The Palaeontological Association

70th Annual Meeting

8th–11th December 2026

University of Oxford
Oxford, UK



PROGRAMME ABSTRACTS

#PalAss26

The Palaeontological Association
70th Annual Meeting
8 – 11 December 2026
University of Oxford, Oxford, UK

Welcome to Oxford

We are delighted to welcome you to Oxford for the 70th Annual Meeting of the Palaeontological Association. This year's Meeting is full of fantastic science and opportunities to connect with old friends and new. It includes the Symposium on 'Deep Time Insights into Major Evolutionary Transitions', several days of interesting research talks and posters, an exciting field-trip to Jurassic Oxfordshire, and the Annual Dinner at historic Merton College, founded 1264.

The Annual Meeting of the Palaeontological Association was last held at the University of Oxford in person in 2005, with our Museum of Natural History hosting the 2020 Virtual Meeting during the pandemic.

The University has a vibrant palaeobiology research group spanning its Department of Earth Sciences and Museum of Natural History. Since the pioneering description of the dinosaur *Megalosaurus*, over 200 years ago, the University has developed a tradition of palaeontological enquiry and stewards over 400,000 fossil specimens in its natural history collections. Today our research centres on understanding the foundations of the modern biosphere and how biodiversity and environmental change are related across the Earth's history.

This booklet provides information for the conference and associated events. If you have any queries, please do not hesitate to contact us via e-mail (<**annualmeeting2026@palass.org**>) or speak with a friendly member of the organizing team.

Visiting Oxford

Oxford is a compact city with excellent transport links and several hotels and areas for eating and drinking within walking distance of the meeting venue. The meeting venue, the Mathematical Institute, is on the edge of the vibrant Jericho area of Oxford and neighbours the new Schwartzman Centre for the Humanities.

Walton Street and Little Clarendon Street in Jericho host numerous bars, restaurants and eateries. The nexus of Radcliffe Square, Broad Street and High Street is around five minutes' walk and, during the meeting, Broad Street will host the city's annual Christmas market. Blackwell's Bookshop, with its vast Norrington Room, is well worth a visit, and the University's Ashmolean, History of Science, Natural History and Pitt Rivers museums, as well as the Bodleian Library and the University's Botanic Gardens, are all near the meeting venue.

For information on visiting the University of Oxford, see <**https://www.ox.ac.uk/about/visit-us**>.

Venue

Unless specified otherwise, all conference events will be held in the Mathematical Institute (Andrew Wiles Building, Woodstock Road, Oxford, OX2 6GG). Pre-conference workshops and tours will be held at designated venues including the Department of Earth Sciences (South Parks Road, Oxford, OX1 3AN), Museum of Natural History (Parks Road, Oxford, OX1 3PW) and All Souls College (High Street, Oxford, OX1 4AL). The Icebreaker will be held at the Museum of Natural History, with the Annual Dinner at historic Merton College (Merton Street, Oxford, OX1 4JD). Our post-conference field-trip will visit sites across Jurassic Oxfordshire, beginning at the Museum of Natural History.

Registration

Upon arrival, all delegates can register at the registration desk on the Mezzanine level of the Mathematical Institute to receive their name badge and delegate pack, including tickets for additional events (*e.g.* Icebreaker and Annual Dinner).

The registration desk will be open on:

Tuesday 8th December 13:00 – 17:15

If you registered for a workshop/tour on the morning of 8th December, please go directly to that event. Following the workshop/tour, you will be able to register for the Meeting at the registration desk in the Mathematical Institute after 13:00.

Registration will not be available at the Icebreaker. You must pick up your delegate pack from the registration desk before attending the Icebreaker. To attend the Icebreaker, delegates must register before 17:15 at the Mathematical Institute.

Wednesday 9th December 08:30 – 17:30

Thursday 10th December 08:30 – 17:30

Catering

Symposium – No catering will be provided during the Symposium, but the Mathematical Institute's Pi café will be open from which you can purchase refreshments.

Icebreaker – Canapés will be provided at the Icebreaker alongside one free drink per delegate (ticket in delegate packs). A cash bar will also operate. Note, red wine is no longer available at the Icebreaker.

Main meeting – Catering will be provided at the main meeting on 9th and 10th December including tea, coffee and pastries on arrival each morning, morning and afternoon breaks with tea, coffee and biscuits and a simple sandwich lunch each day. The catering table will be clearly labelled, and an allergen booklet will be available listing all the food items being served along with the common allergens they contain. Delegates with allergies can refer to the booklet or speak to a member of catering staff if they require further assistance. The caterers will also place the gluten-free and vegan sandwiches separately from the rest of the sandwiches to help avoid confusion. In addition to regular milk, a dairy-free alternative will be provided for tea and coffee. The Mathematical Institute's Pi café will also be open throughout, from which you can purchase additional refreshments.

Talks

Talks are 15 minutes, with 12 minutes allocated for speaking and three minutes for questions. Please prepare slides in 16:9 format. Slides can be either .ppt or .pdf files. Slides must be submitted online by 23:59 on Sunday 6th December. Uploading talks directly before sessions will not be possible. Please ensure videos and custom fonts are embedded to avoid compatibility issues. For most of the conference, we will have three parallel sessions occurring, so keeping to time will be especially important.

Lightning/flash talks

Lightning/flash talks are five minutes maximum. At the end of each lightning talk session there will be 15 minutes of questions for all speakers in that session. Slides should be prepared in 16:9 format and can be uploaded as either .ppt or .pdf files. Slides must be submitted online by 23:59 on Sunday 6th December. Uploading talks directly before sessions will not be possible. Please ensure that videos and custom fonts are embedded to avoid compatibility issues. During the lightning/flash talks, we will have three parallel sessions occurring, so keeping to time will be especially important.

Posters

Posters should be printed in A0 portrait format. Posters should be printed on paper rather than fabric as paper is best accommodated by our poster boards. Those that are eligible for the Council Poster Prize must submit their poster online as a PDF file by 12:00 (noon) on Tuesday 1st December. There will be two poster sessions throughout the conference. Please put up posters on the morning of your session and remove them at the end of the day. Instructions on where to put up posters will be available at the registration desk and volunteers will be available to assist.

Travel grants

Students who have been awarded a PalAss travel grant should see the Executive Officer, Dr Jo Hellawell (e-mail <**executive@palass.org**>) in the exhibition area in the Mathematical Institute to receive their reimbursement.

Breastfeeding and expressing facilities/quiet room

Room C1 in the Mathematical Institute will be available throughout the Annual Meeting as a quiet space.

Accessibility

The University of Oxford is committed to providing accessible learning environments for all students, staff and visitors.

Detailed information on the accessibility of the Mathematical Institute is available here:

<**https://www.ox.ac.uk/about/how-we-are-run/equality-diversity/access-guide/academic-depts/andrew-wiles-building**>

Detailed information on the accessibility of the Museum of Natural History is available here:

<**https://www.ox.ac.uk/about/how-we-are-run/equality-diversity/access-guide/glam/museum-of-natural-history**>

Detailed information on the accessibility of Merton College is available here:

<**https://www.ox.ac.uk/about/how-we-are-run/equality-diversity/access-guide/colleges/merton-college**>

Detailed information on the accessibility of the Department of Earth Sciences is available here:

<**https://www.ox.ac.uk/about/how-we-are-run/equality-diversity/access-guide/academic-depts/earth-sciences**>

Detailed information on the accessibility of All Souls College is available here:

<**https://www.ox.ac.uk/about/how-we-are-run/equality-diversity/access-guide/colleges/all-souls-college**>

Annual Dinner

Founded in 1264 by Walter de Merton – former Chancellor of England and later Bishop of Rochester – Merton College was the first fully self-governed college at the University of Oxford. It includes one of Europe's oldest continuously operating academic libraries, serving scholars and students for more than six centuries. Merton Chapel, which will host a pre-dinner drinks reception, is home to one of England's finest surviving pre-Reformation lecterns, presented to the College in 1504, as well as a striking screen designed by Sir Christopher Wren in 1673. The Great Hall, where dinner will be served, is one of Merton' s oldest and most significant buildings, completed before 1277 and recognized as the oldest surviving college hall in Oxford. It retains elements of its medieval origins, including its remarkable thirteenth-century wrought iron door.

Guests who elected to attend the Annual Dinner will receive their ticket in their delegate packs at registration. Guests must take their Annual Dinner ticket with them to enable access to Merton College.

A platform lift provides step-free access from Front Quad to the Great Hall and the rooms beyond. Within the Great Hall the tables are fixed in place, but movable chairs can be rearranged to create spaces for wheelchair users. The top table is situated on a raised stage and can be accessed using a temporary ramp when required. The Chapel is reached by passing through the College on a level flagstone pathway. Inside the Chapel, there is a change in level between the entrance area and the main vestibule, which is accessible via a ramp.

If you have any questions or concerns about the accessibility of the Annual Dinner venue, please e-mail the meeting organizers at <**annualmeeting2026@palass.org**>.

Sponsors

The organizers of the 70th Annual Meeting gratefully acknowledge the support of the following sponsors and exhibitors:

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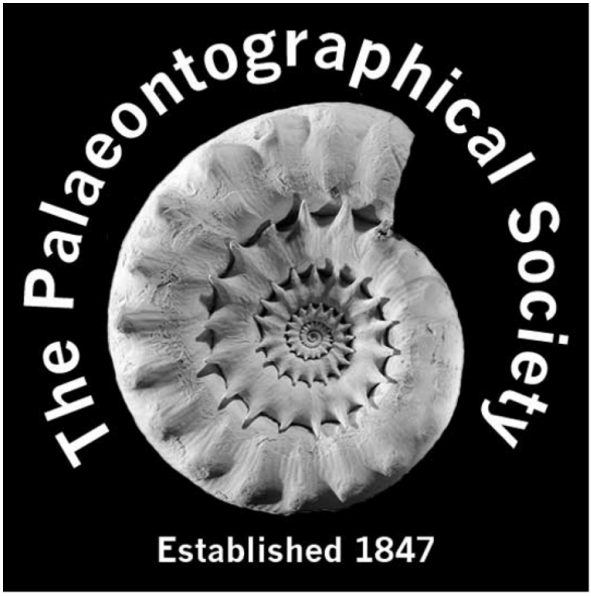

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Organizing committee

Chair: Prof. Ross Anderson

Committee

Prof. Frances Dunn
Dr Duncan Murdock
Dr Emma Nicholls
Prof. Luke Parry
Dr Ricardo Pérez-de la Fuente
Prof. Erin Saupe

Abstract Review Panel

Prof. Ross Anderson
Dr Roger Close
Dr Alison Cribb
Dr Rachel Dobson
Prof. Frances Dunn
Prof. Najmeh Etemad-Saeed
Dr Joe Flannery-Sutherland
Dr Sofía Galván
Dr Corentin Jouault
Dr Gaorong Li
Dr Duncan Murdock
Dr Emma Nicholls
Prof. Luke Parry
Dr Ricardo Pérez-de la Fuente
Dr Tom Roper-Smith
Prof. Erin Saupe
Dr Michael Schmutzer
Dr Julia Schwab
Dr Piyush Sriwastava

Student and post-doctoral volunteers and staff

We thank all student and post-doctoral members of the Oxford Palaeobiology community, across the Departments of Earth Sciences and Biology as well as the Museum of Natural History, for their help pre- and during the conference in organization and in chairing sessions. We also thank staff across the Mathematical Institute, Museum of Natural History, Merton College and the Department of Earth Sciences. The logo for the 70th Annual Meeting of the Palaeontological Association was designed by Minxuan Zhu, Lucy Jackson and Lois Houlgate.





<palaeobiology.site.ox.ac.uk>

Prize judging panels

President's Prize and Council Lightning/Flash Talk Prize:

Prof. Philip Donoghue (University of Bristol, UK, Chair)
Dr Bethany Allen (GFZ Helmholtz Centre for Geosciences, Germany)
Prof. Paul Barrett (Natural History Museum, London, UK)
Prof. Frances Dunn (University of Oxford, UK)
Rosa Parkin (University of Edinburgh, UK)
Dr Valentina Rossi (University College Cork, Ireland)
Prof. Daniela Schmidt (University of Bristol, UK)
Prof. Paul Wignall (University of Leeds, UK)

Council Poster Prize:

Prof. Barry Lomax (University of Nottingham, UK, Chair)
Dr Nidia Álvarez-Armada (Manchester Museum, UK)
Dr Orla Bath Enright (Staatliches Museum für Naturkunde Stuttgart, Germany)
Dr Richard Dearden (University of Birmingham, UK)
Dr Phil Jardine (University of Münster, Germany)
Dr Imran Rahman (Natural History Museum, London, UK)
Dr Shea Slater (University College Cork, Ireland)
Dr Alan Spencer (Imperial College London, UK)



The Palaeontological Association

Reg. Charity No. 1168330

Code of Conduct for Palaeontological Association Events

The Palaeontological Association holds regular meetings and events throughout the year. The Association's Events Code of Conduct relates to the behaviour of all participants and attendees at all events run by the Association, and acts alongside the Code of Conduct for Members.

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.

Delegates should respect common sense rules for professional and personal interactions, public behaviour (including behaviour in public electronic communications), common courtesy, and respect for private property.

Demeaning, abusive, harassing or threatening behaviour, discrimination on the basis of race, ethnic origins, immigration status, religion, age, marital status, parental status, sex, sexual orientation, gender identity or expression, socioeconomic background, educational background, or disability will not be tolerated. Inappropriate physical contact, unwelcome sexual attention, including verbal or physical actions of a sexual nature towards other attendees or towards meeting volunteers, exhibitors or facilities staff and security will not be tolerated, in either personal or electronic interactions.

Digital images and social media:

Respect for the intellectual property of presenters should be maintained at all times. Photographing or recording a talk without the author's express permission is forbidden. While the default assumption is to allow open discussion of presentations on social media, delegates are expected to respect any request by an author to not disseminate the contents of their talk or poster. Questions and discussion should be constructive, respectful, and focus on data and ideas rather than individuals.

Reporting unacceptable behaviour:

If you are the subject of unacceptable behaviour or have witnessed any such behaviour, you can report it (anonymously if you choose to) via the Report code of conduct violation form (accessed via the PalAss webpage at <**https://palass.org/code-conduct-palaeontological-association-events**> or linked from the bottom of the main website). Alternatively you can notify a designated member of the Palaeontological Association Council on site: President Prof. Philip Donoghue; Vice-President Prof. Crispin Little; Vice- President Prof. Barry Lomax; Diversity Officer Dr Nidia Álvarez-Armada; or Executive Officer Dr Jo Hellawell.

Anyone experiencing or witnessing behaviour that constitutes an immediate or serious threat to public safety, or a criminal act, is expected to contact the appropriate law enforcement agency (in the UK for the police, or for fire or medical emergencies, call 999). Those witnessing a potential criminal act should also take actions necessary to maintain their own personal safety.

Resulting actions

Following a report of a Code of Conduct violation, resultant action taken by the Palaeontological Association will be decided based on the individual circumstances of the violation, its severity, and whether it was a single event or a repeated infringement. As a preliminary action, the ethics committee leader and designated safe person(s) on the Association's Council will meet, investigate, and implement any necessary immediate actions to safeguard the affected individual(s). The subject of the enquiry (*i.e.* the party or parties whose behaviour is reported to be in breach of the Code) may be given a warning or asked to leave the Meeting venue while further investigations are conducted to ensure immediate safeguarding of the affected individual(s). The result of Code of Conduct violation investigations will be shared to the Association's Council at the next regular meeting.

Further reprimands may include, but are not restricted to, written reprimand or warning, removal from Association positions, suspension from presenting at Association meetings, suspension from attending future Association activities (including events, field-trips, short courses and meetings), suspension from submission of manuscripts to *Palaeontology* and *Papers in Palaeontology*, suspension of Association membership, expulsion from the Association, and/or denial or revocation of grants and awards. For full details see the Association's website.

Key contacts:

President: Prof. Philip Donoghue

Vice-President: Prof. Crispin Little

Vice-President: Prof. Barry Lomax

Diversity Officer: Dr Nidia Álvarez-Armada

Executive Officer: Dr Jo Hellawell

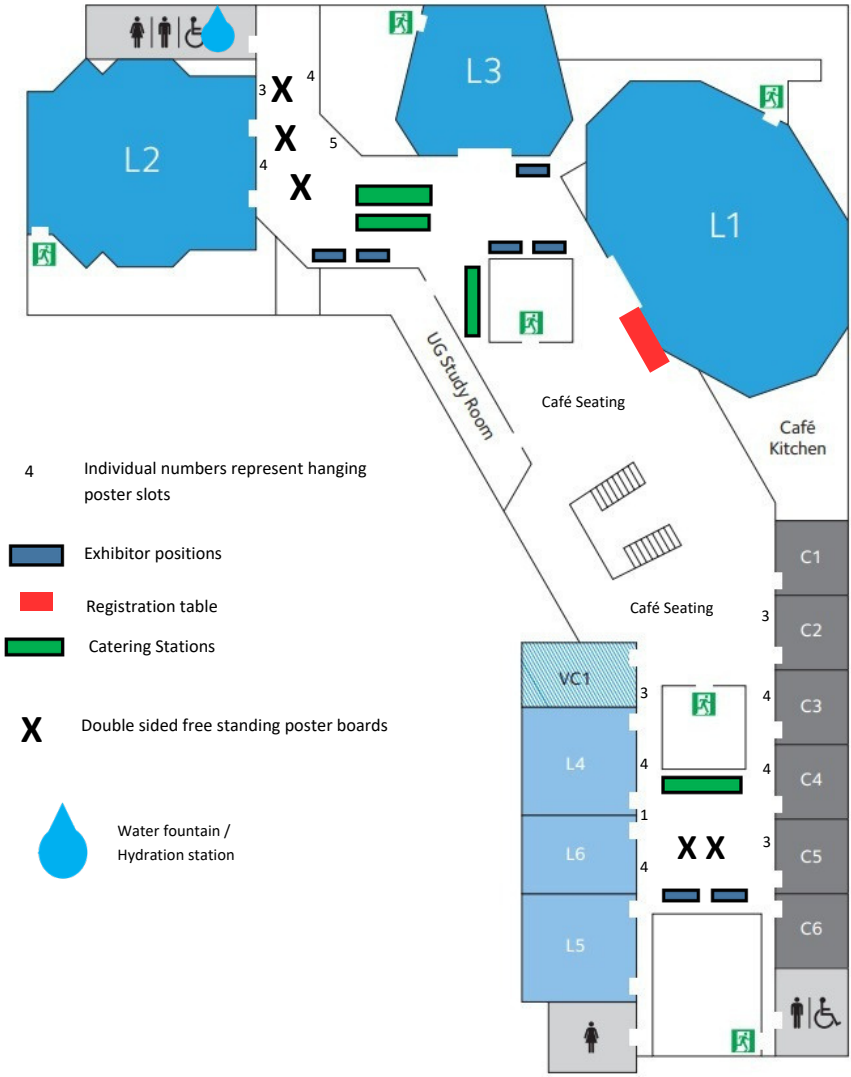
Maps

See <**https://www.ox.ac.uk/about/visit-us/map**> or use the QR code to access the University of Oxford map.

Mathematical Institute front entrance



Mathematical Institute Map of mezzanine level



Summary of Schedule

Tuesday 8th December: Workshops, Symposium, Icebreaker

The morning of 8th December features a workshop entitled 'Spatial standardization in the fossil record: a workshop in R' led by Prof. Erin Saupe, a workshop on storytelling in science communication by Dr Soledad De Esteban-Trivigno (Transmitting Science), and tours of the University's Museum of Natural History collections led by Dr Duncan Murdock and Dr Emma Nicholls. A college tour of All Souls College is led by Prof. Ross Anderson. If you registered for a workshop/tour you will receive further details of location *etc*. via e-mail from the relevant leader. Please go directly to that event on the morning of the 8th. Following the workshop/tour, you will be able to register for the Meeting at the registration desk in the Mathematical Institute after 13:00.

In the afternoon, the scientific part of the Annual Meeting will begin with a Symposium in the Mathematical Institute L1 entitled 'Deep time insights into major evolutionary transitions' led by Professors Frances Dunn and Luke Parry. Registration will be available from 13:00 to 17:15 in the Mathematical Institute Mezzanine level.

Following the Symposium there will be an Icebreaker from 18:00 to 20:00 at the Museum of Natural History, organized by Dr Emma Nicholls. Canapés will be provided and each delegate registered for the Icebreaker will receive one drink voucher. A cash bar will also be available. Registration will not be available at the Icebreaker. To attend the Icebreaker, please ensure you pick up your delegate pack at registration before 17:15 at the Mathematical Institute. This will include your drink voucher.

This special event offers delegates the opportunity to explore the Museum's newest permanent exhibits, unveiled in 2026. These displays trace the evolving relationships between life and our planet, while showcasing Oxfordshire's internationally renowned geological and palaeontological heritage. The displays feature type material of dinosaurs such as the famous *Megalosaurus*, the first dinosaur to be scientifically named and described in the world, reimagined in dynamic new poses. Alongside rock, fossil and mineral specimens are specially commissioned artworks that bring these extraordinary prehistoric worlds vividly to life and a series of revamped touchable specimens.

Delegates will also have the opportunity to visit the temporary exhibition *34: The critical raw materials shaping our future*. Critical raw materials are fundamental to modern technology, yet their future supply presents major scientific, environmental and geopolitical challenges. This thought-provoking exhibition explores how researchers are developing innovative solutions to secure these vital resources sustainably and ethically.

During the Icebreaker, come to the Museum's Lecture Theatre for a selection from palaeontologist Adam Lindholm's play *William Shakespeare's Walking With Dinosaurs!* Adapting the first episode of the hit 1999 BBC documentary series, 'New Blood', into an iambic pentameter drama, witness the bloody usurpation of Pseudosuchia by a cadre of lean and hungry dinosaurs. Performances run for approximately 20 minutes and will take place at 18:10, 19:00 and 19:40. Cry "havoc!" and let slip the pterosaurs!

Wednesday 9th December: Conference, AGM, Annual Address and Annual Dinner

Registration will be open from 08:30 to 17:30 in the Mathematical Institute Mezzanine level. Pastries, tea and coffee will be available at the Mathematical Institute from 08:30.

The conference will start with parallel sessions at 08:50 in Mathematical Institute L1, L2 and L3. All further sessions will be in these three lecture halls.

From 11:00 to 12:30 we will hold the first session of President's Prize talks in Mathematical Institute L1.

Posters will be set up in the Mathematical Institute Mezzanine level, where morning and afternoon tea/coffee breaks and lunch will also be held. There will be a dedicated poster session before lunch.

During lunch, there will be a Diversity Meeting convened by Dr Nidia Álvarez-Armada (PalAss Diversity Officer) in Mathematical Institute L3.

The Annual General Meeting (AGM) will begin at 15:55 in Mathematical Institute L1, followed by the Annual Address given by Prof. Anjali Goswami FRS at 16:30.

