redox and trace metal proxies will better constrain changes in oxygen levels coeval with short-lived benthic colonisation events. I will also carry out organic geochemical and biomarker studies, to assist in tying colonisation events to basin-scale processes. I anticipate that this project will aid in understanding what event beds of benthos mean, in a basinal context, and the response of benthic communities to the development of low-oxygen conditions. The recent rise in the occurrence of hypoxia in modern shelf environments warrants an understanding of how anthropogenic forcing contributes to marine community restructuring. Understanding the response of marine communities to periods of oxygen restriction in the past, will better prepare us for the consequences of hypoxia in the present.

Reappraisal of the anatomy and phylogenetic relationships of *Diplocynodon hantoniensis*, a basal alligatoroid from the Late Eocene of the United Kingdom

Jonathan Rio[1], Philip Mannion[2], Emanuel Tschopp[3], Jeremy Martin[4], Massimo Delfino[5]

[1]Department of Earth Science and Engineering, Imperial College London
[2]Department of Earth Sciences, University College London
[3]Division of Paleontology, American Museum of Natural History
[4]Université Lyon
[5]Institut Català de Paleontologia Miquel Crusafont, Universitat Autònoma de Barcelona

Diplocynodon is a genus of basal alligatoroid crocodylian that was ubiquitous in European freshwater ecosystems during the Cenozoic. Nine species, spanning the late Paleocene to middle Miocene are considered valid. Despite recent revisions of most *Diplocynodon* species, one of the earliest named and most complete, *Diplocynodon hantoniensis*, has not been re-described for over 150 years. This species is known from the remains of numerous individuals from the Priabonian (late Eocene) Headon Hill Formation, which crops out in southern England, UK. Here we re-describe and diagnose *Diplocynodon hantoniensis*, and for the first time present a detailed description of its axial and appendicular skeleton. *Diplocynodon hantoniensis* is diagnosed by three local autapomorphies: retention of ectopterygoid-pterygoid flexure throughout ontogeny, prominent laminae lateral to the choanae, and low preorbital ridges on the lacrimals. We incorporate *Diplocynodon hantoniensis* into a phylogenetic analysis including all putative *Diplocynodon* species (103 taxa scored for 187 characters). Analyses were repeated under four character weighting schemes: equal weights, implied weighting (k value of 8) and extending implied weighting (k=4 and k=8). We recover a monophyletic *Diplocynodon* in three of the four analyses. However, the analysis with the strongest downweighting of homoplastic characters recovers the Paleocene *Diplocynodon remensis* outside *Diplocynodon*. We provide one of the most comprehensive descriptions of a basal alligatoroid, facilitating comparisons within *Diplocynodon* and other basal alligatoroids. Furthermore, our extensive postcranial description, frequently neglected in studies of crocodylomorph anatomy, provides a rich source of new character data, and a basis for comparing postcranial anatomy in other fossil crocodylians.

Determining the defensive capabilities of early jawlless fish exoskeletons against eurypterid predation

Caitlin Sclater[1], Emily J. Rayfield [1], Philip C. J. Donoghue[1]

[1]University of Bristol

Understanding of the evolution of the mineralised skeleton has been at the forefront of palaeontological endeavours since the 1900's, when a morphologically diverse group of early vertebrate armoured fish, the ostracoderms, were discovered. Palaeontological pursuits of this topic have centralised around the identification and characterisation of these ancient dermal structures, an endeavour aided significantly by the development of more sophisticated and powerful imaging and computer-aided techniques. It is imperative that our questions evolve with our methods, and as such, a greater understanding of the "how" merely opens the doorway for a pursuit of the "why". We present the first quantitative study into the defensive capabilities of these early structures against simulated loads representative of their perceived dominant predator, the eurypterids. Finite element models based on two groups, *Anglaspis*, representing a simple, homologous cancellous structure, and *Psammosteus*, representing an anastomising, heterogenous cancellous structure, have been created to represent the scope of complexity within this diverse group. With a focus on the changing complexity of cancellous elements, it has been possible to record the stress, strain and deformation experience by these structures, from which inferences as to their survival potential has been made. It is hoped that this research serves as a gateway for further research, not just on the defensive potential of early skeletal elements, but in the quantitative analysis of other hypotheses proposed in the literature to explain the sudden, and crucial appearance of this novel vertebrate structure.