The Annual Dinner will take place at historic Merton College, organized by Prof. Frances Dunn. Doors open at 19:00. Following a drinks reception in the College's chapel, a delicious menu will be served in Oxford's oldest surviving college hall, completed before 1277. Guests who elected to attend the Annual Dinner will receive their ticket in their delegate pack.

Thursday 10th December: Conference

Registration will be open from 08:30 to 17:30 in the Mathematical Institute Mezzanine level. Pastries, tea and coffee will be available at the Mathematical Institute from 08:30.

Parallel sessions will begin at 9am in Mathematical Institute L1, L2 and L3. All further sessions will be in these three lecture halls.

From 11:00 to 12:30 we will hold the second session of President's Prize talks in Mathematical Institute L1. Later in the day, from 14:00 to 15:00, the Lightning/Flash Talk Prize session will be held also in L1.

Posters will be set up in the Mathematical Institute Mezzanine level, where morning and afternoon tea/coffee breaks and lunch will also be held. There will be a dedicated poster session before lunch.

During lunch, there will be an LGBTQ+ Meeting convened by Dr Nidia Álvarez-Armada (Diversity Officer) in Mathematical Institute L3.

The final session of oral presentations will start at 15:30 in Mathematical Institute L1, after which the conference will close with presentations by the organizing committees of upcoming meetings, the awarding of the President's Prizes, Council Lightning/Flash Talk Prize, and the Council Poster Prizes, as well as concluding remarks.

Following the conclusion of the conference, we will host an informal quiz evening at the Museum of Natural History, organized by Adam Lindholm. Come along for a bit of friendly competition in a

'pub quiz' combining general and palaeontological knowledge in unexpected ways. Be prepared for eight rapid-fire rounds, each with a different theme, and to puzzle out some secret answers that can net you bonus points (if rumours are to be believed). The event is first come, first served for ten teams of six people each. There will be prizes!

Friday 11th December: Post-conference field-trip

The one-day field-trip, led by Dr Duncan Murdock, will visit key locations in the Jurassic fossil-bearing successions of Oxfordshire. The county has a long history of important palaeontological discoveries from the first dinosaur scientifically described to one of the largest dinosaur tracksites in the world. This trip will transect the Jurassic strata exposed in Oxfordshire to reveal both this deep history and the changing environments that the rocks and fossils describe.

The coach will depart from the Museum of Natural History, Parks Road, Oxford, OX1 3PW at 08:15 and return to Oxford around 17:30. Stops are planned at a Corallian reef in Rock Edge Nature Reserve, the famous mammal bed at Kirtlington quarry, and the village of Stonesfield – home to the first scientifically-named dinosaur, *Megalosaurus*. A detailed itinerary will follow for those registered. Field-trip registration fees include the coach transportation and a field guide. Participants will be able to purchase their own lunch at a local pub.

The trip will be largely on accessible pathways, but please do indicate any access requirements at registration. Hard hats are not necessary, but we strongly recommend sturdy footwear and wet-weather clothes.

Detailed Schedule

Tuesday 8th December

Registration

13:00 – 17:15 Mathematical Institute

Pre-conference workshops

These are for pre-booked participants only as spaces are limited.

10:00 – 12:00 **Spatial Standardization in the fossil record: a workshop in R**
(Department of Earth Sciences)
Convener: Erin Saupe

10:00 – 12:00 **Using storytelling to communicate your science**
(Museum of Natural History)
Convener: Soledad De Esteban-Trivigno (Transmitting Science)

10:30 – 12:30 **Museum of Natural History Collections Tours**
(Museum of Natural History)
Conveners: Duncan Murdock and Emma Nicholls

10:00 – 11:00 **Oxford College Tour**
(All Souls College)
Convener: Ross Anderson

Symposium

13:30 – 17:15 Symposium: Deep time insights into major evolutionary transitions
(Mathematical Institute L1)

Chairs: Frances Dunn and Luke Parry

13:30 – 13:45 **Welcome and opening remarks**

13:45 – 14:15 Life before eukaryotes
Kurt O. Konhauser

14:15 – 14:45 Constraining the environmental conditions of early eukaryote evolution: fossils from the middle Proterozoic Greater McArthur Basin, northern Australia
Maxwell A. Lechte

14:45 – 15:15 The coevolution of animals and seafloor bioturbation
Lidya G. Tarhan

15:15 – 15:45 **Break (uncatered)** (Mathematical Institute Mezzanine)

15:45 – 16:15 Deciphering feeding in the precursors of jawed vertebrates using 3D imaging
Lisa Schnetz

16:15 – 16:45 Life on the edge: vegetated coastal wetlands before flowering plants
Brennan O'Connell

16:45 – 17:15 The rise of terrestrial animals
Russell J. Garwood

Icebreaker

18:00 – 20:00 Museum of Natural History

18:10, 19:00, 19:40 *William Shakespeare's Walking With Dinosaurs!*
(Museum of Natural History Lecture Theatre, 3 performances)

Wednesday 9th December

Underlined author is the presenter.

Registration

08:30 – 17:30 Mathematical Institute Mezzanine

08:30 – 08:50 **Tea/coffee/pastries** (Mathematical Institute Mezzanine)

Conference, AGM, Annual Address and Annual Dinner

Session 1a (08:50 – 10:30)
(Mathematical Institute L1) Chair: Emma Nicholls

08:50 – 09:00 **Welcome and opening remarks**

09:00 – 09:15 **Development of alligator thecodonty sheds light on evolution of archosaurian tooth implantation**
Yihui Ke, Tiffany Gama, Mark W. J. Ferguson and Aaron R. H. LeBlanc

09:15 – 09:30 **'Whiplash' tail variability in flagellicaudatan sauropods**
Tom T. P. van der Linden, Robert S. H. Smyth, Carl M. Mehling, Dennis M. Hansen and Emanuel Tschopp

09:30 – 09:45 **Testing the hypothesis of parrot-like mandibles in oviraptorosaurs**
Damiano Landi, James L. King, Emily J. Rayfield and Michael J. Benton

09:45 – 10:00 **Biting through life: an evolutionary tale of ornithischian dental sierras and jaw biomechanics**
Isaura Aguilar Pedrayes, David J. Button, Emily J. Rayfield and Michael J. Benton

10:00 – 10:15 **Joint mobility in the hallux of anisodactyl birds as a proxy for non-neornithine avialan pedal function**
Grace Kinney-Broderick, Oliver E. Demuth and Daniel J. Field

10:15 – 10:30 **The diet of enantiornithine birds**
Case Vincent Miller, Jen A. Bright, Xiaoli Wang, Xiaoting Zheng and Michael Pittman

Session 1b (08:50 – 10:30)
(Mathematical Institute L2) Chair: Roger Close

08:50 – 09:00 **Welcome and opening remarks**

09:00 – 09:15 **Causal inference of macroevolutionary dynamics from the fossil record**
Nicole Obren, Trond Reitan and Lee Hsiang Liow

09:15 – 09:30 **Body size and the evolution of tissues and organs in Metazoa**
Arsham Nejad Kourki and James DiFrisco

09:30 – 09:45 **What is the effect of ancestral state estimations on disparity analyses?**
Caleb Scutt, Natalie Cooper, Gavin Thomas and Thomas Guillerme

09:45 – 10:00 **TrajecTools, an R package to compare multivariate ontogenetic trajectories: insights into morphological convergence in ammonites**
Aimie Doriath-Döhler, Isabelle Rouget, Nicolas Goudemand, Nour Helin, Sylvain Gerber and Jérémie Bardin

10:00 – 10:15 **When clustering fails: testing bioregionalization methods with realistic simulated bioregions**
Liudas Daumantas and Andrej Spiridonov

10:15 – 10:30 **Food web dynamics determine extinction outcomes through the Phanerozoic**
Baran Karapunar, Tanya Strydom, Andrew Beckerman, Annabel Nicholls, Catalina Pimiento, Pincelli Hull, Jennifer A. Dunne, Andy Ridgwell, Crispin T. S. Little and Alexander M. Dunhill

Session 1c (08:50 – 10:30)
(Mathematical Institute L3) Chair: Duncan Murdock

08:50 – 09:00 **Welcome and opening remarks**

09:00 – 09:15 **Kaolinite and exceptional fossilization: testing a taphonomic association with new mineral mapping technologies**
William J. McMahon, Nicholas J. Butterfield and Stefan C. Löhr

09:15 – 09:30 **Sediment controls the trajectory of microbial necrobiome succession during marine invertebrate decay**
Felicity M. Roberts, Sophie Nixon, Christopher Boothman, Jane Reeves and Robert S. Sansom

09:30 – 09:45 **Characterization of decay in filamentous cyanobacteria reveals a predictable, broadly conserved taphonomic pathway**
Philip B. Vixseboxse and Sean McMahon

09:45 – 10:00 **The origin of burrowing: a multidisciplinary approach to asking 'how did the first burrowers move through sediments?'**
Jane Reeves, Katie Hill, Peter Cooper, Christopher Holland, Robert S. Sansom, William Sellers, Luke A. Parry and Russell J. Garwood

10:00 – 10:15 **Digging deeper: piperock and the agronomic revolution in the Mahto Formation, Alberta, Canada**
Baptiste Coutret, Scott Melnyk, Drew Brown, Kurt O. Konhauser and Murray Gingras

10:15 – 10:30 **Ordered sheaths and oriented calcites: calcification and preservation of an Ordovician cyanobacterial fossil**
Changtai Niu, Peng Tang, Lijing Liu, Kui Yan and Ke Pang

10:30 – 11:00 **Break (catered)** (Mathematical Institute Mezzanine)

Session 2 – President's Prize (11:00 – 12:30)
(Mathematical Institute L1) Chair: Ricardo Pérez-de la Fuente

Talks in this session have been shortlisted for consideration for the President's Prize.

11:00 – 11:15 **Optical-photothermal infrared (O-PTIR) spectroscopic study on Neoproterozoic carbonaceous macrofossils from South China**
Hanzhi Qu, Xiaopeng Wang, Corentin Loron, Guangjin Li, Xunlai Yuan, Ke Pang and Sean McMahon

11:15 – 11:30 **Origination shapes the marine latitudinal diversity gradient through deep time**
Naïs M. S. Laporte, Daniele Silvestro, Bernard Hugueny, Erin E. Saupe and Jonathan Rolland

11:30 – 11:45 **Quantifying 400-million-year forest structural evolution**
Bingcai Liu, Kai Wang, Alexander J. Hetherington and Honghe Xu

11:45 – 12:00 **Environmental heterogeneity predicts regional biodiversity across 500 million years of Earth history**
Hanhui Huang, Tianyi Chu, Alex Farnsworth, Daniel J. Lunt, Paul J. Valdes and Erin E. Saupe

12:00 – 12:15 **Cosmopolitanism during the Early Carboniferous (Tournaisian) in the context of Late Palaeozoic trends**
Lila Blake, Paul B. Wignall and Alexander M. Dunhill

12:15 – 12:30 **A Jurassic fossil reveals the stepwise evolution of thorny-headed worms**
Cihang Luo, Luke A. Parry, Brendon E. Boudinot, Shengyu Wang, Edmund Jarzembowski, Haichun Zhang and Bo Wang

12:30 – 13:00 **Poster Session 1**
(Mathematical Institute Mezzanine)

13:00 – 14:00 **Lunch (catered)**
(Mathematical Institute Mezzanine)

13:15 – 14:00 **Diversity Meeting**
(Mathematical Institute L3)

Session 3a (14:00 – 15:30)
(Mathematical Institute L1) Chair: Julia Schwab

14:00 – 14:15 **A fresh look at the eurysternid turtles from Late Jurassic of France**
Gaël E. Spicher, Walter G. Joyce, Pierre Guériau and Jérémy Anquetin

14:15 – 14:30 **Functional significance of tubular enamel in extinct Rhynchocephalia: insights from extant uromastycine lizards**
Marco Bianchin, Daniel Marke, Marc E. H. Jones and Aaron R. H. LeBlanc

14:30 – 14:45 **Estimating visual performance in Mesozoic marine reptiles using preserved scleral rings**
Matthew D. McKeown, Francesco Della Giustina, Valentin Fischer and Eric W. Wilberg

14:45 – 15:00 **'Brain vs brawn': the effect of allometry on trade-offs between brain and jaw muscle shape in mammals**
Jack Oyston, Andrew Knapp, James Thorson and Ryan Felice

15:00 – 15:15 **High functional optimality in mammalian jaws revealed through theoretical morphologies**
Harry Berks, Emily J. Rayfield and Philip C. J. Donoghue

15:15 – 15:30 **Skulls, genes, and deep time: total evidence dating in cetaceans**
Laura Mulvey, Joseph Minus, Guatavo A. Ballen and Mario dos Reis

Session 3b (14:00 – 15:30)
(Mathematical Institute L2) Chair: Piyush Sriwastava

14:00 – 14:15 **Exceptional three-dimensional cellular preservation of enigmatic macrofossils from the Proterozoic of Australia**
Brooke Johnson, Russell J. Garwood, Leon Bowen, Martin R. Smith, Rosalie Tostevin, Stuart Robinson and Nicholas J. Tosca

14:15 – 14:30 **New Ediacaran triradial animal illuminates the origins of ctenophores and cnidarians**
Xiaopeng Wang, Alexander G. Liu, Giovanni Mussini, Frances S. Dunn, Erik Tihelka, Ke Pang, Zhe Chen, Chuanming Zhou and Bin Wan

14:30 – 14:45 **A phylogenetically diverse deuterostome fauna from the late Ediacaran Jiangchuan Biota**
Gaorong Li, Peiyun Cong, Fan Wei, Yang Zhao, Frances S. Dunn, Ross P. Anderson, Imran A. Rahman and Luke A. Parry

14:45 – 15:00 **Three vanes, two species, one problem: a reappraisal of *Pteridinium***
Phillip C. Boan, Chengxi Wu, Danielle Fitzgerald, Marc Laflamme, Orin Lole Durbin, Zhe Chen, Ke Pang and Shuhai Xaio

15:00 – 15:15 **The evolution of Ediacaran morphological disparity**
Thomas J. Roper-Smith, Luke A. Parry and Frances S. Dunn

15:15 – 15:30 **A revisionist interpretation of early spiculate sponges**
Nicholas J. Butterfield and Jago Goodband

Session 3c (14:00 – 15:30)
(Mathematical Institute L3) Chair: Corentin Jouault

14:00 – 14:15 **Pollination ecology of wasps and bees from the paratropical Eocene of northwestern Europe**
Loup Boudet, Christian Geier, Friðgeir Grímsson, Michael Engel, Johannes Bouchal, Silvia Ulrich, Torsten Wappler and Sonja Wedmann

14:15 – 14:30 **How consistent is the genome size – guard cell length relationship across major land plant clades?**
Hannah Morck and Phillip E. Jardine

14:30 – 14:45 **Arboreality in a Middle Jurassic cladotherian mammal from the Kilmaluag Formation of the Isle of Skye**
James R. G. Rawson, Elsa Panciroli, Luke E. Meade, Stig Walsh, Roger B. J. Benson and Richard J. Butler

14:45 – 15:00 **The Clarkia biota: an exceptionally preserved Miocene lake ecosystem**
Joshua W. Turner and Nicholas J. Butterfield

15:00 – 15:15 **Complex biogeographical patterns revealed by new species of fossil snakes from the Oligo-Miocene of South America**
Andres F. Alfonso-Rojas and Jason J. Head

15:15 – 15:30 **Integrated micropalaeontological constraints on the age and palaeoenvironmental evolution of Late Miocene sediments in the Niger**
Helen-Gloria Nwachukwu and Fortune Chiazor

15:30 – 15:55 **Break (catered)**
(Mathematical Institute Mezzanine)

AGM

(Mathematical Institute L1)

15:55 – 16:30 **Annual General Meeting**
We encourage all Association members to attend

Annual Address

(Mathematical Institute L1)

16:30 – 17:30 **Annual Address: The shape of life: a deep-time perspective**
Anjali Goswami

Annual Dinner

(Merton College)

19:00 – 22:30 **Annual Dinner**

Thursday 10th December

Underlined author is the presenter.

Registration

08:30 – 17:30 Mathematical Institute Mezzanine

08:30 – 08:50 **Tea/coffee/pastries** (Mathematical Institute Mezzanine)

Conference

Session 4a (09:00 – 10:30)
(Mathematical Institute L1) Chair: Thomas Roper-Smith

09:00 – 09:15 **Assessing ecological partitioning in the first marine turtles (Thalassochelydia) using stable oxygen isotopes**
Chloe Mazier, Romain Amiot, Jeremy E. Martin, Arnauld Vinçon-Laugier and Jeremy Anquetin

09:15 – 09:30 **Does body size dictate evolutionary rates? Insights from plesiosaur evolution**
Ruizhe Jackevan Zhao and Chi Zhang

09:30 – 09:45 **Latest Cretaceous Laramidian terrestrial communities underwent climatic changes, functional diversity shifts and diversification**
Cassius Morrison, Nicolas A. Stagg, Chance Guest, Evan Wright, Charlie R. Scherer, Steven J. R. Allain, Marc Laflamme, Robin Beck and Benjamin J. W. Mills

09:45 – 10:00 **Ecological reconstruction of the earliest terrestrial predators via digital fossil mining**
Ryo Taniguchi, Yasuhiro Iba, Kanta Sugiura, Aya Kubota, Matthew Humpage, Sophie Burne, Shintaro Sasaki, Mehmet Oguz Derin, Harufumi Nishida and Alexander J. Hetherington

10:00 – 10:15 **The effect of cranial ornamentation on the feeding biomechanics of large theropod dinosaurs**
Lavanya Ralhan, Harrison J. Willoughby, Emily J. Rayfield and Andre J. Rowe

10:15 – 10:30 **Large-bodied mammals explored novel jaw ecomorphologies through the Cenozoic and exhibited increased rates of trait evolution**
Gemma Louise Benevento, John T. Clarke, Matt Friedman, Susanne A. Fritz and Roger B. J. Benson

Session 4b (09:00 – 10:30)
(Mathematical Institute L2) Chair: Sofía Galván

09:00 – 09:15 **Before Mary Anning: did a (proto-)scientific form of palaeontology exist in Ancient Egypt?**
Marwan Kilani and Lauren Dogaer

09:15 – 09:30 **A comprehensive phylogenomic framework for brachiopod evolution among lophotrochozoans**
Mingzhu Yang, Aodhán D. Butler, Natalia López Carranza, Jakob Vinther, Rowan J. Whittle, Daniela Henkel, Hana Jurikova, Gert Wörheide, Mattia Giacomelli, Philip C. J. Donoghue, Davide Pisani, Sandra J. Carlson and Erik A. Sperling

09:30 – 09:45 **Character evolution in fossil non-radial echinoderms**
Lucy Jackson, Frances S. Dunn, Andrew Meade, Martina Nohejlová, Chris Venditti, Samuel Zamora and Imran A. Rahman

09:45 – 10:00 **Redescription of *Priapulites konecniorum* from the Mazon Creek Lagerstätte validates a calibration for crown-group Priapulida**
Thomas P. Farrell, Luke A. Parry, Gregory D. Edgecombe, Tae-Yoon S. Park and Jakob Vinther

10:00 – 10:15 **One model to segment them all: AmberSAM for automated 3D segmentation of amber arthropods**
Corentin Jouault, Ancheng Peng, Mathieu Boderau, Jonathan Perrin, Frédéric Legendre and Shihan Guan

10:15 – 10:30 **Unlocking the origins of spiders: 3D-preserved Carboniferous arachnids from the Montceau-les-Mines Lagerstätte**
Camille Vidal-Marty, Russell J. Garwood, Jason A. Dunlop and Vincent Perrier

Session 4c (09:00 – 10:30)
(Mathematical Institute L3) Chair: Cooper Malanoski

09:00 – 09:15 **Macroevolutionary patterns of cephalic mechanical resistance in early Palaeozoic trilobites**
Alejandro González-Cloquells, Jordi Marcé-Nogué and Jorge Esteve

09:15 – 09:30 **Ammonoid extinction and nautilid survival at the end-Cretaceous: what has hatching size got to do with it?**
Michael Schmutzer, Erin E. Saupe, Christian Klug, Amane Tajika, Frank Wiese, James D. Witts, Corinne Myers, Neil H. Landman, Stijn Goolaerts and Alison J. Rowe

09:30 – 09:45 **High evolutionary turnover of fusulinids during the late Palaeozoic ice age**
Shu-han Zhang, Wolfgang Kiessling, Yu-Kun Shi, Xiang-Dong Wang, Jun-Xuan Fan and Shu-Zhong Shen

09:45 – 10:00 **Deep-sea ostracod faunal change from the Late Cretaceous to the Early Miocene**
Yumeng Wei and Moriaki Yasuhara

10:00 – 10:15 **Quantifying metazoan locomotion**
Harry Savage, Luke A. Parry, Thomas J. Roper-Smith, Jane Reeves, William Sellers and Russell J. Garwood

10:15 – 10:30 **From ambiguity to information: accounting for intraspecific polymorphism in morphological phylogenetics**
Walker Sexton, Sebastian Höhna and Joëlle Barido-Sottani

10:30 – 11:00 **Break (catered)** (Mathematical Institute Mezzanine)

Session 5 – President's Prize (11:00 – 12:30)
(Mathematical Institute L1) Chair: Ricardo Pérez-de la Fuente

Talks in this session have been shortlisted for consideration for the President's Prize.

11:00 – 11:15 **From phylogeny to palaeoecology: what conifer wood anatomy reveals about Cordaitales**
Katherine Bober and Anne Raymond

11:15 – 11:30 **Evolutionary and ontogenetic trends in skull shape underpinned theropod dinosaur ecology**
Charlie R. Scherer, Paul M. Barrett, Stephen L. Brusatte and Paul Upchurch

11:30 – 11:45 **Ichthyosaurs from the Middle Jurassic of the Isle of Skye, Scotland**
Molly Tumelty, Stig Walsh, Stephen L. Brusatte, Davide Foffa, Erin Maxwell and Nicholas Fraser

11:45 – 12:00 **Reptilian domination' in Pleistocene Australia and limited human impacts on competition among its megafaunal carnivores**
Adam Lindholm and Roger A. Close

12:00 – 12:15 **From Caribbean apex predator to Cuban remnant: Holocene range collapse of Crocodylus rhombifer informs its future conservation**
Sachin Bhardwaj Lock, James P. Hansford, Samuel T. Turvey, Lazaro W. Viñola-López, Rachel E. Narducci, Advait M. Jukar and Philip D. Mannion

12:15 – 12:30 **Disentangling oxygen and temperature as controls on extinction risk in marine invertebrates over the Phanerozoic**
Cooper M. Malanoski, Richard G. Stockey, Benjamin J. W. Mills and Erin E. Saupe

12:30 – 13:00 **Poster Session 2**
(Mathematical Institute Mezzanine)

13:00 – 14:00 **Lunch (catered)**
(Mathematical Institute Mezzanine)

13:15 – 14:00 **LGBTQ+ Meeting**
(Mathematical Institute L3)

Session 6a – Council Lightning/Flash Talk Prize (14:00 – 15:00)
(Mathematical Institute L1) Chair: Frances Dunn

Talks in this session have been shortlisted for consideration for the Council Lightning/Flash Talk Prize.

14:00 – 14:05 **Testing the phylogenetic affinities of Archaeocyatha and Chancelloriida within a comprehensive morphological framework of Porifera**
Linjun Zou, Davide Pisani and Philip C. J. Donoghue

14:05 – 14:10 **Mosaic pattern of morphological change in the cranidia and pygidia of Remopleurididae Hawle & Corda (1847) (Trilobita)**
Jesús María Dorado, Fernanda Serra, Daniela S. Monti, Jorge Esteve and Diego Balseiro

14:10 – 14:15 **A Chengjiang-like biota from the Early Cambrian of western Canada**
Giovanni Mussini, Francesco Izzo and Nicholas J. Butterfield

14:15 – 14:20 **An ichnological bridge between two radiations: diverse trace fossils from the middle–late Cambrian of North Wales**
Yorick P. Veenma and Neil S. Davies

14:20 – 14:25 **Reconstructing the postcranial anatomy and locomotion of ostracoderms using X-ray microtomography**
William Newton, Emily J. Rayfield, Elizabeth Martin-Silverstone, Lisa Schnetz, Russell J. Garwood and Robert S. Sansom

14:25 – 14:30 **The thermometabolism of pseudosuchians: a study of phylogenetic comparative methods**
Cassandra Cheyron, Mathieu G. Faure-Brac, François Clarac, Ángela D. Buscalioni, Mercedes Llandres, Isabelle Drouet and Jorge Cubo

14:30 – 14:35 **Biotic succession and palaeoenvironmental change in the Jiufengshan record of the Jehol Biota, Northeast China**
Yan Xue, Daran Zheng, Xiangdong Zhao, Xiao Teng, Xin Zhang, Peihan Liu, Siyu Song, Rui Fang and Gang Li

14:35 – 14:40 **Exploring the correspondence between the brain and the endocranial cavity in sauropsids**
Amelia D. Mead, Edward L. Stanley, Akinobu Watanabe, Paul M. Gignac, Adam Manning, Lawrence M. Witmer, Pavel Nemec, Mathias Osvath and Stephen L. Brusatte

14:40 – 14:45 **Dinosaurian basipterygoid processes (braincase elements): anatomy and evolution**
Annabel K. Hunt, Stephen L. Brusatte and Daniel J. Field

14:45 – 15:00 **Questions**

Session 6b – lightning/flash talk session (14:00 – 15:00)
(Mathematical Institute L2) Chair: Alison Cribb

14:00 – 14:05 **New organic-walled microfossil assemblage from the 1.8-billion-year-old Rove Formation, Animikie Group, Canada**
Sanaa Mughal, Daniela Gutierrez Rueda, Baptiste Coutret, Achyuth Venugopal, Zhiquan Li, Philip W. Fralick, Simon W. Poulton, Ross P. Anderson and Kurt O. Konhauser

14:05 – 14:10 **Pliocene ecosystems at Chinchilla (Queensland, Australia): insights from large herbivores**
Oscar E. Wilson, Caitlin Syme and Julien Louys

14:10 – 14:15 **Low-latitude within-area speciation drove early trilobite bioregionalization**
Elizabeth M. Dowding, Adriane R. Lam, Luis Collantes, James D. Holmes, Katherine Jordan-Burmeister, Harriet B. Drage, Lukáš Laibl, Kelsey Lucas and M. Gabriela Suárez

14:15 – 14:20 **Metazoan diversification characterized by elevated rates of evolution during the middle Ediacaran to earliest Cambrian**
Zhiqing Guo, Thomas J. Roper-Smith, James Clark, Jordi Paps, Ruolin Wu, Davide Pisani and Philip C. J. Donoghue

14:20 – 14:25 **Gut morphology and preservation in trilobites from the Fezouata Shale**
Francesc Pérez-Peris, Sarah R. Losso, Bruno Becker-Kerber and Javier Ortega-Hernández

14:25 – 14:30 **Low background oxygen enabled aerobically selective extinction during the Late Ordovician mass extinction**
Pedro Monarrez, Evren Arif, Alexandre Pohl, Richard G. Stockey, Jood Al Aswad, Ryan Yohler, Seth Finnegan and Erik A. Sperling

14:30 – 14:35 **Heliolitids as analogues for modern reef corals: a case study from the Devonian of Queensland**
Jan J. Król, Mikołaj K. Zapalski, Błażej Berkowski and John W. Pickett

14:35 – 14:40 **Quantifying changes in ammonoid morphological disparity during the Late Devonian**
Ninon Allaire, Néo Nicollet, Samuel Ginot, Dieter Korn, Claude Monnet and Catherine Crônier

14:40 – 14:45 **Macroevolutionary shift in early ray-finned fishes associated with the Devonian–Carboniferous transition**
Sam Giles, Emily M Troyer, Zach Lyons-Weiler, Rodrigo Tinoco Figueroa, Ben Igielman, Richard P. Dearden, Abigail Caron, Michael I. Coates, Stephanie E. Pierce and Matt Friedman

14:45 – 15:00 **Questions**

Session 6c – lightning/flash talk session (14:00 – 15:00)
(Mathematical Institute L3) Chair: Michael Schmutzer

14:00 – 14:05 **Trajectories of taxonomic and functional diversity of marine organisms across the Permo-Triassic extinction and radiation**
Clare Liedstrand, Rachel Wood and Amelia Penny

14:05 – 14:10 **Beyond the cuticle: hidden internal anatomy in Mesozoic terrestrial arthropods**
Shengyu Wang, Xuheng Du, Ross P. Anderson, Zixiao Yang, Baoyu Jiang, Haichun Zhang and Bo Wang

14:10 – 14:15 **Three-dimensional mineralized skin in Triassic drepanosaurs from Italy**
Valentina Rossi, Giovanni Serafini and Davide Foffa

14:15 – 14:20 **DinoSAW experimental biomechanical system: testing the cutting efficiency of ziphodont teeth in theropod dinosaurs**
Manabu Sakamoto and Philip S. L. Anderson

14:20 – 14:25 **Mapping stomatal variation in the Cretaceous conifer *Frenelopsis*: insights into ecophysiology and taxonomy**
Axel Montigny, Bernard Gomez, Véronique Daviero-Gomez and Christophe Lecuyer

14:25 – 14:30 **Taste of change: floral turnover and the restructuring of herbivore communities before the K-Pg extinction in the Hell Creek Formation**
Nicolas A. Stagg, Chance Guest, Evan Wright, Charlie R. Scherer, Robin Beck, Cassius Morrison and Haytham El Atfy

14:30 – 14:35 **Environmental heterogeneity and contrasting oyster-bank-associated molluscan communities from the Eocene of western India**
Adrisuta Ghosh, Shiladri S. Das and Kanishka Bose

14:35 – 14:40 **A niche modelling approach adapted to small datasets**
Pauline Guenser, Alexandre Pohl, Mathéo Leroy, Dominik Hülse and Grégory Beaugrand

14:40 – 14:45 **Lyell in Chicago: a historic collection illuminates a missing chapter in nineteenth century geology**
Roy E. Plotnick, Pamela McIntyre and Rachel Krick

14:45 – 15:00 **Questions**

15:00 – 15:30 **Break (catered)**
(Mathematical Institute Mezzanine)

Session 7 (15:30 – 17:00)
(Mathematical Institute L1) Chair: Erin Saupe

15:30 – 15:45 **Episodic body size variations in early Palaeozoic trilobites linked to marine redox changes**
Zhixin Sun, Fangchen Zhao, Han Zeng, Douglas H. Erwin and Maoyan Zhu

15:45 – 16:00 **An early Cambrian mosaic stem-euarthropod sheds light on the origin of arthropodized trunk appendages**
Yu Wu, Stephen Pates, Cong Liu, Yuheng Wu, Chenguang Guo, Xingliang Zhang and Dongjing Fu

16:00 – 16:15 **Biogeochemical consequences of benthic ecosystem engineering in the aftermath of the end-Permian mass extinction**
Alison T. Cribb, Richard G. Stockey, Aspen Sartin, Bethany J. Allen, Pedro Monarrez and Dominik Hülse

16:15 – 16:30 ***Rhyniognatha* revisited: rethinking the oldest 'insect'**
Emma J. Long, Gregory D. Edgecombe, Markus Koch and Xiaoya Ma

16:30 – 16:45 **Rapid evolution of mammalian brain shape preceded encephalization in the Late Cretaceous**
Andrew Knapp, Ryan Marek, Ornella Bertrand, Madlen Lang, Alberto Boscaini, Eli Amson, Quentin Martinez, Deborah Nganga and Ryan Felice

16:45 – 17:00 **Back to the water – coordinated evolution of the inner ear and cervical spine in aquatic carnivorans**
Julia A. Schwab, Thomas M. B. Kirkwood, Stephanie M. Palmer, Amandine Gillet, Stephanie E. Pierce and Katrina E. Jones

Closing business

(Mathematical Institute L1)

17:00 – 17:15 **Presentations by ProgPal27 and PalAss27 committees**

17:15 – 17:30 **Awards and closing remarks**

Quiz

(Museum of Natural History Lecture Theatre)

18:00 – 19:30 **Informal PalAss Quiz**

Friday 11th December

Post-conference field-trip

(Departure and return: Oxford University Museum of Natural History)

08:15 – 17:30 **Jurassic of Oxfordshire**
Lead: Dr Duncan Murdock

This is a separate ticketed event that participants must have selected and paid for during online registration.

Annual Address

The Annual Address will be given on Wednesday 9th December in Mathematical Institute L1, from 16:30 to 17:30, following the AGM.

The shape of life: a deep-time perspective

Prof. Anjali Goswami FRS
Natural History Museum, London, UK

Why do some species survive extreme changes in their environment and quickly exploit new opportunities, while others are consigned to the fossil record? Why do some diversify into highly varied forms, while others potter along at low numbers, seemingly unchanged for millions of years? Why do groups that dominate global ecosystems disappear suddenly, allowing minor players to take the lead? As we enter a period of unprecedented environmental change, lessons from the past have never been more important. In this talk I will explore the evolutionary paths that have shaped life on Earth over hundreds of millions of years. With examples spanning single-celled organisms to dinosaurs, I will explain how my lab's research uses new technologies, especially imaging and AI, to piece together the pace of evolutionary change across diverse species and to understand what determines which ones can keep up.

Abstracts of Symposium presentations

Deep time insights into major evolutionary transitions

Underlined author denotes designated speaker.

The rise of terrestrial animals

Russell J. Garwood
The University of Manchester, UK; Natural History Museum, London, UK

The transition from living in the oceans to living on land – terrestrialization – is a key event in the evolutionary history of animals, and life more broadly. The majority of known species are terrestrial arthropods, the terrestrialization of vertebrates was a key step in our own evolutionary history, and the development of terrestrial ecosystems has fundamentally reshaped the Earth's biosphere. Terrestrialization has occurred independently across multiple animal lineages since the Palaeozoic. In this talk, I will provide an overview of: the challenges posed by living on land; the trace and body fossil record of terrestrial animals; the timing of terrestrialization in key clades; and major events in the development of land ecosystems. I will highlight some of the latest research on terrestrialization, and discuss future research directions with the potential to help us better understand these transitions, their impacts, and their broader significance for understanding evolution itself.

Tuesday 8th December, Symposium, Mathematical Institute L1, 16:45 – 17:15.

Life before eukaryotes

Kurt O. Konhauser
University of Alberta, Canada

Macroscopic life did not evolve in isolation. Every complex organism owes its existence to an ancient microbial biosphere that spent billions of years altering the Earth's surface and atmosphere. The earliest chapters of evolutionary history span from the emergence of the first bacteria to the geochemical shifts that ultimately permitted eukaryotic cells to arise. During the Archean, early anaerobic microbes persisted on a volatile, anoxic planet through primitive metabolic pathways. A pivotal innovation later transformed this early biosphere: the evolution of oxygenic photosynthesis in cyanobacteria. The capacity to utilize water as an electron donor fundamentally reshaped planetary chemistry. This metabolic breakthrough drove the Great Oxidation Event, a profound transition that disrupted existing anaerobic ecosystems while creating high-energy aerobic niches. Adapting to an oxygenated world established the ecological and metabolic foundations necessary for endosymbiosis and the origin of eukaryotes. Understanding these early prokaryotic dynamics provides the essential evolutionary context for the subsequent diversification of complex organisms.

Tuesday 8th December, Symposium, Mathematical Institute L1, 13:45 – 14:15.

Constraining the environmental conditions of early eukaryote evolution: fossils from the middle Proterozoic Greater McArthur Basin, northern Australia

Maxwell A. Lechte[1], Leigh Anne Riedman[2], Susannah M. Porter[2], Galen P. Halverson[3] and Margaret Whelan[3]

[1]The University of Sydney, Australia; [2]University of California, Santa Barbara, USA; [3]McGill University, Canada

The innovation of the eukaryotic cell represents one of the most important biological transitions in Earth's history, facilitating the evolution of large, complex, multicellular life. Despite major advances into this process from studies of the genomes of living microbes, only geology can provide information about extinct lineages. However, the nature of the oldest eukaryotes in the fossil record remains enigmatic, and the role of oxygen in driving eukaryote evolution is particularly controversial, given their emergence in a time when marine environments were largely anoxic. To constrain the environmental conditions of the habitats of these early eukaryotes, we studied the mid-Proterozoic geological record of the Greater McArthur Basin (Northern Territory), including the oldest-known eukaryote microfossils. Our integrated palaeontological, sedimentological and geochemical study showed that although fossil eukaryotes were found in samples from a range of environments from coastal to offshore, they are almost entirely restricted to those with oxygenated bottom waters. This distribution suggests that early eukaryotes were aerobes (obligate, facultative or microaerophilic), placing a key constraint on the nature of these organisms. Given the diversity and complexity of these eukaryote ecosystems, we suggest that this also implies that eukaryotes had acquired mitochondria by this time. Overall, this study shows how oxygen has long shaped the course of eukaryote evolution, and may support models wherein eukaryogenesis was driven by the Great Oxidation Event.

Tuesday 8th December, Symposium, Mathematical Institute L1, 14:15 – 14:45.

Life on the edge: vegetated coastal wetlands before flowering plants

Brennan O'Connell

University of Cambridge, UK; University of Vienna, Austria

Vegetated coastal wetlands provide nursery habitat, support biodiversity, and are Earth's most efficient blue carbon sink. Knowing when these ecosystems first emerged is critical for reconstructing global carbon cycling, halophyte evolution and coastal ecosystems through geological time. Yet, the evolutionary history of coastal wetland ecosystems is unresolved. The prevailing model is that vegetated coastal wetlands emerged with the evolution of flowering plants (angiosperms) in the Cretaceous, ~100 million years ago. This model is largely based on the dominance of angiosperms in coastal wetlands today. But what if plants could colonize coastlines long before angiosperms evolved? In this talk, I will test an alternative hypothesis that vegetated coastal wetlands existed as early as the Carboniferous. Evidence includes *in situ* plant material along tidal channel margins and interbedded with tidal-flat sedimentary deposits. These deposits preserve tidal rhythmites, desiccation cracks, bidirectional ripples, and flaser, wavy and lenticular bedding. Trace fossils indicating marine or brackish conditions, together with elevated sulphur contents in the sediment, provide further evidence of marine influence. These findings suggest that salt-tolerant vegetation grew along intertidal and supratidal coastlines during the Carboniferous. This would push the origins of vegetated coastal wetlands back by more than 200 million years, roughly tripling their inferred age. Vegetated coastlines may therefore have helped shape Earth's climate and the evolution of life long before angiosperms evolved.

Tuesday 8th December, Symposium, Mathematical Institute L1, 16:15 – 16:45.

talks

Deciphering feeding in the precursors of jawed vertebrates using 3D imaging

Lisa Schnetz[1,2], Richard P Dearden[1], Héctor Botella[3], Francisco Huera-Huarte[4], Andy S Jones[5], Agnese Lanzetti[6], Stephan Lautenschlager[1,5], Kathleen Dollman[7], Vincent Fernandez[7], Sam Giles[1,5,6], Zerina Johanson[6] and Ivan J. Sansom[1]

[1]University of Birmingham, UK; [2]Natural History Museum Vienna, Austria; [3]University of Valencia, Spain; [4]Universitat Rovira i Virgili, Spain; [5]Lapworth Museum of Geology, Birmingham, UK; [6]Natural History Museum, London, UK; [7]European Synchrotron Radiation Facility, Grenoble, France

Re-engineering of the vertebrate head to accommodate jaws in support of feeding and ventilation is a crucial transition in early vertebrate history, resulting in the dominance of jawed vertebrates in past and present ecosystems. Extant jawless vertebrates in contrast only comprise a miniscule proportion of modern vertebrate diversity. However, jawless stem-gnathostomes dominated the vertebrate fossil record prior to the end-Devonian. They play a pivotal role in examining the early evolution of vertebrates but the reasons for their initial success are poorly understood. Little is known about their feeding structures, which limits our understanding of the evolution of the vertebrate head. Using CT and synchrotron tomography, we visualize complex anatomical features in the oral regions of heterostracans, the most diverse stem-gnathostome group. Our results indicate that at least some heterostracans were microphagous suspension feeders. Additional hydrodynamic studies reveal complex morphological adaptations to further enhance this feeding behaviour. The discovery of extensive oral structures in these heterostracans improves our understanding of the evolution of early gnathostome feeding. Rather than increased predation as proposed by the New Head Hypothesis, feeding strategies in jawless stem-gnathostomes may instead reflect increasing nektonic activity in the Late Silurian and early Devonian as part of the Nekton Revolution.

Tuesday 8th December, Symposium, Mathematical Institute L1, 15:45 – 16:15.

The coevolution of animals and seafloor bioturbation

Lidya G. Tarhan and Kate H. Pippenger

Yale University, USA

Bioturbation, sediment mixing and ventilation by burrowing animals, is one of the foremost examples of ecosystem engineering and shapes modern seafloor ecology, sediment properties and global marine biogeochemical cycling. Bioturbation is primarily recorded by homogenized sediments of the seafloor mixed layer and the discrete and commonly deep burrows of the underlying transition layer. Although these two zones can be readily measured today, there has been limited understanding of how the mixed and transition layers evolved – and the extent to which their trajectories have been decoupled – over the Phanerozoic. Using sedimentological data and a new burrow depth dataset, we describe the Phanerozoic coevolution of the sedimentary mixed and transition layers. We find that deepening of the mixed layer likely spanned hundreds of millions of years. In contrast, a deep transition layer was established as early as the Cambrian and did not further deepen until the Mesozoic. We also document evidence for onshore–offshore expansions in the depth of both the mixed and transition layers, mirroring evolutionary trends previously described from body fossil and ichnodiversity records. We attribute these patterns in mixed and transition layer development to marine evolutionary radiations, changes in nutrient cycling and shifts in oxygen bioavailability.

Tuesday 8th December, Symposium, Mathematical Institute L1, 14:45 – 15:15.

Abstracts of oral presentations

* Candidates for the President's Prize are marked with an asterisk
Underlined author denotes designated speaker.

Biting through life: an evolutionary tale of ornithischian dental sierras and jaw biomechanics

Isaura Aguilar Pedrayes, David J. Button, Emily J. Rayfield and Michael J. Benton
University of Bristol, UK

Ornithischian dinosaurs evolved different craniodental adaptations for herbivory, yet many trended towards posterior bites. Previous studies have suggested a link between increased dental surface complexity, posterior bite efficiency and dental batteries. The latter evolved independently at least twice in cerapodan ornithischians. Here we test for the first time whether bite efficiency and dental batteries directly affected dental surface complexity in ornithischians across phylogenetic and temporal contexts. We measure both toothrow surface complexity and average tooth complexity with the orientation patch count rotated method and test these hypotheses with phylogenetic comparative methods. Our research confirms that higher posterior bite efficiency does directly correlate with higher toothrow surface complexity, but not with average tooth surface complexity. However, this finding is dependent on phylogeny. Surprisingly, dental batteries do not correlate with dental surface evolution. Yet, we do see an increase in dental complexity from species without dental batteries to species with one-row dental batteries to species with multirow dental batteries. Additionally, we detect a trend toward higher toothrow complexity in Ornithischians, except in Thyreophora, in a macroevolutionary context. Our results suggest bite efficiency drove ornithischian toothrow evolution, and each lineage accommodated this change with different cranial adaptations.

Wednesday 9th December, Session 1a, Mathematical Institute L1, 09:45–10:00.

Complex biogeographical patterns revealed by new species of fossil snakes from the Oligo-Miocene of South America

Andres F. Alfonso-Rojas and Jason J. Head
University of Cambridge, UK

The Miocene of South America represents a pivotal interval in the establishment of modern snake faunas. By this time, several extant booid lineages including *Eunectes*, *Epicrates*, *Boa* and *Corallus* were already present, and fossils of colubroids, the most diverse clade of living snakes, had begun to appear across the continent. During the first two decades of the twentyfirst century, numerous Oligocene and Miocene localities in Bolivia, Peru, Colombia, Venezuela and Panama have yielded an expanding record of fossil snakes. Here we present multiple colubroid fossils, including a potential *Ninia*, as well as a new lineage of a widespread non-caenophidian alethinophidian snake. These colubroid fossils provide unambiguous support for molecular biogeographical hypotheses proposing the arrival of colubroids to South America from North America prior to the Miocene, with a potential dispersal route via Central America. The fossils also display a broad range of vertebral morphologies, indicating that colubroids were already a diverse clade by the Miocene, particularly within the Pebas system. Additionally, a new species of large-bodied

non-caenophidian snake recovered from multiple depositional environments across northern South America suggests the existence of an ecologically diverse lineage capable of dispersing from Andean settings to the Greater Antilles.

Wednesday 9th December, Session 3c, Mathematical Institute L3, 15:00–15:15.

Large-bodied mammals explored novel jaw ecomorphologies through the Cenozoic and exhibited increased rates of trait evolution

Gemma Louise Benevento[1,2], John T. Clarke[1,2], Matt Friedman[3], Susanne A. Fritz[1,2] and Roger B. J. Benson[4]

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Mammals radiated morphologically across the Cretaceous-Palaeogene (K-Pg) boundary. Morphological adaptations to the jaw, relating to feeding ecologies, increase in disparity during the Cenozoic. Mammal body mass also increases across the K-Pg boundary and is intrinsically linked to many aspects of a mammal's ecological niche, including their feeding ecology and therefore jaw morphology. Using continuous character traits for Jurassic-Eocene and Recent mammals, we analysed jaw ecomorphological disparity across small and large-bodied mammals using a principal component analysis and rates of jaw ecomorphological evolution across size classes using a metatree. We find that: large- and small-bodied mammals occupy different regions of function space, especially today; large-bodied mammals have displayed greater jaw ecomorphological disparity than small-bodied mammals since the K-Pg boundary; rates of evolution are higher in large-bodied mammals for at least some jaw ecomorphological traits; and after accounting for sampling, total jaw disparity is similar in the Eocene and today, but this reflects increased large-bodied and decreased small-bodied disparity between the Eocene and today. We show that small- and large-bodied mammals evolved unique sets of jaw ecomorphological traits throughout. Large-bodied mammals explored novel ecomorphologies after the Eocene, likely linked to novel ungulate feeding ecologies accompanying widespread grassland expansion.