The completeness of the early shark fossil record

Lisa Schnetz[1], Richard Butler[1], Ivan Sansom[1]

[1]University of Birmingham

Chondrichthyans are central to our understanding of vertebrate evolution. They have maintained their status as apex-predators in the oceans for over 400 million years and still play a crucial role in modern-day aquatic ecosystems. Their early 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 teeth and scales. Recent phylogenetic consideration of acanthodians (a wide-ranging Palaeozoic group of early fishes) as part of the chondrichthyan stem-group has partially filled this gap. However, considerable uncertainties remain in how the completeness of chondrichthyan fossils impact on the phylogenetic narrative of vertebrates. Here, we use a variation 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 early chondrichthyan fossil record. Initial work has involved fitting and adapting the existing SCM models to the cartilaginous fish body plan. Initial data on acanthodians has been collected from museum collections in the UK and Europe and will continue for both acanthodians as well as Palaeozoic chondrichthyans. Data from both museum collection visits and literature will be analysed statistically to understand their completeness in comparison with other vertebrate and invertebrate groups, trends in global marine biodiversity as well as the influence of potential biases (ecological, habitat preferences and sampling effort) on the quality of their fossil record.

The taphonomy of pterosaurs from the Cretaceous Kem Kem beds of S.E. Morocco

Roy Smith[1], David Martill[1], Nizar Ibrahim[1,2]

[1]University of Portsmouth
[2]University of Detroit Mercy

The mid Cretaceous (Albian? - Cenomanian) Kem Kem beds of Morocco represent a dominantly fluvial depositional environment. Its vertebrate assemblage is highly diverse and includes a wide variety of elasmobranchs, osteichthyans, turtles, crocodilians, dinosaurs and pterosaurs. The rarity of pterosaur remains in Africa makes the Kem Kem beds of significance for understanding these enigmatic animals in this part of Gondwana. Surprisingly pterosaur remains occur frequently in the Kem Kem beds but are usually fragmented and always isolated. The material indicates a high diversity of pterosaurs with representatives of Azhdarchidae and Ornithocheiridae, and possibly Pteranodontidae and Tapejaridae. Kellner and Mader (1996) reported the first remains, and since then many, more specimens have been described, representing at least four species *Siroccopteryx moroccanus*, *Alanqa saharica*, *Xericeps curvirostris* and *Coloborhynchus fluviferox*. Interestingly, azhdarchid jaw tip fragments constitute approximately 50% of the pterosaur material from the Kem Kem, indicating either a taphonomic or a collecting bias, or both. Quantitative analysis of pterosaur elements from comparative deposits, including the Cambridge Greensand of the UK and Bissekty Formation of Uzbekistan, suggest a taphonomic fingerprint with enhanced abundances of cervical vertebrae, humeri and scapulocoracoids. This pattern is not seen in the Kem Kem beds suggesting additional biases may be acting upon the material. No clear causative agent has yet been identified to explain this preservational bias. Human collecting bias is ruled out due to observations of the miners collecting every fragment of bone.

Comparative analysis of morphology and composition of the synarcual in extinct and extant Batoids (skates and rays)

Rebekah Smith[1]

[1]Birkbeck, University of London and Natural History Museum, London

Batoidea (Chondrichthyes) comprise approximately 550 species, inhabiting almost all marine ecological niches. Identified by their dorsoventrally depressed body and, endoskeletally, by their synarcual (fused anterior vertebrae). Research into the batoid vertebral column and synarcual has predominantly focused on overall morphology, but a detailed study of the individual vertebral elements, (including tesserae -surficial cartilage mineralisation- and centra) across the synarcual is lacking. This information will provide a better understanding of the growth processes involved whilst also highlighting the evolutionary changes of the synarcual; for example, interspecific variation in these features occurs as the synarcual becomes an increasingly more important part of the axial skeleton in extant versus extinct batoids. Computed tomography (CT) scans of the synarcual from each major order of extant batoids were 3-D rendered, allowing observations on the shape, size and density variations of tesserae to be made, and incorporation of dorsal and ventral vertebral elements, and anterior centra. Tesserae shape was highly variable surrounding the anteriormost centrum among extant batoids which, in turn, appears only partially formed. More derived taxa (Raja clavata) showed less centrum distortion and more regularly shaped tesserae immediately surrounding centra. In less derived taxa (*Rhinobatos formosensis*), tesserae were irregularly shaped and the centra distorted. In extinct batoids (†*Asterodermus platypterus*) the synarcual was shorter, while centra extended through the synarcual and were undistorted. Future work will focus on absence of mineralised centra in the synarcual of extant batoids (possible resorption), including comparative studies into the functionality of morphologically different tesserae within each taxa.