Thursday 10th December, Session 4a, Mathematical Institute L1, 10:15–10:30.

High functional optimality in mammalian jaws revealed through theoretical morphologies

Harry Berks, Emily J. Rayfield and Philip C. J. Donoghue

University of Bristol, UK

The extraordinary diversity of mammalian lower jaws reflects adaptation to a wide range of ecologies and feeding strategies. However, it remains unclear whether these morphologies represent functionally optimal solutions. Theoretical morphologies provide an opportunity to evaluate biological structures free from evolutionary and developmental constraints, allowing assessment of whether alternative forms could outperform those found in nature. Here we use a 2D theoretical morphospace and optimality analysis to test whether mammalian mandibles have achieved optimal performance within the trade-off between bite strength and speed. We compare the jaws of 2,000+ extant and extinct mammal species with 500 theoretical jaw shapes. Functional performance was quantified using finite element analysis to estimate bite strength and rotational efficiency to estimate speed. These

metrics were combined using Pareto optimality ranking to identify regions of morphospace that maximize performance across the trade-off. Despite their extensive morphological and ecological diversity, mammalian jaws consistently occupy regions of high optimality. Our results reveal that mammalian mandible evolution has generally converged on highly efficient solutions within competing functional demands, highlighting the strong influence of feeding performance on the evolution of the mammalian jaw. This project was supported by a John Templeton Foundation Grant (JTF 62574) (to E.J.R. and P.C.J.D.; the opinions expressed in this article are those of the author and do not necessarily reflect the views of the John Templeton Foundation).

Wednesday 9th December, Session 3a, Mathematical Institute L1, 15:00–15:15.

From Caribbean apex predator to Cuban remnant: Holocene range collapse of *Crocodylus rhombifer* informs its future conservation

Sachin Bhardwaj Lock[1,2,3]*, James P. Hansford[4], Samuel T. Turvey[3], Lazaro W. Viñola-López[5], Rachel E. Narducci[6], Advait M. Jukar[6,7,8] and Philip D. Mannion[1]

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The Cuban crocodile (*Crocodylus rhombifer*) is today one of the most critically endangered and range-restricted extant crocodylian species. Its present endemism belies a recent history that saw its populations span the West Indies. Despite a rich fossil record, the chronology and causes of the species' decline over the course of the Holocene remain largely unknown. Using a holistic approach, incorporating data from the fossil record and historical archives into species distribution models, we disentangle the compounding factors that drove a formerly widespread species to the brink of extinction. Extinction chronology mapping strongly implicates anthropogenic drivers of extinction, suggesting extinction events correlating with the spread of Taíno peoples over the past millennium and accelerating following the arrival of Europeans in the late fifteenth century. With exceptions, the observed pattern of range collapse is generally consistent with the theory of island biogeography, with larger and less-isolated landmasses providing the most enduring refugia. Estimates of body sizes from Holocene specimens suggest patterns of evolution driven by insular biogeography, with smaller landmasses generally associated with smaller morphologies. New estimates for the upper limits of *C. rhombifer* body sizes suggest the necessity of a revision of our understanding of the species' palaeoecology. This longer-term approach to assessing threats to species survival can track extinction events and anthropogenic forces across much longer timescales than are usually considered in conservation, contributing novel baselines for species status, an increased understanding of extinction dynamics, and a more robust assessment of species vulnerability and resilience to human pressures.

Thursday 10th December, Session 5, Mathematical Institute L1, 12:00–12:15.

talks

Functional significance of tubular enamel in extinct Rhynchocephalia: insights from extant uromastycine lizards

Marco Bianchin[1], Daniel Marke[1], Marc E. H. Jones[2] and Aaron R. H. LeBlanc[1]
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Enamel is composed almost entirely of mineral, making it the hardest vertebrate tissue. However, in rare cases, some taxa have evolved enamel caps that are perforated by a network of organic tubules. This feature occurs in some early fossil mammals and marsupials, but we report here on similar features in extinct and extant rhynchocephalians, and in several groups of extant acrodontan lizards. Given that this feature has evolved convergently in lineages with limited tooth replacement, we tested the hypothesis that tubular enamel serves to increase tooth sensitivity and the tooth's capacity to respond to heavy tooth wear. We evaluated this using synchrotron micro-CT, histology and electron microscopy in a sample of extant squamates and fossil rhynchocephalians. We established spiny-tail lizards (Uromastycinae) as the best extant model for enamel tubule formation and function, as their enamel and patterns of tooth wear most closely resemble extinct rhynchocephalians. Using an ontogenetic sample of uromastycines, we show that enamel tubules facilitate rapid tertiary dentine and bone infilling in response to severe attrition, protecting the pulp in non-replacing dentitions. Consequently, tubular enamel represents a key adaptation driving rapid pulp closure, enabling oligophyodont amniotes to maintain functional, lifelong dentition despite extreme wear.

Wednesday 9th December, Session 3a, Mathematical Institute L1, 14:15–14:30.

Cosmopolitanism during the Early Carboniferous (Tournaisian) in the context of Late Palaeozoic trends

Lila Blake*, Paul B. Wignall and Alexander M. Dunhill
University of Leeds, UK

The global Hangenberg Crisis (~359 Ma) marks a major Phanerozoic extinction event and was followed by an exceptionally slow recovery interval; marine biodiversity remained low for >20 million years. Here we examine the biogeographic dynamics of marine invertebrates across the Devonian-Carboniferous in relation to post-extinction recovery patterns. Using a series of biogeographic metrics on a dataset of 4,530 marine invertebrate genera, we identified two episodes of faunal cosmopolitanism: one in the Frasnian and another in the Tournaisian. A third potential cosmopolitanism episode in the Moscovian-Kasimovian is likely an artifact of restricted spatial sampling. Comparing the biogeographic connectedness values of newcomers, survivors, and all genera in the Famennian and Tournaisian indicates that post-Hangenberg faunal cosmopolitanism was driven by the selective extinction of endemics and the geographic expansion of survivors. Low β-diversity during the Tournaisian supports the idea of an ecologically undersaturated Early Carboniferous ecosystem in which there is a low degree of competition for niche space, and hence, weaker selection pressures, resulting in slower diversification rates. Additionally, β-diversity partitioning reveals that biodiversity was rebuilt slowly and sequentially, with richness gradients recovering before strong geographic differentiation. Additional factors, such as extreme environmental perturbations and palaeogeography, likely also contributed to delayed recovery.

Wednesday 9th December, Session 2, Mathematical Institute L1, 12:00–12:15.

Three vanes, two species, one problem: a reappraisal of *Pteridinium*

Phillip C. Boan[1], Chengxi Wu[2,4], Danielle Fitzgerald[1], Marc Laflamme[3], Orin Lole Durbin[1], Zhe Chen[4], Ke Pang[4] and Shuhai Xiao[1]

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The Ediacara biota comprises a suite of complex macroscopic organisms tentatively divided into subgroups such as rangeomorphs, dickinsoniomorphs and erniettomorphs. One of the most iconic and widespread erniettomorph genera is *Pteridinium*, a trifoliate organism composed of unornamented tubular modules. Two species are currently recognized within this genus: *P. simplex* and *P. carolinaensis*. However, there is ongoing debate over whether these represent separate species or taphonomic variants of one species. Here we examine *Pteridinium* specimens from the USA, China, Namibia, Canada, Australia and Russia that collectively span the last ~28 million years of the Ediacaran period. By examining module morphology, such as the marginal curvature and terminations, and relationships between vanes, we argue that *P. carolinaensis* and *P. simplex* are distinct species. These morphological differences imply distinct constructions, life modes, and potentially different ecological niches. Specifically, we agree with prior interpretations of *P. simplex* as partially infaunal, but we interpret *P. carolinaensis* as a recumbent epifaunal organism based on the angular relationship between vanes and observations of *in situ* specimens. Given the palaeogeographic and temporal distribution of *Pteridinium*, distinguishing *P. carolinaensis* from *P. simplex* has broad implications for interpretations of Ediacaran ecology and evolutionary history of these enigmatic organisms.

Wednesday 9th December, Session 3b, Mathematical Institute L2, 14:45–15:00.

From phylogeny to palaeoecology: what conifer wood anatomy reveals about Cordaitales

Katherine Bober* and Anne Raymond

Texas A&M University, USA

Palaeontologists routinely infer relationships among extinct organisms from a single durable tissue, without testing whether its traits record shared ancestry or ecological adaptation. If wood anatomy is to be used to classify fossil taxa, its characters should carry phylogenetic signal: a tendency for related taxa to resemble one another beyond chance. Using phylogenetic comparative methods (Blomberg's K, Pagel's λ, and the D statistic) on an established conifer phylogeny (Leslie *et al*. 2018), we tested for signal in tracheid, pit and ray traits across extant conifers. Most showed no detectable signal: only minimum and maximum pit diameter retained weak but significant signal under Blomberg's K, no continuous trait was significant under Pagel's λ, and among discrete traits multiseriate pitting was phylogenetically clustered. This is consistent with greater ecological or functional lability than phylogenetic constraint. A parsimony analysis of these characters across five conifer families and the extinct order Cordaitales produced an almost entirely unresolved consensus, consistent with the weak signal detected by the comparative analyses. These results caution against placing single-tissue fossil taxa by anatomy alone and suggest wood anatomy may track environment rather than ancestry: a hypothesis these results motivate and a possible route to Cordaitales palaeoecology.

Thursday 10th December, Session 5, Mathematical Institute L1, 11:00–11:15.

Pollination ecology of wasps and bees from the paratropical Eocene of northwestern Europe

Loup Boudet[1,2], Christian Geier[3], Friðgeir Grímsson[3], Michael Engel[4], Johannes Bouchal[3], Silvia Ulrich[3], Torsten Wappler[5,6] and Sonja Wedmann[1]

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Insect–plant interactions are a major component of modern ecosystems, and they were similarly important in past environments. Exceptionally preserved fossils from the Messel Lagerstätte in Germany provide a rare opportunity to study such past interactions directly. Using specialized sampling techniques, *in situ* pollen grains associated with fossil insects can be recovered, prepared for analysis, and then compared with pollen from extant plants. This approach provides new insights into the flower-visiting behaviour of 47-million-year-old crown wasps, scoliid wasps and bees. Crown wasps appear to have been sparse opportunistic flower visitors in the forested areas surrounding the palaeolake. In contrast, scoliid wasps and bees were important generalist pollinators. They searched for nectar or pollen from a wide range of flowering plants in both forested habitats and more open areas. Many of these fossil insects are closely related to extant taxa, and their inferred pollination ecology resembles that of related groups in present-day environments. The early Cenozoic is often regarded as a key interval in the development of modern ecosystems. The fossil evidence from Messel suggests that this was also true for the pollination ecology of wasps and bees. Funded in part by DFG grant to SW, project number 533185608, and in part by FWF grant DOI: 10.55776/P34303 to FG.

Wednesday 9th December, Session 3c, Mathematical Institute L3, 14:00–14:15.

A revisionist interpretation of early spiculate sponges

Nicholas J. Butterfield and Jago Goodband

University of Cambridge, UK

Sponges are the simplest of all animals and their biomineralized spicules figure centrally in the early fossil record. Because spicule morphology usefully tracks higher order relationships in extant sponges, this has long been the basis for the classification of fossil counterparts. Even so, there is a conspicuous clash between spicule form and spicule mineralogy across a broad swathe of Palaeozoic and early Mesozoic sponges: taxa long accepted as silica-biomineralizing hexactinellids – *e.g.* Cambrian *Protospongia* and *Calcihexactina*, Devonian *Mattaspongia*, Triassic *Naybandospongia* – are regularly preserved in calcite. Moreover, SEM-cathodoluminescence (SEM-CL) and electron backscatter diffraction (EBSD) analysis identify an underlying architecture and microstructure unknown in extant hexactinellids, but with intriguing similarities to the calcareous spicules of extinct 'heteractinids' – *e.g.* Cambrian *Eiffelia*, Silurian *Astraeospongium*, Carboniferous *Wewokella*. Heteractinids have long been viewed as stem-group calcareans based on their calcareous spicules, but these lack both the morphology and microstructures of extant counterparts. In view of molecular evidence for the reiterative evolution of spiculogenesis in siliceous sponges, we propose a second (now extinct) instance of carbonate-based spiculogenesis to accommodate this protospongiid/heteractinid lineage. The predominance of calcareous (if not calcarean) spicules in the early fossil record bears centrally on questions of early poriferan evolution.

Wednesday 9th December, Session 3b, Mathematical Institute L2, 15:15–15:30.

Digging deeper: piperock and the agronomic revolution in the Mahto Formation, Alberta, Canada

Baptiste Coutret[1], Scott Melnyk[2], Drew Brown[3], Kurt O. Konhauser[1] and Murray Gingras[1]
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The Cambrian Mahto Formation records an important interval of early Palaeozoic evolution in the Canadian Rocky Mountains. Stratigraphically, it is underlain by the Miette Group, which preserves some of North America's earliest shelly fossils, and is overlain by the Burgess Shale Lagerstätte, one of the world's most renowned Cambrian fossil assemblages. The marine sediments of the Mahto Formation record the vertical expansion of the animal colonization zone, a key step in the 'Agronomic Revolution'. Here we document a well-preserved piperock trace-fossil assemblage composed of *Diplocraterion* isp., *Rosselia* isp. and *Skolithos linearis*, which together provide insights into early animal–sediment interactions in high-energy nearshore sandstones. Trace fossils penetrate 15–20 cm into cross-bedded quartzose sands, demonstrating substantial sediment reworking within the shallow colonization zone beneath the sediment–water interface. Burrow-infill composition points towards distinct behaviours, including selective clay ingestion and localized vertical sediment advection, underscoring complex behavioural evolution. Our study also explores the paradox of dense burrowing without pervasive homogenization, highlighting the behavioural innovations in musculature and appendage development that enabled effective infaunal activity. Together, these observations position the Mahto Formation as a critical yet underappreciated succession bridging two of North America's most iconic windows into early animal evolution.

Wednesday 9th December, Session 1c, Mathematical Institute L3, 10:00–10:15.

Biogeochemical consequences of benthic ecosystem engineering in the aftermath of the end-Permian mass extinction

Alison T. Cribb[1,2], Richard G. Stockey[2], Aspen Sartin[2], Bethany J. Allen[3], Pedro Monarrez[4] and Dominik Hülse[5]
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Bioturbators are fundamental ecosystem engineers in benthic communities, as their sediment mixing behaviours influence key biogeochemical cycles. The catastrophic losses of bioturbators during the end-Permian mass extinction (EPME) have long been implicated in Early Triassic recovery. However, bioturbators and their ecosystem engineering effects are highly sensitive to local environmental conditions, so global narratives built on geographically biased fossil sampling are unlikely to capture the true heterogeneity of the consequences of Early Triassic bioturbators. Here we combine trace and body fossil data from continuous EPME sections from the Tethys, cGENIE Earth system model outputs, and reactive-transport models to simulate local sediment oxygen and organic carbon dynamics. First, we find that the severity of the assumed global bioturbation collapse varies dramatically across sites, ranging from near-total disappearance in some regions to minimal disruption in others. Second, we find evidence for benthic refugia where environmental conditions could physiologically support a complex infaunal community, but limited evidence that infaunal ecosystem engineers created refugia themselves. Ultimately, we find that these fossil records are significantly biased to a few regions with extremely contrasting

environmental conditions. These results caution against treating recovery in the aftermath of the EPME as a uniform, global process.

Thursday 10th December, Session 7, Mathematical Institute L1, 16:00–16:15.

When clustering fails: testing bioregionalization methods with realistic simulated bioregions

Liudas Daumantas and Andrej Spiridonov
Vilnius University, Lithuania

Bioregionalization methods are often evaluated using empirical datasets in which the underlying biogeographic structure is unknown, making their true accuracy difficult to assess. We developed an R-based simulation framework that imposes bioregional structures of known properties on real fossil-occurrence data. Using Miocene mammal occurrence data for the USA from the Paleobiology Database, the simulations preserve locality positions and numbers of occurrences per locality, thereby retaining the original spatial sampling structure, while approximately preserving taxon occurrence frequencies. The framework generates spatially explicit bioregions with user-defined binary hierarchical topologies and boundary strengths, while allowing constraints on minimum geographic size, numbers of localities and occurrences, and their compatibility with region size. We used these simulations to evaluate HespDiv, a recursive hierarchical bioregionalization method, against spatially constrained and unconstrained hierarchical cluster analysis using multiple linkage functions. Preliminary results show that cluster analysis performs unexpectedly poorly even for the simplest scenario of two bioregions separated by a strong boundary, irrespective of linkage function. HespDiv accurately recovers simple divisions, but errors emerge in more complex scenarios, particularly at second- and third-order hierarchical divisions. These simulations provide a direct way to quantify when bioregionalization methods succeed or fail under realistic sampling conditions. This study was supported by project S-MIP-24-62, 'BretEvoGeneralized'.

Wednesday 9th December, Session 1b, Mathematical Institute L2, 10:00–10:15.

TrajecTools, an R package to compare multivariate ontogenetic trajectories: insights into morphological convergence in ammonites

Aimie Doriath-Döhler[1,2], Isabelle Rouget[1], Nicolas Goudemand[2], Nour Helin[1], Sylvain Gerber[3] and Jérémie Bardin[1]
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Ontogenetic trajectories, defined as patterns of shape variation throughout development of an organism, have a central role in palaeo-evo-devo. They provide key insights into morphological covariations, allometries, heterochrony and the underlying morphogenetic and evolutionary mechanisms. Reconstructing these trajectories from current highly dimensional data, typically geometric morphometric data, however, requires approaches capable of capturing multivariate changes without restricting analyses to a small subset of dimensions, or to a global linear trend. TrajecTools is a new R package designed to enhance the study of multivariate ontogenetic trajectories. It provides functions for simulating trajectories, estimating trajectory local properties as well as quantifying and visualizing dynamics of those properties through ontogeny and among groups. Concrete

pipelines are formalized for main palaeo-evo-devo topics: characterization of ontogenies, recognition of ontogenetic stages and heterochronies, clusters detection. To illustrate the use of Trajectools, we dissect an example of morphological convergence between two Jurassic ammonite families, Cardioceratidae and Amaltheidae. By comparing changes in direction, morphospace occupation and variance of the trajectories through ontogeny, we assess whether convergence results from similar or distinct ontogenetic dynamics.

Wednesday 9th December, Session 1b, Mathematical Institute L2, 09:45–10:00.

Redescription of *Priapulites konecniorum* from the Mazon Creek Lagerstätte validates a calibration for crown-group Priapulida

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Dating the tree of life requires robustly justified fossil calibrations but identifying suitable calibrations can be challenging in entirely soft-bodied groups of organisms with sparse or uneven fossil records. Priapulida is a phylum of infaunal, marine ecdysozoan worms known today from only 22 species. Early Palaeozoic priapulidan fossils are well known, but none are suitable for dating the priapulidan crown-group because they lack priapulidan synapomorphies or are poorly resolved phylogenetically. The best candidate may be *Priapulites konecniorum*, from the Carboniferous-aged Mazon Creek Lagerstätte, USA. Despite its potential importance in bridging the temporal gap between Early Palaeozoic and Modern priapulidans, and its prior use as a calibration fossil for crown-group Priapulida, it has not been redescribed since 1977. This is concerning, because its described anatomy conflicts with a crown-group priapulidan affinity. Here we apply modern methods including digital macro photography and reflectance transformation imaging to new and previously described specimens. We illustrate previously undocumented anatomy in *Priapulites*, including the scalid morphology, ring papillae and longitudinal muscles and clarify the number of scalid rows. We confidently resolve its phylogenetic position, demonstrating that *Priapulites* is a member of crown-group Priapulidae, allowing it to be used as a calibration fossil with improved phylogenetic precision.

Thursday 10th December, Session 4b, Mathematical Institute L2, 09:45–10:00.

Macroevolutionary patterns of cephalic mechanical resistance in early Palaeozoic trilobites

Alejandro González-Cloquells[1], Jordi Marcé-Nogué[2] and Jorge Esteve[1]

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Biomechanics evaluates the mechanical behaviour and physical constraints of biological systems, yet its application to invertebrates remains limited. This study integrates plane finite element analysis (FEA) using quasi-ideal meshes (QIM) to evaluate the structural resistance of 304 trilobite cephala across Cambrian and Ordovician orders, testing the hypothesis that mechanical specialization expanded alongside ecological diversification. Interquartile ranges and the intervals method further complement FEA outputs by characterizing stress distribution patterns.Results show that Ordovician trilobites exhibit a

broader overall range of Von Mises stress than Cambrian taxa, indicating greater functional disparity. Benthic lifestyles (epibenthic, semi-infaunal and infaunal forms), display lower stress values and more uniform mechanical performance, whereas pelagic taxa exhibit significantly higher stress levels, potentially reflecting reduced environmental resistance. Despite substantial phylogenetic and size differences, pelagic Agnostida from the Cambrian and Asaphida and Proetida from the Ordovician show similar stress distributions, supporting early biomechanical optimization for swimming. Mechanical disparity associated with enrolment behaviours also increased during the Ordovician, particularly among discoidal and spheroidal morphotypes. Although plane FEA models capture macroevolutionary patterns effectively, morphological features such as genal and glabellar spines, as well as other disparities, may introduce biomechanical noise, highlighting the necessity of 3D modelling for specific biomechanical evaluations. This work is a contribution to projects PID2021-125585NB-I00 and CNS2024-154147 of the Ministerio de Ciencia e Innovación de España.

Thursday 10th December, Session 4c, Mathematical Institute L3, 09:00–09:15.

talks

Environmental heterogeneity predicts regional biodiversity across 500 million years of Earth history

Hanhui Huang[1]*, Tianyi Chu[2], Alex Farnsworth[3,4], Daniel J. Lunt[3], Paul J. Valdes[3] and Erin E. Saupe[1]

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Species and genus richness vary markedly across geographic space, yet the environmental processes underlying these biogeographic patterns remain unknown. The spatial variation in environmental conditions, or environmental heterogeneity, has long been proposed to promote regional richness, but evidence for this relationship comes predominantly from modern ecosystems. Here we test whether the regional richness of marine invertebrates is consistently associated with both the average level and spatial heterogeneity of environmental conditions across ~500 million years of Earth history. We integrated fossil occurrence data with Earth system model simulations to quantify genus- and species-level richness and the mean and heterogeneity of sea-surface temperature and salinity across shallow-marine regions. Generalized linear mixed-effects models showed that both the mean and heterogeneity of temperature consistently and significantly predict regional richness, whereas salinity heterogeneity showed no significant relationship with richness. These patterns were robust to alternative definitions of geographic regions and to different methods for estimating richness and environmental heterogeneity. Although thermal heterogeneity partly covaried with the latitudinal extent of regions, latitude had substantially weaker predictive power than thermal conditions, suggesting the observed relationship was not simply a consequence of regional geographic properties. Our results extend the positive association between environmental heterogeneity and biodiversity from modern ecosystems to deep time, and they provide evidence for the significant role of spatial thermal conditions in shaping richness patterns in marine organisms.