CT analysis reveals new information on the diversity of small theropods of the Kem Kem beds, southeastern Morocco

Robert Smyth[1], David Martill[1], Nizar Ibrahim[1,2]

[1]University of Portsmouth
[2]University of Detroit Mercy

The Kem Kem beds of Morocco have yielded abundant material of giant theropod dinosaurs, but remains of small theropod taxa are rare. Here we describe external and internal morphology of a theropod cervical vertebra (RS-KK-2019-06) revealed by µCT-scanning. These provide much needed information on the diversity of small-bodied theropods in Gondwana during the 'mid' Cretaceous. An anterior cervical vertebra (RS-KK-2019-06) assigned to Abelisauroidea based on deeply excavated spinoprezygopophyseal and spinopostzygopophyseal fossae and a neural arch bearing lateral cavities opening into the neural canal. Noasauridae based on extremely well developed centroprezygapophyseal fossae and an anteriorly positioned neural spine. The internal structure shows regular branching pattern of septae, wide chambers with at least 3 main camerae, and pneumatic pedicles connecting wide, deep fossae of the neural arch. These are indicative of a polycamerate centrum and a procamerate neural arch typical of Ceratosauria. This vertebra may represent juvenile Deltadromeus, a taxon regularly recovered as noasaurid in phylogenetic analyses. However, this specimen may represent a new addition to the Kem Kem theropod assemblage. Noasaurid material is extremely rare, and the described vertebra adds to the few records of this clade from the African 'mid' Cretaceous.

Patterns of Morphological Disparity, Genomic Disparity and Diversity in Vertebrates

Conrad van den Ende[1], Mark Puttick[1], Araxi Urratia[1], Matthew Wills[1]

[1]Department of Biology and Biochemistry and Milner Centre for Evolution, University of Bath

The correlation between genetic and morphological change is a fundamental question of Biology. Yet, studies which further the understanding of this relationship are scarce. If there is a clear relationship between morphological and genetic disparity we expect to find an empirical relationship. Here, we attempt to get a measure of the relationship of these two factors which underpin the evolution of biodiversity. Our initial analyses focuses on one clade, Mammalia, as this clade represents a highly morphological diverse group, which additionally are genetically well sampled. By applying disparity tests to morphological datasets we obtained a measure of morphological disparity for each taxa. We then quantified the genetic disparity for each species by performing a similar test on a dataset consisting of a mitochondrial gene sequence of the same species in our morphological dataset. By obtaining a measure of the eccentricity of both factors for every species we hope to gain empirical evidence for this fundamental relationship in biology. Our expectations are that such a correlation in genetic disparity and morphology exists, however, if our results indicate otherwise we believe this to be an equally significant result.

Rays through time

Eduardo Villalobos-Segura[1]

[1]Birkbeck College

Phylogenetic comparative methods are a powerful tool for understanding biological evolution and reach even greater potential when are scaled trough time, allowing the estimation of divergence times and node ages. There are two main approaches for time scaling a phylogeny:a posteriori time-scaling (APT) (date a pre-existing unscaled topology, given a set of stratigraphic data for the taxa involved) and tip a relatively new approach, commonly implemented by Bayesian phylogenetic analysis of molecular data, that looks for a set of nodal depths (distance between an ancestral node to is descendants) that maximize the probability of obtaining a data set.

The present study is the first to present a time scaled phylogenetic analysis of batoids using morphological data, tip dating, minimum branch length and basic methods were used and compared by estimating from their corresponding resulting cladograms four stratigraphic consistency indices. The analysis includes several fossil species from the Jurassic and Cretaceous with relatively good skeletal fossil record and topological constrains to account for the phylogenetic relations recovered by previous works. The results suggest that batoids was an already well defined monophyletic since the Early Jurassic (Toarcian) and support and Late Triassic-Early Jurassic origin for the group as suggested by molecular clocks, although no Triassic remains have been found. The nodes ages estimated with all methods are compared with those recovered by previous phylogenetic and diversity estimates analyses.

Palynomorphs, marine invertebrates and citizen science: A multi-proxy study of the early Jurassic recovery at Lyme Regis, UK

Rebecca Walley[1], Richard Twitchett[2], Jessica Whiteside[3], Steve Stukins[2]

[1]University of Southampton / NHM, London
[2]NHM, London
[3]University of Southampton

A multi-proxy approach is essential for understanding the effects of climate change in deep time on the ecosystem. With the breakup of Pangaea and the emplacement of the Central Atlantic Magmatic Province, the end of the Triassic is characterised by global changes in climate affecting both the terrestrial and marine realms. Key studies on UK sites have focussed mainly on marine vertebrates and molluscs, with some attempts to tie these in with geochemistry. This study looks at the terrestrial and marine palynomorphs from Lyme Regis, UK, to characterise the early Jurassic recovery. It integrates these novel data with marine invertebrate data collected through a NERC funded citizen science project, from the same location.

Devonian ctenophore from the Hunsrück Shale: Clues to the origins of animals

David Whitaker[1]

[1]University of Bristol

Debates about the evolutionary placement of ctenophores have significant implications for our understanding of the origin of complex life. Estimating the age of the phylum is important to establish the ctenophore rate of evolution, which would help address the question of whether ctenophores or poriferans are the most basal animal phylum. The Devonian fossil *A. hunsrueckiana* is a possible crown ctenophore, but it has also been hypothesised to be a brachiopod. The fossil was originally found within a Hunsrück shale tile by 2-dimensional X-ray imaging. New 3-dimensional X-ray computed tomography methods were used to rescan the fossil at a much higher resolution and model the morphological characters of *A. hunsrueckiana*. As this fossil can now definitely be seen to lack valves, a lophophore, or a pedicle, the brachiopod hypothesis can be rejected. Features identified by computed tomography imaging include tentacular sheaths, meridianal canals, and an apical organ, suggesting that the fossil is a ctenophore. Its apparent retractable tentacle sheaths face away from the mouth, which is a crown group feature. However, it also has structures which could be interpreted as stem group characters. Further work is needed to resolve its status as either a crown or stem ctenophore. If, after further analysis, the fossil were found to be a crown group fossil, that would support a Paleozoic origin for crown ctenophores, suggesting that the group is evolving at a slower rate than some have suggested and supporting the hypothesis that ctenophores are the most basal animal phylum.

Benthic foraminifera as bioindicators of the Deepwater Horizon oil spill

Chloe Young[1], Laura Cotton[1], Patrick Schwing[2]

[1]University of Bristol
[2]University of South Florida

The Deepwater Horizon (DWH) oil spill in 2010 was one of the largest oil spills in global history, releasing 4.0 million barrels of crude oil into the Northern Gulf of Mexico and devastating marine ecosystems. Multi-core data has been collected annually since the event, enabling pre and post-oil spill baselines to be established, making it an ideal study to investigate the ecological response to oil pollution. Benthic foraminifera have successfully been used as bioindicators of the event with a significant decline of their diversity and density coinciding with the oil spill. This is then followed by a recovery period to a steady state within 3-5 years (Schwing et al, 2018). However, no work has yet been conducted on size and morphological response within the benthic foraminiferal species. It is known from previous research that anthropogenic pollution can have significant effects on benthic foraminifera reproduction, expressed through changes in size and growth rates. Here we present the preliminary results of a size study focusing on taxa passing through the DWH spill to determine if their growth and reproduction was affected. The species, *Uvigerina peregrina*, *Bulimina mexicana*, *Bulimina* sp., *Bolivina* sp. and *Brizalina* sp. were picked from 2 mm intervals from the top 50 mm of the core and measured for body length, width and number of chambers. These results enable us to have a better understanding of ecosystem recovery and what strategies may be allowing taxa to survive, aiding us to mitigate the impacts of future oil spills.

Identifying changes in brachiopod community structures and correlating type sections from the Upper Ordovician in the eastern Baltics

Aija Zāns[1]

[1]*Faculty of Chemistry and Geosciences, Vilnius University, Vilnius, Lithuania.*