Wednesday 9th December, Session 2, Mathematical Institute L1, 11:45–12:00.

Character evolution in fossil non-radial echinoderms

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The fossil record of echinoderms (*e.g.* starfish, sea urchins) preserves many disparate extinct groups, for which phylogenetic relationships and character evolution are poorly understood. Ctenocystoids and cinctans are extinct groups that both possess flattened bodies with a marginal frame of plates. Ctenocystoids are bilaterally symmetrical to weakly asymmetrical and have no appendage while cinctans are asymmetrical and have a posterior 'stele'. Gen. et sp. nov. from the Czech Republic, described herein, uniquely possesses ctenocystoid features and a posterior appendage. To investigate the phylogenetic relationship cinctans and ctenocystoids, and the affinity of Gen. et sp. nov., we combined character matrices from two recent studies and analysed the resultant matrix of 40 taxa and 128 characters in the Bayesian software BEAST2. We recover a sister relationship between cinctans and ctenocystoids, with Gen. et sp. nov. nested within the ctenocystoid genus *Courtessolea*. Ancestral state reconstruction supports independent acquisition of asymmetry and a posterior appendage in cinctans and in Gen. et sp. nov., and a bilaterally symmetrical cinctan-ctenocystoid ancestor with no posterior appendage. This comprehensive phylogeny of ctenocystoids and cinctans shows that character evolution was rapid even amongst closely related non-radial Cambrian echinoderm groups during early diversification at the origin of the phylum.

Thursday 10th December, Session 4b, Mathematical Institute L2, 09:30–09:45.

Exceptional three-dimensional cellular preservation of enigmatic macrofossils from the Proterozoic of Australia

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Macroscopic fossils are rare in pre-Ediacaran rocks, and poor preservation can limit biological inferences and taxonomic placement. New pre-Ediacaran macrofossils allow us to probe the highly debated origin and early diversification of macroscopic organisms, and of multicellularity. Here we describe a new suite of macrofossils from the mid-Proterozoic (~1.4 Ga) of northern Australia. The fossils are preserved in clastic rocks as carbonaceous compressions, and as low relief mineralized moulds, with rare instances of *in situ* 3D organic matter exhibiting cellular preservation. Gross fossil morphology is of an ovoid frond and holdfast, with a host of unusual external and internal features. Together these suggest the fossils have a eukaryotic affinity, either as multicellular organisms, or as highly differentiated colonies. The fossils display an affinity for environments with dynamic redox gradients. In deep water settings the organisms were abundant enough to form distinct sedimentary fabrics, and acted as significant pathways for the burial of organic carbon, iron and phosphate. We present life reconstructions of the fossils and discuss their implications for the evolution of the Proterozoic biosphere. Finally, we discuss the

temporal range of this group and the implications of this discovery through a geobiological and astrobiological lens.

Wednesday 9th December, Session 3b, Mathematical Institute L2, 14:00–14:15.

One Model to segment them all: AmberSAM for automated 3D segmentation of amber arthropods

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Despite advances in semi-automatic segmentation of amber inclusions, tomography-based studies remain limited by the time-consuming process of manual segmentation. In amber µ-CT volumes, insect inclusions may have low contrast, be degraded, or be surrounded by bubbles, cracks and resin boundaries that mislead conventional and promptable segmentation tools. We present AmberSAM, a fossil-aware, extant-to-extinct framework for automated volumetric detection and segmentation of amber-preserved insects. To leverage abundant extant insect CT data despite scarce fossil annotations, we transformed 11,735 publicly accessible extant-insect CT volumes into pseudo-amber training data by embedding insect anatomy within amber-like intensity fields and artefacts. These volumes were used to train InsectFinder, a 3D detector that localizes inclusions and generates bounding-box prompts for a fine-tuned SAM2 segmentation module. We then applied the framework to a dataset of 377 synchrotron and laboratory X-ray CT scans comprising more than 500,000 slices, with 135 manually segmented specimens providing fossil-domain labels and reference masks. Across a heterogeneous test set, AmberSAM outperformed thresholding methods, random-forest classifiers, supervised volumetric networks, semi-automated tools, and unadapted SAM-series models. AmberSAM therefore offers a scalable route from raw museum tomography to reusable three-dimensional digital fossil specimens.

Thursday 10th December, Session 4b, Mathematical Institute L2, 10:00–10:15.

Food web dynamics determine extinction outcomes through the Phanerozoic

Baran Karapunar[1], Tanya Strydom[2], Andrew Beckerman[2], Annabel Nicholls[1], Catalina Pimiento[3], Pincelli Hull[4], Jennifer A. Dunne[5], Andy Ridgwell[6], Crispin T. S. Little[1] and Alexander M. Dunhill[1]

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Mass extinctions have repeatedly reshaped marine ecosystems, yet extinction rates have declined through the Phanerozoic and no hyperthermal event since the Mesozoic has produced a global marine biodiversity crisis. To investigate whether changes in community structure contributed to this trend, we reconstructed marine food webs from fossil occurrence and ecological trait data spanning the Phanerozoic. Marine trophic networks exhibit numerous phases of reorganization corresponding to key evolutionary transitions. Through time, food webs became increasingly connected and had more redundant nodes, characterized by higher levels of omnivory and longer food chains. These

shifts were particularly pronounced following the Permian-Triassic transition and during the ecological restructuring associated with the Mesozoic Marine Revolution. Network architecture strongly predicts extinction outcomes. During intervals, when communities had higher connectance and more generalist consumers, extinction rates were low, whereas elevated direct competition was associated with increased extinction rate. While most extinction and hyperthermal events reduced functional redundancy, Cenozoic communities displayed network structures linked to greater resilience despite continued environmental perturbation. Our results suggest that the long-term evolution of marine food-web structure fundamentally altered extinction dynamics, with increasingly complex ecological networks buffered against biodiversity loss and helping explain the declining severity of extinction events through geological time.

Wednesday 9th December, Session 1b, Mathematical Institute L2, 10:15–10:30.

Development of alligator thecodonty sheds light on evolution of archosaurian tooth implantation

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Thecodonty (socketed teeth) is widespread among amniotes and is best known from mammals and crocodilians. Crocodilians combine thecodonty with continuous tooth renewal, making them particularly relevant to the dinosaur–bird evolution: toothed birds exhibit relatively symmetrical implantation resembling adult crocodilians, in contrast to the more asymmetric tooth implantation in non-avian theropods, yet how this transition evolved remains unclear. We provide new insights into this evolutionary transition by examining an embryonic and ontogenetic series of *Alligator mississippiensis* using soft- and hard-tissue histology. We show that alligator thecodonty is established progressively through embryonic stages by repositioning the dental lamina and forming the lingual socket wall by alveolar bone. Following hatching, tooth implantation shifts from a theropod-like asymmetrical condition, with replacement teeth lingual to functional teeth, towards a more symmetrical condition in adults. This shift is not driven by soft tissue rearrangement but tooth initiation timing: adult successor teeth initiate closer to the functional root apex due to a reduction in tooth replacement rate. These findings suggest that alligator thecodonty is not a stable condition but a progressive developmental process, which may provide a developmental mechanism for interpreting the transition from asymmetric theropod-like implantation to avian thecodonty across dinosaur-bird evolution.

Wednesday 9th December, Session 1a, Mathematical Institute L1, 09:00–09:15.

Before Mary Anning: did a (proto-)scientific form of palaeontology exist in Ancient Egypt?

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The fascination with fossils is not a modern phenomenon: fossils were collected in ancient Greece, trilobites featured in classical Chinese medicine and ammonites were displayed in a Neolithic temple in Jordan. Yet curiosity alone does not make a scientific discipline, and palaeontology is assumed to emerge only in the eighteenth century. Yet, is it truly so? This paper argues that ancient Egyptians showed an interest for fossils surpassing mere curiosity,

and approaching (proto-)scientific engagement, already in the late second millennium BCE. We identify three features signalling a (proto-)scientific approach: systematic recording of a find's context; biologically accurate interpretation of fossil remains, aware of their antiquity; and its embeddedness within broader attempts to organize and understand the natural world. Three examples from Ancient Egypt support this argument: a priest recorded the quarry where he found a fossil sea urchin; Pleistocene bones from Qau el-Kebir, correctly identified as hippopotamus remains, were deliberately selected from strata containing other fossils and treated as remnants of a remote, 'divine', or we can say 'prehistoric' past; and finally, contemporary systematic and encyclopaedic depictions of items from various natural domains (flora, fauna, stars, geographical features) suggest this proto-palaeontological interest emerged within a wider proto-scientific discourse.

Thursday 10th December, Session 4b, Mathematical Institute L2, 09:00–09:15.

Joint mobility in the hallux of anisodactyl birds as a proxy for non-neornithine avialan pedal function

Grace Kinney-Broderick, Oliver E. Demuth and Daniel J. Field
University of Cambridge, UK

Extant birds exist across a wide range of habitats and exhibit a vast array of hindlimb behaviours. The evolutionary origin of hindlimb grasping was an important innovation in avian evolutionary history, in part to offset the loss of manus dexterity. Little is known about the hindlimb function of most Mesozoic birds, partly due to the difficulty of identifying useful functional correlates in the feet of extant birds that can be reliably applied to fossils. Here we use high-resolution CT scans of the tarsometatarsus and reversed hallux (pedal digit I-1) of an ecologically and phylogenetically diverse set of extant birds (n = 39), focusing on anisodactyl taxa, and the Cretaceous avialan *Confuciusornis sanctus*. We performed range of motion simulations of the tarsometatarso-hallucal joint and simulated their ligamentous constraints in Blender, then quantified the resultant mobility boundaries using spherical frame projection (SFP). The shapes of these boundaries were subsequently analysed using (spherical) Riemannian functional principal component analysis (sfPCA), and an ecological and phylogenetic framework (EcoPhyloMobilitySpace) was generated with each species' pedal ecology classified by predominant use: perching, ground (walking), prey capture and vertical climbing. Our analyses reveal a low but significant phylogenetic signal in pedal joint mobility and high classification accuracy, with model testing suggesting a pull towards functional optimization across our sample. Our approach provides new insight into the function and evolution of the avian hallux and presents a case study of the utility of EcoPhyloMobilitySpace for enabling palaeontologists to link the evolution of form and function through joint range of motion estimates across phylogenetic and geological history.

Wednesday 9th December, Session 1a, Mathematical Institute L1, 10:00–10:15.

Rapid evolution of mammalian brain shape preceded encephalization in the Late Cretaceous

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The extraordinary morphological and ecological diversity of mammals is reflected in the extremely variable brain morphologies they exhibit. We used 3D brain shape data of 348 extant and 118 extinct mammal species to explore neuroanatomical evolution. We found strong support for a modular pattern of brain evolution, with four distinct modules. Using a reversible-jump MCMC algorithm, we recovered strongest support for a variable-rate Lambda model of phenotypic evolution, with individual brain modules experiencing distinct dynamics of rate change through time. Evolutionary rates of both brain shape and relative brain size began to accelerate in the Late Cretaceous, but brain shape evolutionary rate accelerates earlier and occurs at a far higher level than brain size. Using a state-specific Brownian motion model to estimate and compare evolutionary rates among ecological and life history traits, we found high rates in aquatic, diurnal, and herbivorous mammals, but no clear difference between in rates between social and solitary taxa. Ecology may therefore play an important role in mammalian brain evolution. The decoupling of brain shape from size allowed the rapid evolution of diverse brain morphologies at a time when mammalian body size variation remained low and may have contributed to the adaptive radiation of mammals.

Thursday 10th December, Session 7, Mathematical Institute L1, 16:30–16:45.

Testing the hypothesis of parrot-like mandibles in oviraptorosaurs

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Oviraptorosaurs were unusual Cretaceous theropod dinosaurs with jaws that might have been adapted to herbivory. They possessed short, relatively tall skulls and, in most species, edentulous, beaked jaws. Their mandibles have been considered morphologically and functionally analogous to those of parrots and have even been misidentified as such. Here we tested the validity of this long-standing comparison using two-dimensional geometric morphometrics and functional characters informative about mandibular biomechanics. Taxa from across theropod phylogeny were included for comparison. Variation in overall lower jaw and beak shape was evaluated through Elliptical Fourier analysis and two-dimensional morphometric landmarking, respectively. A multivariate analysis was used to measure the variation of key mandibular functional traits. We confirm the broad morphological resemblance between oviraptorosaur and parrot beaks, with both groups being distinct from the comparison taxa. This similarity, however, is more nuanced than previously suggested: oviraptorids closely match parrots, whereas basal oviraptorosaurs and all but one caenagnathid differ significantly from them. Our results provide a quantitative morpho-functional basis for the long-standing comparison beyond superficial

resemblance, while narrowing its scope. The observed convergence is consistent with the growing body of evidence of dietary adaptations in oviraptorosaurs distinct from those of their carnivorous theropod ancestors.

Wednesday 9th December, Session 1a, Mathematical Institute L1, 09:30–09:45.

Origination shapes the marine latitudinal diversity gradient through deep time

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The latitudinal diversity gradient (LDG), defined as the increase in species richness from high to low latitudes, has been recognized for over two centuries, but the processes underlying its origin and persistence remain uncertain. The fossil record provides an opportunity to determine the relative contributions of speciation, extinction and dispersal to the latitudinal diversity gradient by examining patterns of diversification across latitudes and through geological time. Here we estimate origination (*i.e.* speciation) and extinction rates at low and high latitudes over the past 200 million years in four major marine groups—anthozoans, bivalves, gastropods and foraminifera—using a Bayesian birth-death neural network framework (Hauffe *et al.* 2024). Origination and extinction rates were persistently higher at low latitudes, resulting in greater turnover. Origination, however, consistently outpaced extinction, producing higher net diversification at low latitudes compared to high latitudes. This pattern remained robust to several sensitivity analyses that accounted for fossil sampling biases. These spatial differences in diversification persisted through major climatic transitions, suggesting elevated low-latitude origination has been a major driver of the marine LDG over hundreds of millions of years, and illustrating how processes in deep time have shaped the marine biosphere today.

Wednesday 9th December, Session 2, Mathematical Institute L1, 11:15–11:30.

A phylogenetically diverse deuterostome fauna from the late Ediacaran Jiangchuan biota

Gaorong Li[1,2], Peiyun Cong[1], Fan Wei[1], Yang Zhao[3], Frances S. Dunn[2], Ross P. Anderson[2], Imran A. Rahman[4] and Luke A. Parry[2]

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Deuterostomes are one of the two major groups of bilaterians and include some of the most widely divergent body plans in the animal kingdom, including the ambulacrarians (echinoderms and hemichordates) and the chordates. Both molecular divergence estimates and the presence of likely protostome body fossils strongly implies the presence of deuterostomes during the Ediacaran Period, but fossil evidence of this group is limited to the Cambrian Period, with the most ancient confirmed fossil being *Sokoloviina* – a pterobranch hemichordate. Here we report three groups of deuterostome fossils from the late Ediacaran Jiangchuan Biota, eastern Yunnan, China. These discoveries include cambroernids – stem-group ambulacrarians – and *Margaretia* – most recently interpreted as the dwelling tube of the acorn worm hemichordate *Oesia disjuncta*. Additionally, we

report a complex skeletonizing animal possessing an annulated, columnar body with an expanded end bearing a mosaic of ossicles, inviting comparison with the early Cambrian *Yanjiahella* (interpreted conservatively as an ambulacrarian) and early echinoderms. These findings confirm that the major divergences within the deuterostomes and ambulacrarians had occurred by this time, and for the first time, provides positive fossil constraints for Precambrian deuterostome evolution.

Wednesday 9th December, Session 3b, Mathematical Institute L2, 14:30–14:45.

'Reptilian domination' in Pleistocene Australia and limited human impacts on competition among its megafaunal carnivores

Adam Lindholm* and Roger A. Close
University of Oxford, UK

Pleistocene Australia's unique terrestrial megafauna included marsupials, reptiles and birds. It notably included multiple large reptilian predators, but only one large marsupial predator, *Thylacoleo carnifex*. This has led to the idea of 'reptilian domination' of large predatory niches, either because of reptiles outcompeting marsupials, or an innate inability of marsupials to occupy these niches. We test this hypothesis by quantifying competition for available prey biomass between mammalian, reptilian and avian predators >1 kg across eight Middle–Late Pleistocene Australian localities. We find that small mammalian predators generally experience higher competition for food, while smaller reptiles and birds experience lower competition. *Thylacoleo* generally experiences higher competition than megafaunal reptiles where both coexist, and remains under high competition even when large reptiles are absent. This suggests a complex signal of 'reptilian domination': reptiles are better at exploiting the stressed, low-productivity continental system of Pleistocene Australia than predatory mammals, which are inherently difficult to sustain. When included as a predator, humans do not noticeably increase the competition experienced by other megafaunal predators, although this does not preclude impacts arising as an accessory effect of declining prey abundance driven either by faunal overkill or climatic shifts.

Thursday 10th December, Session 5, Mathematical Institute L1, 11:45–12:00.

Quantifying 400-million-year forest structural evolution

Bingcai Liu[1,2]*, Kai Wang[1], Alexander J. Hetherington[2,3,4] and Honghe Xu[1,5]
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Forest ecosystems have shaped terrestrial biodiversity and climate since their emergence in the Middle Devonian (~390 Ma), yet their structural evolution through ~400 million years remains poorly quantified. We develop a framework for reconstructing fossil forest structure from stem diameter and density, allowing estimation of tree height, biomass and spatial pattern. We first apply this framework to the Middle Triassic Qingjian Forest of North China, where 439 *in situ* sphenopsid trunks across 2,264 m^2 reveal a high-density forest dominated by small-diameter trees. We then extend the approach to a compilation of *in situ* fossil forests spanning the Devonian to Quaternary, enabling comparison of forest structural change. Palaeozoic forests occupy a distinct region of structural space, whereas Triassic forests encompass broader configurations, including combinations that bridge

Palaeozoic and Mesozoic forests. By the Jurassic and Cretaceous, several forests occupy structural space overlapping with modern forests, despite turnover in floristic composition. This pattern reveals a decoupling between structural and floristic evolution, indicating that forest structure changed through the emergence and reorganization of structural configurations rather than simple replacement of dominant plant groups. Our results establish a framework for tracing forest structural evolution through deep time.

Wednesday 9th December, Session 2, Mathematical Institute L1, 11:30–11:45.

Rhyniognatha revisited: rethinking the oldest 'insect'

Emma J. Long[1,2,3], Gregory D. Edgecombe[2], Markus Koch[4] and Xiaoya Ma[1]

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Insects are phenomenally diverse, yet their evolutionary origins remain poorly understood. The fossil *Rhyniognatha hirsti* from the Early Devonian Rhynie chert (*c.* 408 Ma) has been widely accepted as the earliest insect and a crown-group pterygote (flying insect), based on the interpretation of short, dicondylic mandibles. For over two decades, this fragmentary specimen has served as a key calibration point in insect molecular phylogenies. An alternative hypothesis has proposed a myriapod affinity, citing ocular, antennal and maxillary structures. Here we re-examine *Rhyniognatha* using confocal laser scanning microscopy. We find no evidence for an anterior mandibular acetabulum, refuting true dicondyly and undermining its placement within Dicondylia (silverfish-pterygote clade). We reassess the proposed centipede affinity, demonstrating that certain diagnostic features are more plausibly interpreted as exoskeletal folds, and that the mandibles lack a clear myriapod-type base plate. Comparative analysis reveals similarities with apterygote hexapods, including bifurcated maxillary endites and comb-like superlinguae, and myriapods, such as an edafopodan-like elongate suspensorium, but does not support assignment to any specific mandibulate lineage. Consequently, *Rhyniognatha* cannot be placed within crown-group Insecta and is unsuitable as a calibration fossil for insect evolution, shifting the minimum age of winged insects by approximately 80 million years.

Thursday 10th December, Session 7, Mathematical Institute L1, 16:15–16:30.

A Jurassic fossil reveals the stepwise evolution of thorny-headed worms

Cihang Luo[1,2,3*], Luke A Parry[4], Brendon E. Boudinot[3], Shengyu Wang[1], Edmund Jarzembowski[1,5], Haichun Zhang[1] and Bo Wang[1]

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Parasitic worms often differ radically from their closest free-living relatives, but their sparse fossil record obscures how these specialized body plans evolved. Living acanthocephalans (thorny-headed worms) lack jaws and a digestive tract, yet molecular evidence indicates their origin from jaw-bearing rotifer ancestors. To investigate this transition, we examined *Juracanthocephalus daohugouensis* from the Middle Jurassic Daohugou biota of China, approximately 165 million years old. We combined light and scanning

electron microscopy, elemental mapping and phylogenetic analyses of 247 morphological characters across 68 taxa. The fossil preserves a hooked attachment organ (proboscis) and copulatory bursa characteristic of acanthocephalans, together with an internal jaw apparatus absent from living members. Parsimony and Bayesian analyses consistently recover *Juracanthocephalus* as a stem-group acanthocephalan. Its combination of attachment structures and retained jaws suggests that adaptations to internal parasitism preceded the loss of the feeding apparatus. As the first unequivocal acanthocephalan body fossil, it bridges a major anatomical gap between rotifers and their highly modified parasitic relatives. This discovery reveals a previously undocumented stage in acanthocephalan evolution and demonstrates how exceptional fossils can resolve the assembly of specialised animal body plans.

Wednesday 9th December, Session 2, Mathematical Institute L1, 12:15–12:30.

Assessing ecological partitioning in the first marine turtles (Thalassochelydia) using stable oxygen isotopes

Chloe Mazier[1,2], Romain Amiot[3], Jeremy E. Martin[3], Arnauld Vinçon-Laugier[3] and Jeremy Anquetin[1,2]

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The ecology of thalassochelydians is relatively unknown. While this group, found mainly in the Late Jurassic of Europe, is known as the first radiation of turtles into marine environments, the ecological partitioning between the different species of thalassochelydians remains unstudied. More than 30 species have been described within the Kimmeridgian-Tithonian interval, with great morphological disparities and few morphological adaptations to life at sea. The rich diversity within the group could indicate the exploitation of different ecological niches. The oxygen isotopic ratios preserved in the apatite of fossil bones can be used as a proxy to estimate the salinity of the water in which the sampled individuals lived; it is particularly applicable to aquatic ectotherm vertebrates such as thalassochelydians. Ninety-five specimens of Thalassochelydia with confirmed taxonomic identifications were sampled for this study and subjected to isotopic analyses with a focus on stable oxygen isotope compositions ($\delta^{18}O$). The $\delta^{18}Ow$ values of environmental water, estimated from the PO4-water fractionation equation established for extant turtles, range from –5 ‰ to +1 ‰ (V-SMOW). These values correspond to a variety of aquatic environments, from seawater strongly influenced by freshwater to purely marine waters, suggesting that thalassochelydians did exploit different kinds of habitats. Funded by the Swiss National Science Foundation (SNSF IC00I0-227983).

Thursday 10th December, Session 4a, Mathematical Institute L1, 09:00–09:15.