The position of Baltica during the Ordovician period ranged from around 40-50º south, to a position very close to the equator. The territory of modern day Latvia and Lithuania was located in the central part of the Baltic palaeobasin with sea levels ranging from deep sea, to littoral zones, due to several sea transgressions and regressions. As a result, the Baltoscandian territory has a vast array of marine facies zones. There are significant lateral changes in facies belt deposits in the modern day territories of Latvia and Lithuania, with evident changes in brachiopod communities. The main deposits of this region are limestones, marlstones, and mudstones, but dolomites, argillite, and clays are also commonly found. Most samples are acquired from drill cores due to the Ordovician only outcropping in northern Estonia. To this day, three major issues remain in the eastern Baltic Upper Ordovician formations: i) incomplete type section correlations; ii) the lack of detailed brachiopod community structures, and; iii) a thorough understanding of brachiopod bioevents in Baltica. In a preliminary attempt to solve some of these issues, brachiopods from drill core samples from the Mežciems Formation (Upper Ordovician) in Latvia have been studied. Further research into analogous formations and palaeoenvironments, and significant brachiopod genera occurring in this location, such as the orthids *Dalmanella*, *Howellites*, *Horderleyella*, and *Platystrophia*; strophomenids *Sowerbyella*, *Longvillia*, and *Leptaena*; and the billingsellid, *Vellamo*, has led to a greater understanding of the palaeoenvironmental conditions that lead to changes in brachiopod community structures.

List of delegates

Bethany Allen	University of Leeds	eebja@leeds.ac.uk
Fernando Arnal	University of Bath	paleofermac3@gmail.com
Jake Atterby	University of Manchester	jake-atterby@hotmail.com
Kk Aye	University of Bristol	kyawt.aye@hotmail.co.uk
Alexander Ball	University of Sheffield	ACBall1@sheffield.ac.uk
Tim Barnes	Independent	timothyjackbarnes@hotmail.com
Hollie Bean	University of Bristol	holliebean383@btinternet.com
Juan Benito	University of Bath	J.Benito.Moreno@bath.ac.uk
Charlotte Bird	Independent	charmel1995@googlemail.com
Hannah Bird	Independent	hannahchantelle.bird@gmail.com
Joseph Bonsor	University of Bath	joseph.bonsor@gmail.com
Emily Brown	University of Birmingham	emilyb62@hotmail.com
Hannah Byrne	Uppsala University	hannah.byrne@ebc.uu.se
Amy Campbell	Museum fur Naturkunde	amy.campbell@mfn.berlin
Daniel Cashmore	University of Birmingham	ddcashmore13@gmail.com
Juan Pablo Castaneda	University of Birmingham	JPC672@bham.ac.uk
Kim Chandler	University of Bristol	xo18817@bristol.ac.uk
Rhys Charles	Bristol Dinosaur Project	rhys.charles@bristol.ac.uk
Albert Chen	University of Bath	albertonykus@gmail.com
Alfio Alessandro Chiarenza	Imperial College London	a.chiarenza15@imperial.ac.uk
Jack Cooper	University of Bristol	zs18796@bristol.ac.uk
Thomas Cowgill	Independent	thomas231@cowgill.org.uk
Will Crabbe	University of Leicester	wc117@leicester.ac.uk
Alice de Sampaio Kalkuhl	The University of Manchester	alicekalkuhl@freenet.de
Matthew Dempsey	The University of Manchester	sketchyraptor93@gmail.com
Oliver Demuth	University of Bristol	oliverdemuth@outlook.com
Adam Dickson	University of Manchester	adam.dickson@postgrad.manchester.ac.uk
Amun Dubro	University of Manchester	amun.dubro@postgrad.manchester.ac.uk
Emma Dunne	University of Birmingham	EXD526@bham.ac.uk
Tom Dwyer	University College London	zcictwd@ucl.ac.uk
Joseph Flannery Sutherland	University of Bristol	jf15558@bristol.ac.uk
Isobel Fortune	University of Leeds	ee15ihf@leeds.ac.uk
Sarah Gale	University of Portsmouth	Sarahcgale@outlook.com
Martha Gibson	University of Sheffield	marthae.gibson@gmail.com
Christopher Gralton	University of Southampton	419672cg@gmail.com
Barbara Grant	University of Liverpool	barbara.grant@liverpool.ac.uk
Thomas Gray	University of Leicester	tg147@student.le.ac.uk
Emily Green	University of Bristol	eg15315@my.bristol.ac.uk
Emma Hanson	University of Birmingham	exh601@student.bham.ac.uk
Elise Harris	NHM / Imperial College London	elise.harris@nhm.ac.uk
Struan Henderson	University of Birmingham	struanhenderson@gmail.com
Richard Howard	The Natural History Museum	r.howard@nhm.ac.uk
Krishna Hu	University of Bristol	krishnak.hu@gmail.com