Estimating visual performance in Mesozoic marine reptiles using preserved scleral rings

Matthew D. McKeown[1], Francesco Della Giustina[2], Valentin Fischer[2] and Eric W. Wilberg[1]

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During the land to sea transition, one of the most important adaptations involves a shift in vision related structures. This is necessitated by the differing attenuation and transmission

speeds of light between air and sea water. Here we present results in estimating visual performance through estimating a minimum f-number of Mesozoic marine reptiles, using preserved scleral rings. Bony scleral rings are present in the eyes of many vertebrate groups (*e.g.* marine reptiles, birds and non-avian dinosaurs) and in aquatic vertebrates are thought to provide support to the eye while under pressure. The internal diameter of the scleral ring is an osteological correlate of maximum pupil size. Incorporating linear measurements and scaling relationships from extant taxa, we estimate the minimum f-number of the eye of extinct marine reptiles. Higher values suggest better visual performance in brighter conditions, and lower values in dimly lit settings. These minimum f-numbers can then be used to infer depth preference for predation across our sample of over 100 marine reptiles. Our results show clear differences between groups, with ichthyosaurians displaying lower values, and mosasaurians displaying higher. These differences may suggest depth preference adds an additional dimension to niche partitioning in Mesozoic marine ecosystems.

Wednesday 9th December, Session 3a, Mathematical Institute L1, 14:30–14:45.

Kaolinite and exceptional fossilization: testing a taphonomic association with new mineral mapping technologies

William J. McMahon[1], Nicholas J. Butterfield[1] and Stefan C. Löhr[2]
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Kaolinite has regularly been invoked in the taphonomy of carbonaceous compression fossils. However, despite experimentally demonstrated preservational effects, the timing of kaolinite formation – and thus its taphonomic relationship – in fossil-bearing shales and mudrocks often remains ambiguous. This is partly because kaolinite is also a common product of later-stage burial diagenesis, making spatial associations with fossils potentially incidental. Progress has been hindered by a lack of tools capable of texturally resolving the origins of kaolinite associated with exceptional fossilization. Advances in scanning electron microscopy energy-dispersive spectrometry mineral mapping now permit individual clay grains and their petrographic relationships to be assessed at micrometre-scale resolution. Here we combine this approach with morphological criteria to differentiate detrital, early authigenic and burial-diagenetic kaolinite across six successions renowned for their compression fossils. These encompass a broad temporal, depositional and taphonomic range, from Proterozoic organic-walled microfossils to classic Burgess Shale-type deposits and exceptionally preserved Miocene flora. The analysed samples do not share a common mode of kaolinite occurrence, but span a spectrum from abundant early-formed kaolinite with potential taphonomic significance to exclusively burial-diagenetic kaolinite with no plausible role in fossil preservation. More broadly, the mineral maps suggest that exceptional preservation can arise through diverse clay mineralogical pathways.

Wednesday 9th December, Session 1c, Mathematical Institute L3, 09:00–09:15.

The diet of enantiornithine birds

Case Vincent Miller[1], Jen A. Bright[2], Xiaoli Wang[3,4], Xiaoting Zheng[3,4] and Michael Pittman[5]
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Enantiornithines or 'opposite birds' were the most abundant and speciose group of Mesozoic birds. While enantiornithines are known to be morphologically diverse, their trophic diversity has remained largely speculative. We investigated the diet of members

of the three best known enantiornithine groups (Pengornithidae, Bohaiornithidae and Longipterygidae) by comparing them to over 140 species of living birds. Body mass, claw morphometrics, jaw mechanical advantage and jaw finite element analysis were used together as an analytical framework to reconstruct the most likely diet for each extinct species. Members of Pengornithidae show adaptations for feeding on vertebrates, with *Pengornis* showing the earliest evidence of macrocarnivory in a bird. Bohaiornithidae is the most trophically diverse of the three clades with carnivorous, omnivorous and herbivorous representatives. Members of Longipterygidae are reconstructed as invertivorous, though plant consumulites in *Longipteryx* highlight the differing timescales that palaeodiet proxies reflect. Enantiornithines evolved to inhabit diverse trophic niches in a timespan comparable to crown birds, which suggests that the ecological diversity of birds today is enabled by traits in the common ancestor of Ornithothoraces (Enantiornithes + the lineage that gave rise to crown birds).

Wednesday 9th December, Session 1a, Mathematical Institute L1, 10:15–10:30.

How consistent is the genome size – guard cell length relationship across major land plant clades?

Hannah Morck and Phillip E. Jardine
University of Münster, Germany

The genome size (GS) of land plants has varied greatly over time. Its direct impact on cell size has been linked to key traits such as growth habit/rate, geographic range and diversification rate. It is also hypothesized that GS has played a significant role in the survival and extinction rates of land plants. Therefore, reconstructing GS variation in fossil plants is essential to better understand its effects on plant evolution and (palaeo)ecology. Although GS cannot be measured directly in fossil plants, it can be estimated using cell size measurements. Especially its relationship with stomatal guard cell length (GCL) has shown potential as a proxy for palaeo-GS reconstructions. However, further multi-clade analyses are required to improve our understanding of the consistency of the GS–GCL relationship across plant groups. Here we thoroughly test the palaeobotanical GS proxy across major plant groups, using GCL data compiled from literature and new measurements obtained from herbaria and botanical gardens. Our results demonstrate considerable differences in the GS–GCL relationship across major plant clades. This suggests that a single GS–GCL scaling relationship cannot be used to estimate GS in fossil plants, potentially challenging the use of the proxy in extinct plant clades.

Wednesday 9th December, Session 3c, Mathematical Institute L3, 14:15–14:30.

Latest Cretaceous Laramidian terrestrial communities underwent climatic changes, functional diversity shifts and diversification

Cassius Morrison[1,2], Nicolas A. Stagg[3], Chance Guest[4], Evan Wright[5], Charlie R. Scherer[1], Steven J. R. Allain[6], Marc Laflamme[7], Robin Beck[8] and Benjamin J. W. Mills[2]
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The Campanian–Maastrichtian shift in dinosaurian diversity of Laramidia (North America) has been used as a proxy for a taxonomic decline prior to the Cretaceous-

Palaeogene extinction, suggesting ecosystems were more vulnerable to collapse after the end Cretaceous bolide impact. Yet, preservational and sampling biases, alongside changes in the environment might be driving such interpretations. Here we reconstruct and investigate ecosystems in the Campanian and Maastrichtian, using the R package Cheddar. Climate shifts impacted plant and dinosaurian communities, especially in the Maastrichtian. Environmental changes resulted in dinosaurian community shifts in both ecological functionality diversity (EFD) and structure, primarily within the megaherbivore guild and this likely drove the apparent localized taxonomic decline in northern Laramidia. Hadrosaur and ceratopsian communities and population demographics, alongside EFD, had a greater impact on ecosystem structure compared to ankylosaurs and were directly affected by both climate and plant community shifts. Potential changes in gregarious behaviour especially during ontogeny may have been the ecological mechanism that drove the changes in megaherbivore co-occurrence. Our study provides alternative metrics to assess stability and changes in biodiversity, alongside the potential ecological mechanisms rather than just numerical taxonomic assessments through time. Additionally, ecosystem analyses are required rather than time averaged datasets. Funded by the Royal Society.

Thursday 10th December, Session 4a, Mathematical Institute L1, 09:30–09:45.

talks

Skulls, genes, and deep time: total evidence dating in cetaceans

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Total-evidence dating combines morphological and molecular data to place extinct and extant taxa on a single evolutionary timescale, drawing on the fossil record to illuminate the deepest branches of the tree of life. Discrete morphological characters remain the most common data type for this purpose, but they introduce subjectivity in character choice and grouping, and struggle to accommodate trait correlation or intraspecific variation without heavy computational cost. Continuous, quantitative morphological data offer great potential for divergence time estimation, allowing correlation and intraspecific variation to be modelled directly. Existing implementations, however, still recompute the full phylogenetic likelihood at every MCMC step, limiting how large a dataset can realistically be analysed. Here we expand the scalability of such analyses by developing the approximate likelihood approach for continuous characters. We apply this to a geometric morphometric dataset of 6,084 characters (123 landmarks, 1,905 semilandmarks) from 200 extant and extinct cetacean crania, the largest quantitative morphological dataset used for divergence time estimation to date. Comparing datasets of varying density, with and without molecular data, we assess how dataset scale and trait correlation affect divergence time estimates and their uncertainty.

Wednesday 9th December, Session 3a, Mathematical Institute L1, 15:15–15:30.

Body size and the evolution of tissues and organs in Metazoa

Arsham Nejad Kourki[1,2] and James DiFrisco[1]

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Why do tissues and organs evolve? Accounts of major evolutionary transitions usually explain how cells formed multicellular organisms, but not why essential functions came to be performed by tissues and organs. We propose that body size is part of the answer. As

animal bodies evolved larger sizes, ciliary propulsion, diffusion and intracellular digestion met physical limits; collective ways of moving, transporting materials and processing food became possible—or necessary. This history cannot be recovered from living animals alone. Fossils preserve extinct combinations of size and anatomy, reveal intermediate body plans, and show when organizational changes occurred. We combine fossil and living evidence in a dated animal phylogeny to trace how animals moved, fed and transported materials internally, asking when each function shifted between the cellular, tissue and organ levels. Preliminary reconstructions already show each function reaching the organ level repeatedly rather than once. Digestive organs appear independently at least a dozen times, in all three major branches of Bilateria, between 553 and 324 million years ago, and are lost again in several lineages. Internal transport shows six such origins, added above the cavities and capillaries that two-thirds of animals retain. Tissues and organs look like recurrent solutions to changing physical demands.

Wednesday 9th December, Session 1b, Mathematical Institute L2, 09:15–09:30.

Ordered sheaths and oriented calcites: calcification and preservation of an Ordovician cyanobacterial fossil

Changtai Niu[1], Peng Tang[1], Lijing Liu[2], Kui Yan[1,3] and Ke Pang[1,3]

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Calcified cyanobacteria were widespread components of Palaeozoic carbonate ecosystems, yet the organization, mineralization and preservation of their extracellular sheaths remain poorly understood. We investigated Middle–Late Ordovician *Phacelophyton* from slope-facies limestones of the Wulalike Formation, Ordos Basin, North China, using optical microscopy, FIB-SEM, EBSD, Raman spectroscopy, cathodoluminescence and EPMA. *Phacelophyton* preserves a distinctive multilayered sheath in which longitudinally continuous lamellae overlap, producing a rotational, swirl-like pattern in cross-section. This structure indicates that cyanobacterial extracellular polymers could assemble into highly ordered architectures, potentially reflecting organization of microscopic sheath fibrils. EBSD shows that the calcified sheaths of *Phacelophyton* and a co-occurring Oscillatoriaceae morphotype contain submicron microcrystalline calcite with distinct crystallographic preferred orientations, suggesting that different sheath architectures influenced carbonate nucleation and crystal arrangement. Raman spectroscopy links mineralized sheaths with organic-rich domains, while cathodoluminescence and EPMA reveal significant compositional differences between sheath calcite and surrounding microspar. These results suggest that organic-rich sheath domains promoted microcrystalline calcite nucleation and crystallization while inhibiting later recrystallization, preserving fine sheath architecture and crystallographic fabrics. These fossils reveal how cyanobacterial extracellular architecture governed carbonate biomineralization and preservation in deep time while retaining unusually rich morphological and mineralogical information.

Wednesday 9th December, Session 1c, Mathematical Institute L3, 10:15–10:30.

talks

Integrated micropalaeontological constraints on the age and palaeoenvironmental evolution of Late Miocene sediments in the Niger

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Understanding the timing and environmental evolution of deltaic systems requires integration of microfossil groups with complementary stratigraphic and ecological sensitivities. This study integrates calcareous nannofossil and foraminiferal evidence with lithological observations to constrain the age and depositional environment of sediments in the shallow offshore Niger Delta Basin, Nigeria. A total of 290 ditch-cutting samples from two wells were examined for calcareous nannofossils and foraminifera. The calcareous nannofossil assemblage includes *Discoaster quinqueramus* and *Discoaster berggrenii*, whose co-occurrence identifies the NN11 nannofossil zone, while the foraminiferal assemblage includes *Cyclammina minima* and *Saccammina omplanate*, supporting assignment to the N17 foraminiferal zone. Together, these biozones establish a Late Miocene (Messinian) age for the diagnostic intervals and provide complementary age control for correlation between the two wells. Foraminiferal assemblages, integrated with fine-grained, clay-rich lithologies, indicate a predominantly middle to outer neritic marine environment, approximately 40–250 m water depth, with fluctuations in marine conditions, terrigenous input and water depth. The correspondence of independent nannofossil and foraminiferal biozonation demonstrates the value of integrating the two fossil groups for refining stratigraphic correlation and reconstructing depositional conditions in complex deltaic systems.

Wednesday 9th December, Session 3c, Mathematical Institute L3, 15:15–15:30.

Causal inference of macroevolutionary dynamics from the fossil record

Nicole Obren, Trond Reitan and Lee Hsiang Liow
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Macroevolutionary dynamics of marine molluscs are shaped by biotic interactions and abiotic drivers. However, it is challenging to distinguish correlative from causal connections without controlled experiments. In addition, many palaeontological studies rely on global fossil data compilations, risking the loss of region-specific signals. We first ask whether regional New Zealand bivalve and gastropod (*i.e.* biotic) dynamics differ from global ones. We then examine the interactions among biotic dynamics in a formal time-series framework. We analyse our time series using linear stochastic differential equations with the R package layeranalyzer, which parametrically characterizes processes, temporal correlation and Granger-type causal connections. Our results reveal New Zealand and global macroevolutionary trajectories are not realizations of a common process, with clear regional-global differentiation in both clades. Causal inference of the New Zealand molluscan system finds bivalve extinction is the central dynamic process, with causal directional links to gastropod extinction and bivalve origination and a correlative association with gastropod origination. The inclusion of palaeoenvironmental proxies yielded no detectable connections to the biotic time series. These findings demonstrate that process-based causal inference can uncover important processes of macroevolutionary dynamics obscured in correlative studies and can inform how we interpret past, present and future ecosystem dynamics.

Wednesday 9th December, Session 1b, Mathematical Institute L2, 09:00–09:15.

'Brain vs brawn': the effect of allometry on trade-offs between brain and jaw muscle shape in mammals

Jack Oyston[1], Andrew Knapp[1], James Thorson[2] and Ryan Felice[1,3]

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Both the jaw muscles and brain take up space within the head and it has been hypothesized that competition for space between these two traits may have influenced their evolution. While this seems to be supported in primates and canids, it is unclear whether similar patterns of 'brain vs brawn' hold more broadly. Correlated shape changes could also be the result of allometric effects, which may vary across groups. Using 3D landmark data of 340 extant and 28 fossil and subfossil taxa, spanning the entire mammal tree, we used variable slope structural equation modelling (SEM) to investigate the effects of allometry on correlated shape evolution of these traits. Allometry affects the integration between the jaw muscles and brain differentially. In marsupials, covariation between brain and jaw muscle shape does not correlate strongly with size, while carnivorans, sloths and primates exhibit stronger allometric effects. Whereas larger body sizes are associated with more globular brains in both sloths and carnivorans, these clades show the opposite effect of size on jaw muscle shape. The effect of jaw muscle and brain shape on each other appears much weaker than these clade specific allometric patterns, suggesting these apparent trade-offs are strongly size dependent.

Wednesday 9th December, Session 3a, Mathematical Institute L1, 14:45–15:00.

Optical-photothermal infrared (O-PTIR) spectroscopic study on Neoproterozoic carbonaceous macrofossils from South China

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Raman and Fourier transform infrared (FTIR) spectroscopic analyses are some of the most important tools when investigating chemical characteristics of fossils. While Raman has been widely applied with a fine resolution, FTIR faces limitations from spatial resolution and the preparation of samples, particularly for carbonaceous fossils. In this study we present the first application of the high spectral (~2 cm^{-1}) and spatial resolution (~500 nm), *in situ* optical-photothermal infrared spectrometer (O-PTIR) on Neoproterozoic carbonaceous fossils from the Tonian Liulaobei Formation, and the Ediacaran Lantian and Dengying formations, South China. The spectra are generally characterized by weak or broad aliphatic bands and strong aromatic bands, indicating a high thermal maturity. Infrared mappings of the carbon film reveal patchy distribution of functional groups at a micron-scale; spectra acquired from these areas show variable aliphatic preservation while their Raman spectra share typical G and D bands regarding the carbon backbone structure. This contrast indicates that the carbonaceous material that appears homogeneous in terms of its backbone structure but retain spatially heterogeneous molecular signatures at the functional-group level. Our study establishes O-PTIR as a promising, non-destructive approach for molecular characterization of carbonaceous compression fossils at a high resolution.

Wednesday 9th December, Session 2, Mathematical Institute L1, 11:00–11:15.

talks

The effect of cranial ornamentation on the feeding biomechanics of large theropod dinosaurs

Lavanya Ralhan, Harrison J. Willoughby, Emily J. Rayfield and Andre J. Rowe
University of Bristol, UK

Although cranial ornamentation in dinosaurs is commonly associated with the prominent horns and crests of ornithischian dinosaurs, theropod dinosaurs also exhibit cranial bony structures. These ornamentations have been interpreted to have varying functions such as stress buttresses, combat weapons or display and signalling structures. Here we investigate the role of ornamentation in feeding biomechanics using three-dimensional finite element analysis of theropod crania with ornamentation digitally removed and exaggerated. A range of species were tested with varying forms of ornamentation, including crests (*Dilophosaurus*, *Monolophosaurus*), horns (*Carnotaurus*, *Majungasaurus*, *Ceratosaurus*), bone rugosities (*Majungasaurus*, *Carnotaurus*, *Tyrannosaurus*, *Daspletosaurus*) and lacrimal horns (*Allosaurus*, *Giganotosaurus*, *Neovenator*). Preliminary results suggest that the horns of allosauroids and ceratosaurs were unlikely to function as buttresses for feeding-induced stresses. In contrast, abelisaurid cranial rugosity does appear to play a role in feeding biomechanics. Additionally, the results suggest that the cranial crests of *Dilophosaurus* may have served a biomechanical function beyond display.

Thursday 10th December, Session 4a, Mathematical Institute L1, 10:00–10:15.

Arboreality in a Middle Jurassic cladotherian mammal from the Kilmaluag Formation of the Isle of Skye

James R. G. Rawson[1], Elsa Panciroli[1,2], Luke E Meade[1], Stig Walsh[2], Roger B. J. Benson[3] and Richard J. Butler[1,4]
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Almost all modern mammals belong to Theria. Therians originated in the Jurassic, a time when mammals and other mammaliaforms demonstrated a variety of locomotory modes including arboreality, swimming, burrowing and gliding. Several early therians have been interpreted as arboreal, but the rarity of well-preserved postcrania for Jurassic therians and their close relatives makes it unclear when this trait evolved on the therian stem. Here we present a nearly complete skeleton of *Palaeoxonodon ooliticus*, a cladotherian previously known only from partial jaws and isolated teeth, from the Middle Jurassic Kilmaluag Formation of the Isle of Skye in Scotland. Digital reconstruction of the limbs from µCT data has uncovered features correlated with climbing, including elongated digits, a short olecranon process of the ulna and a mobile ankle. We quantitatively tested the hypothesis of arboreality in *Palaeoxonodon* by inputting postcranial linear measurements into recently published multiple regression models that showed high predictive power for locomotory mode in small mammals. *Palaeoxonodon* is reliably recovered in these analyses as arboreal or scansorial, improving our understanding of locomotion close to the origin of Theria. This specimen adds to the growing list of exceptionally preserved mammaliaforms from the Kilmaluag and further establishes the site's importance for understanding early mammalian ecomorphological diversity.

Wednesday 9th December, Session 3c, Mathematical Institute L3, 14:30–14:45.

The origin of burrowing: a multidisciplinary approach to asking 'how did the first burrowers move through sediments?'

Jane Reeves[1], Katie Hill[1], Peter Cooper[2], Christopher Holland[2], Robert S. Sansom[1], William Sellers[1], Luke A. Parry[3] and Russell J. Garwood[1,4]

[1]The University of Manchester, UK; [2]University of Sheffield, UK; [3]University of Oxford, UK; [4]Natural History Museum, London, UK

The transition from horizontal to vertical burrowing through sediment at the end of the Ediacaran (~541 million years ago) generated extensive environmental changes. It is one of many suggested triggers of the 'Cambrian Explosion', the dramatic, rapid radiation of animal life that established most modern phyla. An extensive trace fossil record suggests muscular hydrostatic systems (fluid enclosed within a tube) are likely the plesiomorphic locomotion method. However, a limited body fossil record, along with difficulties in identifying trace makers, leaves questions about the earliest burrowers' morphology and behaviours unanswered. To address this, we studied the extant marine annelid *Arenicola marina* as a model organism. This species uses mucus and a muscular hydrostat to create and sustain U-shaped burrows; we quantify mucus material properties, and demonstrate, with neo-ichnological experiments, that mucus is essential for burrow production, highlighting how biological substances cause potentially unnoticed taphonomic filters in the trace fossil record. Furthermore, we present a novel pipeline, currently in development, which combines CT imaging and biomechanical data to create a digital organism for burrowing simulations to test hypotheses about organism-sediment interactions. Our work creates a taphonomic framework for interpreting ichnotaxa and generates a robust model needed to understand the origin of burrowing.

Wednesday 9th December, Session 1c, Mathematical Institute L3, 09:45–10:00.

Sediment controls the trajectory of microbial necrobiome succession during marine invertebrate decay

Felicity M. Roberts, Sophie Nixon, Christopher Boothman, Jane Reeves and Robert S. Sansom

The University of Manchester, UK

Experimental taphonomy has been fundamental to testing hypotheses of fossil preservation, yet the microbial ecology of marine animal decay remains poorly characterized. Furthermore, the extent to which sediment influences necrobiome succession is unresolved. To test the effect of sediment presence in decomposition experiments, we tracked the microbial communities of decaying crustaceans (*Munida rugosa*) under sediment-associated and sediment-free laboratory conditions (120 days). Communities were characterized by 16S rRNA gene sequencing, with 30 samples retained at a rarefaction depth of 4,509 reads per sample. Both environments showed progressive replacement of the host-associated microbiome by decomposer-associated communities but their successional trajectories differed. Weighted UniFrac ordination indicated greater temporal restructuring of sediment-associated communities during later decomposition whereas sediment-free communities remained comparatively constrained through time. Taxonomic composition also diverged: sediment-associated communities increasingly contained lineages characteristic of anaerobic marine sediments including *Sedimentibacter* and *Malaciobacter/Arcobacter* whereas sediment-free communities retained greater representation of facultatively anaerobic heterotrophs including *Puteibacter* and *Saccharicrinis*. These results indicate sediment altered the trajectory of necrobiome succession and acted as an important ecological determinant of necrobiome community assembly. Sediment should therefore be

considered an active component of experimental taphonomic systems when evaluating the microbial context in which decay and early fossilization processes occur.

Wednesday 9th December, Session 1c, Mathematical Institute L3, 09:15–09:30.

The evolution of Ediacaran morphological disparity

Thomas J. Roper-Smith, Luke A. Parry and Frances S. Dunn
University of Oxford, UK

The Ediacaran Biota comprises a taxonomically diverse assemblage of soft-bodied macrofossils exhibiting a plethora of unique body plans. While the morphological diversity of this biota is well established, how and why this disparity of form fluctuates throughout the Ediacaran (~635.0–538.8 Ma) remains poorly understood, particularly in light of new material described in recent years. Here we address this gap by analysing a comprehensive new morphological dataset at multiple spatial scales and temporal resolutions whilst explicitly accounting for biases arising from the heterogeneity of the Ediacaran fossil record. We then contrast these results with coincident patterns in taxonomic richness and interrogate the impact of lithology, palaeobathymetry and palaeogeography on perceptions of Ediacaran morphological disparity. Collectively, these results present the most complete picture of the spatial and temporal distribution of morphological variety throughout the Ediacaran to date.

Wednesday 9th December, Session 3b, Mathematical Institute L2, 15:00–15:15.

Quantifying metazoan locomotion

Harry Savage[1], Luke A. Parry[2], Thomas J. Roper-Smith[2], Jane Reeves[1], William Sellers[1] and Russell J. Garwood[1,3]
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Locomotion is fundamental to the survival and evolution of most animals. A wide variety of animal locomotion strategies are known, many of which have evolved convergently. Previous kingdom-wide studies of animal disparity have found most extant phyla occupy distinct regions of morphospace, and this 'clumpiness' is driven by extinction of intermediate taxa. However, locomotion and morphology are often decoupled; consequently, broad patterns in locomotory evolution remain unstudied through a quantitative framework. We address this uncertainty by using a novel, discrete character dataset that characterizes locomotion for extant adult representatives of all animal phyla to create metazoan 'locomotion space'. Metazoan locomotion space is less structured than morphospace, with regions of high taxon density representing dominant cross-phylum locomotion strategies and minimal phylogenetic clustering. At phylum-level, locomotion spaces are more structured, and phylogenetic clustering is common, indicating fundamental morphological or lifestyle traits may impact locomotion evolution at lower taxonomic ranks. Locomotory disparity varies significantly between phyla and is positively correlated with species richness, with the exception of Arthropoda, a highly speciose phylum with surprisingly low locomotory disparity. Overall, we show the evolution of locomotion within animals is flexible and frequently results in locomotory convergence, but is fundamentally constrained by an animal's evolutionary history.

Thursday 10th December, Session 4c, Mathematical Institute L3, 10:00–10:15.

Evolutionary and ontogenetic trends in skull shape underpinned theropod dinosaur ecology

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Theropod dinosaurs were the dominant predators in late Mesozoic terrestrial ecosystems. Studies of theropod morphology and ecology are therefore crucial for understanding the selective pressures underpinning the macroevolution of dinosaur communities. Theropod skulls exhibit significant morphological diversity, attributable to taxonomic, ontogenetic or ecological variation, or a combination of these. Central to skull morphology and dietary function is the maxilla, which forms a substantial portion of the facial region and houses most of the upper tooth row. We apply geometric and phylogenetic comparative analyses to a dataset of theropod and other archosaurian maxillae to test hypotheses regarding skull shape and function and how they changed over evolutionary time and during ontogeny. We find that: the non-avian theropod maxilla has a distinct morphology in each major clade; maxilla ontogeny recapitulates theropod phylogeny; and maxilla geometry is a useful proxy for investigations of trophic ecology and ontogenetic variation. In particular, ontogenetic maxilla shape variation facilitated inter-and intraspecies niche partitioning in large-bodied theropods (especially allosauroids and tyrannosaurids); achieved by successive ontogenetic stages acting as ecologically distinct functional groups. Furthermore, multiple allometric trajectories within maxilla development suggest that ontogenetic and evolutionary factors likely shaped theropod ecology, highlighting interplay between these factors and theropod skull form.

Thursday 10th December, Session 5, Mathematical Institute L1, 11:15–11:30.

Ammonoid extinction and nautilid survival at the end-Cretaceous: what has hatching size got to do with it?

Michael Schmutzer[1], Erin E. Saupe[1], Christian Klug[2], Amane Tajika[3], Frank Wiese[4], James D. Witts[5], Corinne Myers[6], Neil H. Landman[7], Stijn Goolaerts[8] and Alison J. Rowe[9]
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Sixty-six million years ago, the Chicxulub impact devastated global ecosystems. In the aftermath of the impact, the ammonoids, a charismatic, diverse and abundant group of cephalopods with external shells, went extinct. The nautilids, however, their remote and by then far less diverse relatives, survived up to the present day, and are now the only extant externally shelled group of cephalopods. Fascinatingly, a handful of ammonoid species survived for a short time in the wake of the impact. Why did nautilids survive, but ammonoids ultimately go extinct? And what might have helped the last ammonoid survivors to hold out a bit longer? To answer this question, we tested potential predictors of survival in ammonoids and nautilids. We examine hatching sizes, adult body sizes and geographic range sizes for ammonoids and nautilids. Results for nautilids are inconclusive. For ammonoids, we find mixed signals for geographic range size, and no differences between survivors and extinct genera in body size. Intriguingly, we find tentative evidence that hatching size is associated with short-term survival in ammonoids. This finding

reframes the hatching-size hypothesis for nautilid survival and ammonite extinction, and highlights the need for more research into heteromorph biology to better understand ammonoid resilience and extinction.

Thursday 10th December, Session 4c, Mathematical Institute L3, 09:15–09:30.

Back to the water – coordinated evolution of the inner ear and cervical spine in aquatic carnivorans

Julia A. Schwab[1], Thomas M. B. Kirkwood[2,3], Stephanie M. Palmer[4], Amandine Gillet[3], Stephanie E. Pierce[5] and Katrina E. Jones[3]

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The return to water required extensive reorganization of the vertebrate body, yet different anatomical systems might not respond in concert. In aquatic tetrapods the head must be held steady against hydrodynamic forces during swimming. This task is shared by the cervical column and by the vestibular system of the inner ear, which are functionally linked through the vestibulo-cervical reflex. However, whether these two anatomical systems are remodelled in concert across land-to-water transitions is unclear. Carnivorans, spanning terrestrial to aquatic ecologies, offer an ideal test case. We used a landmark-free, atlas-based method to quantify whole-element shape of the bony labyrinth and all seven cervical vertebrae in 58 extant carnivorans and four stem pinnipeds representing successive stages of the transition. Ecology can significantly predict shape in all eight elements, with low phylogenetic signal. Integration between labyrinth and neck was significantly stronger in aquatic than terrestrial taxa, and strongest in the anterior vertebrae. Indeed, modular neck-ear signals seen in terrestrial and semi-aquatic species break down in pinnipeds, most strongly in phocids, but not in intermediate stem pinnipeds. This suggests that coordinated craniocervical evolution emerges only in fully aquatic taxa, with implications for reconstructing lifestyle from isolated elements in the fossil record.

Thursday 10th December, Session 7, Mathematical Institute L1, 16:45–17:00.

What is the effect of ancestral state estimations on disparity analyses?

Caleb Scutt[1,2], Natalie Cooper[2], Gavin Thomas[1] and Thomas Guillerme[1]

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Morphological trait datasets and phylogenies are routinely paired to investigate macroevolutionary patterns during disparity analyses. However, incomplete fossil sampling can distort disparity estimates. Ancestral state estimation can be used for both continuous and discrete traits to extend these analyses beyond incomplete fossil data. However, when ancestral state estimation occurs in the disparity pipeline and the uncertainty in these estimates complicates their integration. Determining the most robust workflow for integrating ancestral state estimation in disparity analyses remains a methodological challenge. Using simulations to generate ground-truth datasets, we evaluated approaches to performing ancestral state estimation and incorporating uncertainty across varying continuous and discrete trait models, fossil sampling densities and disparity metrics. Ancestral state estimation generally improved recovery of disparity relative to sampled taxa-only analyses, though the optimal approach depended on the interaction between trait model and fossil sampling density. We found that probabilistic rather than deterministic

approaches were the most reliable at recovering true disparity. Interestingly, fossil sampling density was a stronger predictor of disparity accuracy than estimation method choice, underscoring that methodologies are only as powerful as the data provided. Our findings offer a decision framework for selecting the most appropriate workflow given the sampling and trait characteristics of a dataset.

Wednesday 9th December, Session 1b, Mathematical Institute L2, 09:30–09:45.

From ambiguity to information: accounting for intraspecific polymorphism in morphological phylogenetics

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Morphological data is critical for generating time-calibrated phylogenies and reconstructing the evolutionary relationships of extinct taxa, for which genetic data is generally unavailable. However, the impact of within-taxon variation on phylogenetic inference has been rarely discussed in a morphological context. Taxa may exhibit multiple discrete or discretized character states when individuals differ in morphology, a condition known as polymorphism. Polymorphic characters are often coded ambiguously or as the most common state. However, polymorphism arises as a consequence of the evolutionary process, and its distribution may therefore be informative for the evolutionary history of a given clade. This project investigates majority, ambiguous and missing-data coding of polymorphic characters under the Mk model, as well as two models that explicitly accommodate polymorphism: an anagenetic gain-loss model and polymorphism-aware phylogenetic models (PoMos). Both models allow transitions between fixed character states through polymorphic intermediates, but differ in how polymorphism is represented. The gain-loss model treats polymorphism as a single intermediate character state, whereas PoMos explicitly model character state frequency change within populations. Using simulated and an empirical morphological dataset from extant geoemydid turtles, we evaluate how coding scheme and model choice affect discrete-character phylogenetic inference in the presence of polymorphism.

Thursday 10th December, Session 4c, Mathematical Institute L3, 10:15–10:30.

A fresh look at the eurysternid turtles from Late Jurassic of France

Gaël E. Spicher[1,2], Walter G. Joyce[2], Pierre Guériau[3] and Jérémy Anquetin[1,2]

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Historically, Eurysternidae (Thalassochelydia) were among the first fossil turtles recognized as different from extant taxa. This group represent a significant component of Late Jurassic European coastal environments and are particularly common in the lithographic limestones. After attracting scientific interest during the nineteenth century, eurysternids received little study for much of the following century, highlighting the need for a revision. In France, their record is concentrated in two Lagerstätten: the late Kimmeridgian limestones of Cerin and the slightly younger Tithonian deposits of Canjuers. Some of this material was described more than 150 years ago, and numerous specimens have never been reassessed using modern methods and perspectives. Here we revisit the French eurysternid record

through detailed morphological examination and modern imaging techniques such as multispectral luminescence imaging. With the recognition of a new species and the reassessment of several historical taxa, our study reveals an overlooked diversity. It also provides new information on poorly known aspects of eurysternid morphology, and documents substantial intraspecific variation. Together, these results provide a new window into eurysternid diversity and morphology in Late Jurassic of Europe and underlines why revisiting long-overlooked historical collections can still provide valuable scientific knowledge.

Wednesday 9th December, Session 3a, Mathematical Institute L1, 14:00–14:15.

Disentangling oxygen and temperature as controls on extinction risk in marine invertebrates over the Phanerozoic

Cooper M. Malanoski[1]*, Richard G. Stockey[2], Benjamin J. W. Mills[3] and Erin E. Saupe[1]
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Thermal tolerance and the magnitude of climate change experienced by a taxon have both been posited as significant drivers of extinction risk over the Phanerozoic. However, modern ecophysiological experiments suggest that oxygen and temperature have synergistic effects on the metabolic fitness of marine ectotherms. The impact of thermal stress would therefore depend on the availability of oxygen, which is relevant considering oxygen concentrations have changed markedly across the Phanerozoic. However, the role of oxygen availability relative to temperature in mediating extinction risk has yet to be tested over Phanerozoic timescales. Here we aim to quantify the relative importance of temperature and oxygen in modulating extinction risk over the Phanerozoic. We reconstruct dissolved oxygen and temperature in three dimensions across the Phanerozoic by linking the SCION and cGENIE Earth system models. We link these reconstructions to ~400,000 marine invertebrate fossil occurrences from the Paleobiology Database, extracting local oxygen and temperature values for each taxon. Then, for each taxon, we quantified both the realized niche and the magnitude of change in oxygen and temperature between time bins. Extinction selectivity was estimated using a generalized linear mixed-effects model (GLMM) framework, and we tested all possible combinations of temperature and oxygen variables and their interactions. We find that both dissolved oxygen and temperature play important, non-trivial roles in modulating extinction over the Phanerozoic. These findings demonstrate the need to consider multiple abiotic stressors when evaluating extinction risk and has implications for identifying marine taxa most vulnerable to ongoing anthropogenic climate change.

Thursday 10th December, Session 5, Mathematical Institute L1, 12:15–12:30.

Episodic body size variations in early Palaeozoic trilobites linked to marine redox changes

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Body size influences physiology, ecology and extinction risk, yet the large-scale dynamics and environmental limits of size evolution remain poorly understood for most extinct

marine invertebrates. To explore patterns and drivers of body-size evolution in trilobites, one of the most iconic fossil groups, we assembled a high-resolution database of body size for 2,435 species belonging to 1,091 genera of Cambrian and Ordovician trilobites, representing more than 90 % of families known from this interval. Trilobite body size changed episodically rather than directionally. Five rapid transitions delimit six long-term phases, including three marked episodes of miniaturization in the early Cambrian Age 4, Guzhangian and late Katian, and a major size increase following the late Tremadocian black shale anoxic event. The same principal changes are recovered across major palaeocontinents, indicating a global signal rather than shifts in regional sampling or composition. Family-level trajectories and model fitting show no persistent tendency toward increasing size, rejecting a simple Cope's-rule explanation. Instead, body-size reductions coincide with widespread anoxic intervals, whereas the strongest expansion followed the termination of prolonged marine anoxia. These results identify marine redox conditions as a recurrent environmental constraint on trilobite body size, showing that size evolution during the early Palaeozoic was governed by discrete environmental perturbations rather than a uniform directional trend. The dataset provides a framework for testing whether oxygen-related size constraints were shared by other early marine animal clades.

Thursday 10th December, Session 7, Mathematical Institute L1, 15:30–15:45.

Ecological reconstruction of the earliest terrestrial predators via digital fossil mining

Ryo Taniguchi[1], Yasuhiro Iba[2], Kanta Sugiura[2], Aya Kubota[3], Matthew Humpage[1], Sophie Burne[1], Shintaro Sasaki[2], Mehmet Oguz Derin[4], Harufumi Nishida[5] and Alexander J. Hetherington[1,6,7]
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The 407-million-year-old Rhynie chert is one of the best windows into an early terrestrial landscape pioneered by plants and arthropods. Although fossils in the chert are exquisitely preserved, conventional approaches of thin sectioning and serial peeling provide a fragmented view of plants and animals and obscure our ability to investigate the ecological community more generally. Due to this methodological limitation, the exceptional preservation of the Rhynie chert has not been coupled with larger 3D fossil form and habitat space. Here we present abundant spider-like *Palaeocharinus* fossils with 3D anatomical details, using the digital fossil-mining technique, which combines high-resolution grinding tomography with manual/zero-shot learning AI segmentation. Their large, anterior-facing lateral eyes and flexible chelicerae with fangs suggest adaptive predatory behaviour, enabling a wide frontal view and aggressive hunting. Their body size variation and the presence/absence of ventral sacs indicate multiple growth stages and a continuous community. The mode of fossil occurrence supports *in situ* preservation of these *Palaeocharinus* and surrounding plants at the original spatial scale, showing their high density and a well-developed ecosystem rich in primary producers and apex predators in Early Devonian Rhynie.

Thursday 10th December, Session 4a, Mathematical Institute L1, 09:45–10:00.

Ichthyosaurs from the Middle Jurassic of the Isle of Skye, Scotland

Molly Tumelty[1,2]*, Stig Walsh[1,2], Stephen L. Brusatte[1,2], Davide Foffa[3,4,5], Erin Maxwell[6] and Nicholas Fraser[1,2]

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The Middle Jurassic was a critical turnover period in ichthyosaur evolution, marked by the disappearance of non-ophthalmosaurid ichthyosaurs from the fossil record and the first radiation of deep-diving-adapted ophthalmosaurids. This transition was likely driven by global marine regressions that caused the loss of shallow-water coastal shelf environments. Unfortunately, fossils from this period, or more specifically the Aalenian–Bathonian interval, are scarce. Consequently, details on ichthyosaur diversity and the transition from non-ophthalmosaurids to ophthalmosaurids remain unclear. The Isle of Skye in Scotland contains a globally significant Middle Jurassic sequence with fossils that provide crucial data to bridge to these gaps. Only one ichthyosaur has previously been described from the Middle Jurassic of Skye. Here we describe six additional ichthyosaurs from the Bearreraig Sandstone Formation on Skye. One specimen, likely to represent a new taxon, is represented by extensive cranial and post-cranial material, the likes of which only exists in four other described Aalenian–Bathonian specimens worldwide. Results indicate that most of these specimens are non-ophthalmosaurid neoichthyosaurian ichthyosaurs, including two species likely new to science. These fossils expand the known taxonomic diversity of the Middle Jurassic, and provide critical data regarding the final non-ophthalmosaurid lineages.

Thursday 10th December, Session 5, Mathematical Institute L1, 11:30–11:45.

The Clarkia biota: an exceptionally preserved Miocene lake ecosystem

Joshua W. Turner and Nicholas J. Butterfield

University of Cambridge, UK

The Miocene Clarkia lake beds (Idaho, USA) are well-known for their exceptionally preserved plant fossils and have inspired decades of research in palaeobotany and organic geochemistry. A low-manipulation acid maceration technique has now revealed a previously overlooked, diverse assemblage of aquatic insects and crustaceans. These remarkably well-preserved fossils provide a record of Clarkia's autochthonous lake ecology, which was previously limited to fossil fish, a single mayfly nymph and occasional caddisfly cases. The Clarkia biota includes abundant larval and pupal midges, cladoceran crustaceans, mayfly and caddisfly nymphs and acariform mites. The extraordinary preservation and diversity of this assemblage marks Clarkia as one of the most comprehensive records of a lake ecosystem in deep-time. All major clades of modern lacustrine ecosystems are represented in the Clarkia biota, including crustacean zooplankton, midge larvae, littoral-benthic macro- and micro- invertebrates, diatoms, dinoflagellates, teleost fish and aquatic macrophytes. Despite dramatic changes which have shaped terrestrial and marine ecosystems since the Miocene, the Clarkia biota reveals a remarkable stasis in lacustrine ecology. The middle Miocene is one of the closest analogues in the geologic record for near-future climate change, making Clarkia a potential window into the how temperate lake ecosystems may respond in the coming decades.

Wednesday 9th December, Session 3c, Mathematical Institute L3, 14:45–15:00.

'Whiplash' tail variability in flagellicaudatan sauropods

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The 'whiplash' morphology of the tails of flagellicaudatan sauropods earns them their name, and consists of a series of elongated, rod-like slender vertebrae that make up the end of their caudal region. Although several hypotheses exist regarding the function of these elongated tails, little focus has been put towards the morphology of this part of the tail. The morphology, however, informs our understanding of the function of their specialized tails. Here we describe several tails from the historic Howe Quarry, Wyoming, USA (Upper Jurassic, Morrison Formation), some including the terminal caudal vertebra. Through a detailed description of these specimens and comparison with other neosauropod tails, we highlight previously unappreciated morphological variability, and demonstrate that the number of caudal vertebrae making up the whiplash part of the tail can vary significantly within Flagellicaudata. Comparisons with extant taxa underlines the difficulty of whether this variation can be attributed to inter- or intraspecific variation. This work elucidates several clear morphological differences between these Howe Quarry specimens, as well as other neosauropod tails, which needs to be considered when evaluating the function of flagellicaudatan tails and potentially their phylogenetic affinities.

Wednesday 9th December, Session 1a, Mathematical Institute L1, 09:15–09:30.

Unlocking the origins of spiders: 3D-preserved Carboniferous arachnids from the Montceau-les-Mines Lagerstätte

Camille Vidal-Marty[1], Russell J. Garwood[2,3], Jason A. Dunlop[4] and Vincent Perrier[1]

[1]Université Claude Bernard Lyon 1, France; [2]The University of Manchester, UK; [3]Natural History Museum, London, UK; [4]Museum für Naturkunde, Berlin, Germany

The earliest fossil spiders provide key insights into the origin and evolution of key innovations, notably the spinneret-based silk-spinning apparatus. Amongst the oldest known spiders is *Palaeothele montceauensis* from the Carboniferous Montceau-les-Mines Lagerstätte, France (~305 Ma), which preserves the earliest evidence of spinnerets. We investigate four siderite-hosted fossil arachnids using X-ray microtomography, including the first three-dimensional reconstructions of *P. montceauensis*, and two newly described specimens attributable to *Idmonarachne brasieri*. Non-destructive imaging reveals previously inaccessible morphological details, including spinneret organization, the eye tubercle, and appendage morphology. Our results confirm the presence of multi-segmented anteromedian, anterolateral, and posterolateral spinnerets in *P. montceauensis*. The newly studied specimens of *I. brasieri* provide new morphological information missing in the holotype, including a complete prosoma and opisthosoma. Phylogenetic analyses consistently recover *P. montceauensis* as early branching Araneae under both maximum parsimony and Bayesian frameworks. *Idmonarachne* is recovered as sister to Araneae, consistent with previous hypotheses. *P. montceauensis* and *I. brasieri* are identified as key elements of a complex trophic chain in the tropical Carboniferous ecosystem of Montceau-les-Mines.

Thursday 10th December, Session 4b, Mathematical Institute L2, 10:15–10:30.

talks

Characterization of decay in filamentous cyanobacteria reveals a predictable, broadly conserved taphonomic pathway

Philip B. Vixseboxse and Sean McMahon
University of Edinburgh, UK

Cyanobacteria represent 'arguably the most important group of organisms ever to appear on our planet' (Knoll *et al.* 2008). From driving major oxygenation events, to fixing the vast majority of organic carbon on Earth (either as free-living organisms, or as chloroplasts), cyanobacteria are crucial ecosystem engineers that have shaped the whole Earth system. While the geologic consequences of most cyanobacterial life processes are well-characterized, the biases implicit to cyanobacterial fossilization are less well understood. In essence, does the subset of cyanobacteria that entered the fossil record faithfully capture the diversity at the time, or does it exhibit preferential preservation of specific taxonomic groups? If so, how does this distort our understanding of cyanobacterial diversity through time? Here, utilizing a novel taphonomic well slide protocol, we characterize the decay pathways of individual cyanobacterial filaments for multiple strains of cyanobacteria, including representatives of Oscillatoriales, Nostocales and Pseudanabaenales. We explore the impact of heterotrophic microorganisms on decomposition, finding both commonalities and dissimilarities between taxa. Decay rates are found to be highly variable between taxa, but the sequence of decomposition is broadly consistent throughout. We also highlight the use of cyanobacterial taphomorphs as additional informative characters for assigning taxonomic affinities to fossil, putatively cyanobacterial, filaments.

Wednesday 9th December, Session 1c, Mathematical Institute L3, 09:30–09:45.