Eloise Hunt	Imperial College London	eloise.hunt15@imperial.ac.uk
Mike Hynes	University of Bristol	hynes.mg@gmail.com
Megan Jacobs	University of Portsmouth	meganj673@hotmail.co.uk
Natalia Jagielska	University of Manchester	nataliee.jag@gmail.com
Lewis Jones	Imperial College London	l.jones16@imperial.ac.uk
Amy Jones	University of Birmingham	APJ527@bham.ac.uk
Carolina Karoullas	University of Manchester	carolina.karoullas@postgrad.manchester.ac.uk
Kim Kean	University of Edinburgh	kean.kim.j@gmail.com
Fionn Keeley	University of Bristol	fionnkeeley@gmail.com
Sophie Kendall	Independent	sk17540@my.bristol.ac.uk
Julian Kiely	University of Portsmouth	julian.kiely@btinternet.com
Nicola Kirby	University of Birmingham	njk883@student.bham.ac.uk
Miranta Kouvari	University College London	m.kouvari@ucl.ac.uk
Callum Kunz	Bristol	Callum.j.kunz@hotmail.com
Pei-Chen Kuo	University of Edinburgh	s1842861@ed.ac.uk
Rebecca Lakin	University of Bath	r.j.lakin@bath.ac.uk
Grace Lamyman	University of Leeds	grace_l18@btinternet.com
Caitlin Lebel	University of Florida	clebel@ufl.edu
João Leite	The Natural History Museum	j.vasco-leite@nhm.ac.uk
Thomas Lewis	University of Bristol	lewis_tom@hotmail.com
Rob Loveday	Independent	mybadgerhashalitosis@gmail.com
Wai Sum Ma	University of Birmingham	w.ma.1@pgr.bham.ac.uk
Alice Maher	Independent	A.E.Maher@liverpool.ac.uk
Andrew Mair	ESSI / University of Leeds	ee11a2mm@leeds.ac.uk
Michael McKnight	University of Birmingham	MJM797@bham.ac.uk
James McPhee	University of Portsmouth	up770674@myport.ac.uk
Luke Meade	University of Birmingham	luke.edward.meade@gmail.com
Arsham Nejad Kourki	University of Bristol	an16227@bristol.ac.uk
Cecily Nicholl	University College London	cn814@ic.ac.uk
Morten Lunde Nielsen	University of Bristol	mortenlunde@gmail.com
Connor O'Keeffe	University of Leeds	eecso@leeds.ac.uk
Simon Penn	University of Portsmouth	simon.penn@port.ac.uk
Jane Puzey	Independent	Jane@fishingfox.co.uk
Jasmin Rees	UCL	jaz.s.r@hotmail.co.uk
Jane Reeves	University of Manchester	jane.reeves-4@postgrad.manchester.ac.uk
Jonathan Rio	Imperial College London	jr212@ic.ac.uk
Claire Routledge	UCL	claire.routledge.16@ucl.ac.uk
Lisa Schnetz	University of Birmingham	lxs821@student.bham.ac.uk
Julia Schwab	University of Edinburgh	julia.schwab@ed.ac.uk
Caitlin Sclater	University of Bristol	caitlin.sclater@hotmail.com
Roy Smith	University of Portsmouth	roysm3@googlemail.com
Rebekah Smith	Birkbeck, University of London and Natural History Museum, London	rebekah.smith99@yahoo.com
Grant Smith	University of Bath	GRJS20@bath.ac.uk
Robert Smyth	University of Portsmouth	up720567@myport.ac.uk
Mark Stanley	Independent	Mstanle@tcd.ie

Christopher Stockey	University of Leicester	css25@le.ac.uk
Joseph Sutherland	University of Bristol	jf15558@bristol.ac.uk
Matthew Andrew Sutton	Independent	mattasutton96@gmail.com
Alice Turner	Independent	alice.v.s.turner@gmail.com
Conrad van den Ende	Independent	conrad.ende@gmail.com
Eduardo Villalobos-Segura	Independent	elasmo177@gmail.com
Carrie Walker	Open University	carrie.walker@open.ac.uk
Rebecca Walley	University of Southampton / NHM, London	rw1n18@soton.ac.uk
Bridget Warren	University of Birmingham	baw888@student.bham.ac.uk
David Whitaker	University of Bristol	mv18825@bristol.ac.uk
Cariad Williams	University of Portsmouth	cariad.williams1996@gmail.com
Adam Woodhouse	University of Leeds	eeadw@leeds.ac.uk
Chloe Young	Independent	chloeyoung1995@hotmail.co.uk
Aija Valentīna Zāns	Vilnius University	aijavzans@gmail.com
Marta Zaher	University of Bristol	marta.zaher@bristol.ac.uk