New Ediacaran triradial animal illuminates the origins of ctenophores and cnidarians

Xiaopeng Wang[1,2], Alexander G. Liu[2], Giovanni Mussini[2], Frances S. Dunn[3], Erik Tihelka[2], Ke Pang[1,4], Zhe Chen[1], Chuanming Zhou[1,4], Bin Wan[5] and Xunlai Yuan[1,4,6,]
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Ctenophores and cnidarians are early-branching animal groups, and their early fossil records are important for understanding their evolutionary history, resolving the question of whether sponges or ctenophores represent the earliest-branching animal group, and clarifying the relationship between ctenophores and cnidarians. Here we report a new triradial fossil (trilobozoan) from the Ediacaran Wenghui biota of China (~567.3–556.4 Ma) that informs these debates. The new fossil is preserved as a carbonaceous compression and exhibits a threefold-symmetric body plan with feather-like processes, which we interpret as the earliest known filter-feeding tentacles. The three processes each extend from a ficiform lobe. The three lobes are spirally arranged around a presumed central opening, resembling the radially arranged gastrovascular compartments of cnidarians. Meanwhile, the rotational but non-reflective symmetry of the body plan is comparable to the biradial symmetry of ctenophores. The possible presence of multiple anal pores in the new fossil is also a characteristic feature of modern ctenophores. This chimeric combination of characters provides a morphological bridge between ctenophores and

cnidarians. Phylogenetic analyses support the placement of the new fossil as a stem-group coelenterate, resolving the metazoan placement of the Trilobozoa.

Wednesday 9th December, Session 3b, Mathematical Institute L2, 14:15–14:30.

Deep-sea ostracod faunal change from the Late Cretaceous to the Early Miocene

Yumeng Wei[1] and Moriaki Yasuhara[2]

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The history of deep-sea biodiversity remains poorly resolved, but the long-term fossil record offers an important perspective on how deep-sea ecosystems respond to environmental change. Here we use ostracods, small crustaceans with readily fossilized shells, to trace changes in Southern Ocean deep-sea communities over approximately 53 million years. Fossil records from International Ocean Drilling Program Sites 689 and 690 on Maud Rise span the Late Cretaceous to the early Miocene. Ostracod abundance, diversity and community composition followed distinct trajectories: abundance fluctuated substantially, while genus-level diversity remained comparatively stable, and assemblages underwent sustained, directional reorganization. Changes in the dominant genera progressively transformed the Mesozoic fauna into an assemblage increasingly characterized by modern deep-sea typical taxa. This extended record allows successive climatic and oceanographic changes to be considered within a broader history of faunal development.

Thursday 10th December, Session 4c, Mathematical Institute L3, 09:45–10:00.

An early Cambrian mosaic stem-euarthropod sheds light on the origin of arthropodized trunk appendages

Yu Wu[1], Stephen Pates[2], Cong Liu[1], Yuheng Wu[1], Chenguang Guo[1], Xingliang Zhang[1] and Dongjing Fu[1]

[1]Northwest University, China; [2]University College London, UK

Arthropods are the most diverse animal phylum, characterized by arthrodization of body and arthropodized appendages. These appendages are generally thought to have evolved from lobopodian-grade appendages, yet the fossil evidence documenting this transformation remains scarce. Here we describe *Qingjiangloboarthrus radiostomatus* gen. et sp. nov., a stem-group euarthropod from the early Cambrian Qingjiang Lagerstätte (approximately 518 Ma) of China. *Qingjiangloboarthrus* exhibits a unique combination of a radiodont-like oral cone, deuteropod-like sternites, and trunk appendages with a differentiated proximal base contrasting with a lobopodian-grade annulated distal portion. The proximal base is consistent with incipient arthropodization, as indicated by its localized sclerotization comparable to the sternites, gnathobase-like spinose differentiation and telescoping articulation comparable to that of arthropodized appendages. Bayesian and parsimony phylogenetic analyses resolve *Qingjiangloboarthrus* immediately stemward of Radiodonta. These data indicate mosaic evolution along the euarthropod stem and suggest that early arthropodization of trunk appendages may have been regionally expressed at the ventral body–appendage interface before becoming established along the appendage as a whole, providing new insight into the stepwise acquisition of the euarthropod body plan.

Thursday 10th December, Session 7, Mathematical Institute L1, 15:45–16:00.

talks

A comprehensive phylogenomic framework for brachiopod evolution among lophotrochozoans

Mingzhu Yang[1], Aodhán D. Butler[2], Natalia López Carranza[3], Jakob Vinther[1], Rowan J. Whittle[4], Daniela Henkel[5], Hana Jurikova[6], Gert Wörheide[7], Mattia Giacomelli[8] , Philip C. J. Donoghue[1], Davide Pisani[1], Sandra J. Carlson[2] and Erik A. Sperling[9]

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Brachiopods appeared early in the Cambrian radiation and represent an important clade for understanding the origin of animal body plans and the evolution of biomineralized structures. A robust phylogenetic framework of the living representatives is needed to answer persistent questions about the evolution of brachiopod mineralogy, shell morphology and identification of the brachiopod sister group among Lophotrochozoa. Here we present the first phylogenomic analysis of Brachiopoda and related lophotrochozoan lineages using a comprehensive dataset encompassing all five extant brachiopod orders and employing a novel data-refining strategy, compositionally heterogeneous substitution models, and a novel implementation of the parametric-bootstrap likelihood-ratio test. We recover monophyly of Lophophorata, with strong support for Brachiopoda as sister to Bryozoa plus Phoronida. Within Brachiopoda, we recover the clade of inarticulated phosphatic Linguliformea sister to the inarticulated calcitic Craniiformea, with both sister to the articulated calcitic Rhynchonellata, with miniaturized Thecideida unexpectedly nested within Terebratulida. Our phylogeny implies that at least one evolutionary transition in primary mineralogy occurred in Brachiopoda, a phenomenon not recognized in any other metazoan group.

Thursday 10th December, Session 4b, Mathematical Institute L2, 09:15–09:30.

High evolutionary turnover of fusulinids during the late Palaeozoic ice age

Shu-han Zhang[1,2], Wolfgang Kiessling[2], Yu-Kun Shi[1], Xiang-Dong Wang[1], Jun-Xuan Fan[1] and Shu-Zhong Shen[1]

[1]Nanjing University, China; [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

Previous analyses suggested that the late Palaeozoic ice age (LPIA) was characterized by depressed origination and extinction rates of marine invertebrates. Using a newly established global high temporal resolution dataset of fusulinids, a late Palaeozoic group of larger benthic foraminifera, we tested the hypothesis of climatically depressed biodiversity dynamics in the LPIA and the influence of temporal and taxonomic resolutions. We found that turnover rates of fusulinids were higher during the LPIA than in the subsequent greenhouse interval of the Middle and Late Permian at all different temporal and taxonomic resolutions. We suggest that this pattern is related to clade-age dynamics, as the fusulinids emerged just before the LPIA with initially limited geographic ranges and biogeographic connectedness, which facilitated both extinction and origination. In addition, statistically defined evolutionary faunas provide evidence for gradual faunal replacements and a growing influence of origination on fusulinid diversification. Origination-driven diversification happening in the late Palaeozoic indicated that the end-Permian extinction may not be the main trigger for this shift in biodiversity dynamics.

Thursday 10th December, Session 4c, Mathematical Institute L3, 09:30–09:45.

Does body size dictate evolutionary rates? Insights from plesiosaur evolution

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Body size is negatively correlated with molecular evolutionary rates in vertebrates, but whether this relationship extends to phenotypic evolution remains unclear. We combine Bayesian tip-dating, phylogenetic comparative methods, and body-mass estimates for 89 plesiosaur species to test whether body mass predicts morphological rates. Plesiosaur body mass evolution conforms to a three-regime Ornstein-Uhlenbeck model. The regime occupied by most species has an estimated optimum of 407 kg, similar to the published estimates for most extant marine mammals. However, body mass does not predict morphological evolutionary rates across skeletal modules. Rate bursts instead exhibit module-specific distributions and do not cluster within particular body-mass intervals. These results show that body-size effects on evolutionary rates depend on biological organization: the negative relationship widely documented for vertebrate molecular evolution cannot be directly extrapolated to morphology. Plesiosaurs thus demonstrate that body size and morphological innovation can follow decoupled evolutionary trajectories.

Thursday 10th December, Session 4a, Mathematical Institute L1, 09:15–09:30.

Abstracts of lightning/flash talks

* Candidates for the Council Lightning/Flash Talk Prize are marked with an asterisk.
Underlined author denotes designated speaker.

Quantifying changes in ammonoid morphological disparity during the Late Devonian

Ninon Allaire[1], Néo Nicollet[1], Samuel Ginot[1], Dieter Korn[2], Claude Monnet[3] and Catherine Crônier[3]

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Ammonoids are a major group of extinct cephalopods that first appeared during the Emsian (Early Devonian). Recently, we examined ammonoid species richness during their initial Devonian radiation using the fossil record from the Anti-Atlas (Morocco), revealing highly fluctuating diversity patterns characterized by successive phases of diversification and decline, generally correlated with environmental perturbations. The Anti-Atlas provides an exceptional fossil record for the study of Devonian ammonoids, allowing us to also document variations in their morphological disparity. Accordingly, our previous research investigated this complementary dimension of biodiversity throughout the Early and Middle Devonian: a major increase in disparity characterized the Early Devonian, followed by a fluctuating decline during the Middle Devonian. Building on this work, we present here the results of a new study focusing on the Late Devonian, based on the same approach combining geometric and traditional morphometrics. The resulting data are summarized using principal component analysis. Several disparity indices are then used to quantify changes in disparity through time. The results reveal a significant increase in morphological disparity during the Late Devonian, with high values during the Famennian, particularly following the Dasberg Event, exceeding those observed during the Early and Middle Devonian.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:35–14:40.

The thermometabolism of pseudosuchians: a study of phylogenetic comparative methods

Cassandra Cheyron[1]*, Mathieu G. Faure-Brac[2], François Clarac[1], Ángela D. Buscalioni[3], Mercedes Llandres[4], Isabelle Drouet[1] and Jorge Cubo[1]

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Extant crocodilians are ectothermic archosaurs that diverged approximately 250 million years ago from avemetatarsalians, whose only extant members are birds, known to be endotherms. Since extant crocodilians present features linked to endothermy, previous researchers hypothesized that archosaurs were ancestrally endotherms; the switch to ectothermy in crocodilians would then be a derived condition. To constrain this transition both temporally and phylogenetically, we analysed †*Cassissuchus sanziuami* Buscalioni (2017), a small terrestrial gobiosuchid from the Lower Cretaceous of Las Hoyas (Spain)

as its phylogenetic position is key to target the acquisition of ectothermy in Pseudosuchia. Using phylogenetic comparative methods, we inferred both its mass-independent resting metabolic rate and its probability of endothermy, using the osteocyte lacunar density quantified in its primary bone as a proxy. From these analyses, †*C. sanziuami* was inferred to be an endotherm, thus supporting our main hypothesis: the loss of endothermy for Pseudosuchia at the node (Thalattosuchia - Metasuchia). Additionally, we offer an epistemological reflection on the phylogenetic comparative methods employed in this study. The distinctions between phylogenetic generalized least squares, phylogenetic eigenvector maps and phylogenetic logistic regression are analysed and used in an integrative approach.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:25–14:30.

Mosaic pattern of morphological change in the cranidia and pygidia of Low-latitude within-area speciation drove early trilobite bioregionalization

Elizabeth M. Dowding[1], Adriane R. Lam[2], Luis Collantes[3], James D. Holmes[4], Katherine Jordan-Burmeister[5], Harriet B. Drage[6], Lukáš Laibl[7], Kelsey Lucas[8], M. Gabriela Suárez[9], Marc Nikolic[10], Alexis Rojas[11], Fernanda Serra[12], Jorge Esteve[13] and Stephen Pates[14]

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Major features of our modern biosphere, including the development of bioregions and the latitudinal diversity gradient, may originate in the Cambrian. Diversifying rapidly throughout the Cambrian, trilobites are key to understanding this origination of biogeographic patterns. However, their origins and biogeographic history remain poorly understood, with uncertainty over ancestral area. We analysed the palaeobiogeography and spatial evolution of Cambrian trilobites in a phylogenetic context across different biogeographic models to address this uncertainty. Using phylogenetic data from Paterson *et al*. (2019), we used BioGeoBEARS for the first time to reconstruct ancestral states, infer dominant speciation types, and identify global dispersal pathways. The best-fitting model was DEC+j, indicating that the spatial evolution of Cambrian trilobites involved dispersal-mediated range expansions and episodic colonization of three distinct clade-related bioregions. This suggests that founder event speciation was an important mechanism and/or that we have an incomplete fossil record, masking true biogeographic patterns. Results suggest trilobites originated in peri-Gondwana, congruent with previous palaeontological evidence, although this might reflect incomplete taxon sampling. Additionally, the initial break-up of Gondwana and species-species interactions contributed to dispersal and niche partitioning patterns, respectively. Lastly, we highlight the importance of assessing multiple biogeographic models to tease apart true patterns from noise.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:10–14:15.

Environmental heterogeneity and contrasting oyster-bank-associated molluscan communities from the Eocene of western India

Adrisuta Ghosh[1], Shiladri S. Das[1] and Kanishka Bose[2]
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Amidst the accelerating global biodiversity crisis and rising temperatures, understanding the role of marine foundation species in promoting and sustaining biodiversity has become increasingly imperative. The present study examines the diversity of marine molluscan communities associated with *Flemingostrea pseudoflemingi* oyster banks preserved in coeval strata of the Eocene succession of two western Indian basins, Jaisalmer (OB 1) and Kutch (OB 2), against the backdrop of the Middle Eocene Climatic Optimum (MECO). The two palaeocommunities exhibit marked differences in both taxonomic and functional diversity. Rank-abundance modelling identifies a preemption model for OB 1 and a Mandelbrot distribution for OB 2, indicating contrasting ecosystem health despite the presence of the same foundation species and broadly similar depositional conditions, as inferred from petrographic analyses. Their ecospace occupation also differs substantially, with OB 1 lacking infaunal taxa. Notably, the *F. pseudoflemingi* oyster bank in the Jaisalmer Basin appears to have acted as a locus of glauconite grain formation. The occurrence of glauconite within the oyster bank likely indicates weakly reducing, hypoxic conditions that may have limited the recruitment of numerous benthic taxa, suggesting that microenvironmental heterogeneity generated within foundation species can strongly influence diversity and ecological organization of local benthic communities.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:30–14:35.

talks

Macroevolutionary shift in early ray-finned fishes associated with the Devonian–Carboniferous transition

Sam Giles[1], Emily M Troyer[2,3], Zach Lyons-Weiler[2], Rodrigo Tinoco Figueroa[2,4,5], Ben Igielman[1], Richard P. Dearden[1], Abigail Caron[5], Michael I. Coates[5], Stephanie E. Pierce[4] and Matt Friedman[2]
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Ray-finned fishes (Actinopterygii) possess a remarkable diversity of morphologies, ecologies, and life history strategies. An explosion of diversity levels during the Carboniferous has been interpreted as an evolutionary radiation following the end-Devonian extinction, potentially driven by the opening of ecological niches. Here we integrate functional measurements and three-dimensional data from CT scans of well-preserved mandibles in a phylogenetic comparative framework to formally test for a macroevolutionary shift tied to the Devonian–Carboniferous transition. Consistent with past work, we find that Carboniferous actinopterygians occupy significantly expanded regions of trait space and exhibit elevated disparity relative to Devonian species. Importantly, this cannot be attributed to the accumulation of disparity under a uniform macroevolutionary regime. Comparison of multiple scenarios strongly favour a shift in evolutionary mode for jaw shape across the Devonian–Carboniferous boundary. We find overwhelming support for constrained evolution in the Devonian followed by diffusive evolution in the Carboniferous, consistent with an ecological release following Devonian-Carboniferous ecosystem restructuring. One notable emergent feeding strategy appears to be durophagy, with these clades exhibiting the highest evolutionary rates. These results suggest that early actinopterygian success was facilitated by a post-Devonian expansion in

ecological opportunity, leading to increased functional diversification in jaws and teeth.
This work was supported by NSF-EAR grants 2218892, 2219069 and 2219007.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:40–14:45.

A niche modelling approach adapted to small datasets

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The recent development of ecological niche modelling (ENM) has allowed testing of biotic and abiotic constraints on taxa distribution. Although often employed in ecology, its use is less common in palaeontology ('palaeoENM'), mostly due to the scarcity of the fossil record. Here we propose a new workflow especially designed for small datasets to enhance palaeoENM: we generate pseudo-presences to complete the dataset; we model taxa distribution with the Non-Parametric Probabilistic Ecological Niche (NPPEN) model which, contrary to other ENMs, tests all possible combinations of environmental parameters to better model taxa distribution; we map the local contribution of each environmental parameter to taxa distribution using Shapley values; and we quantify the robustness of the simulations among studied taxa. We successfully applied this procedure to two conodont (Vertebrata) genera, *Clarkina* and *Hindeodus*, from the Permian/Triassic boundary (PTB; *c*. 252 Ma). We showed that *Clarkina* species migrated from low to high latitudes, driven by temperature increase and hydrogen sulphide presence in the Tethys, while *Hindeodus* species latitudinally expanded their global distribution, validating previous assumptions from the literature. Our protocol can help palaeontologists to perform reliable ENM on small datasets to extend our knowledge on drivers of extinct taxa distribution.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:35–14:40.

Metazoan diversification characterized by elevated rates of evolution during the middle Ediacaran to earliest Cambrian

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To test causal hypotheses for the emergence of animal bodyplans, we analyse rates of molecular and phenotypic evolution across Opisthokonta, focusing on divergences within the Tonian–Ordovician interval. Both molecular and phenotypic rates increase through the Ediacaran, peaking in an Ediacaran and earliest Cambrian interval before declining thereafter. Partitioning phenotypic characters into categories relating to development, feeding, fossilization potential, locomotion and nervous systems reveal distinct temporal patterns, with developmental traits contributing disproportionately to elevated rates in the metazoan stem lineage. Rate patterns show a temporal lag between the ecological changes integral to hypotheses of developmental evolution and the Cambrian agronomic, substrate and information revolutions and earlier peaks in the evolution of the associated phenotypic characters. These patterns are largely independent of the timescale used. Overall, our results indicate that the primary phase of elevated evolutionary novelty occurred during

the Ediacaran and culminated in the late Ediacaran - earliest Cambrian, providing the foundation for later ecological and taxonomic innovation.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:15–14:20.

Dinosaurian basipterygoid processes (braincase elements): anatomy and evolution

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The cranial kinetic system, which facilitates relative movement of parts of the dinosaurian skull, comprises a complex set of intracranial joints, flexion zones, ligaments and musculature. Basipterygoid processes (paired, stalk-like braincase elements) are a common component of this system, forming joints with the pterygoid bones of the palate. While most non-avian dinosaurs bear these processes, they are variably present among extant dinosaurs (birds). Indeed, neognathous birds (some members of which exhibit the most extensively developed examples of dinosaurian cranial kinesis) include representatives that both bear and lack these processes entirely. In contrast, palaeognathous birds (which exhibit reduced kinetic capacity) always bear basipterygoid processes. At present, the precise function of these processes within the dinosaurian skull remains incompletely understood. To better understand the functional role of basipterygoid processes we provide a thorough assessment of morphological variation of dinosaurian basipterygoid processes, using a dataset built from CT scan-derived three-dimensional models and photographs. We identify an abrupt shift in both the predominant orientation of the basipterygoid processes and the type of contact with the palate between examined extinct and extant dinosaurs. We posit these shifts may be of functional significance and therefore potentially represent necessary precursors for the evolution of avian cranial kinesis.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:40–14:45.

Heliolitids as analogues for modern reef corals: a case study from the Devonian of Queensland

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The Givetian strata of the Burdekin Formation, cropping out in the Fanning River area of Queensland, comprise transgressive deposits that grade from siliciclastic to fossiliferous reefal facies. Tabulates and stromatoporoids dominate the bioconstructions in the carbonate interval, while *Heliolites porosus* accounts for up to 80 % of the massive corals. This study analyses the species' palaeoecology and assesses its potential as a Palaeozoic analogue for modern hermatypic corals. Analyses of coral growth patterns and microfacies support previous interpretations of the environment as a shallow-water, mesophotic coral ecosystem characterized by high turbidity, episodically elevated hydrodynamic energy, and increased sediment influx. Cyclic growth banding in *H. porosus* indicates slow linear extension rates, possibly reflecting turbid mesophotic conditions. Relatively small coralla and abundant growth-interruption surfaces further suggest suboptimal growth conditions. The coral adaptations, palaeoenvironment, and Givetian palaeoclimate closely resemble those of modern turbid reefs in tropical latitudes. Heliolitid corals can be useful analogues for modern massive reef corals because of their inferred environmental preferences,

growth patterns, probable photosymbiosis, and abundance in Middle Palaeozoic reefs. In particular, *H. porosus* thrived during rapid Givetian climate warming and has a direct modern analogue in *Heliopora coerulea*, which developed a nearly identical skeleton through evolutionary convergence.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:30–14:35.

Trajectories of taxonomic and functional diversity of marine organisms across the Permo-Triassic extinction and radiation

Clare Liedstrand, Rachel Wood and Amelia Penny
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Palaeontology defines extinction events by taxonomic loss alone. The Permo-Triassic extinction is the most devastating mass extinction, delineating the transition between Sepkoski's Palaeozoic and Modern evolutionary faunas. Borrowing from ecological methodologies, this study uses Hill numbers to quantify the changes to taxonomic and functional diversity across richness, Shannon diversity and Simpson diversities. These metrics weigh diversity by increasing degrees of abundance, painting a more novel and comprehensive picture of how marine life changed across the Permo-Triassic mass extinction and the subsequent Triassic radiation. In the early Triassic, equatorial palaeolatitudes and Tethyan seas were more taxonomically and functionally diverse. Recovery was delayed until the Carnian in higher latitudes and Panthalassa, but these regions maintained stable levels of taxonomic and functional diversity, while equatorial regions experienced a decline in the late Triassic. Nekton, including cephalopods and chordates, rebounded rapidly by the Olenekian, while epifaunal and infaunal organisms lagged behind. Declines across several taxonomic and functional groups indicates evidence for a small extinction event in the Ladinian. Using these more quantitative interdisciplinary methodologies, our analyses reveal a regionally, latitudinally and functionally heterogeneous trajectory of recovery and radiation.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:00–14:05.

Remopleurididae Hawle & Corda (1847) (Trilobita)

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Remopleuridids constitute important components of Ordovician ecosystems, occupying diverse marine environments across palaeocontinents. They underwent two major diversification events accompanied by pronounced morphological changes. We studied macroevolutionary patterns in Remopleurididae using pygidial morphometric data from 47 genera. Disparity and morphospace occupation were analysed through time and compared with cranidial patterns. Our results reveal a significant shift in pygidial morphology from spinous, laterally expanded forms towards more streamlined morphologies. By the Middle Ordovician, pygidia were restricted to a narrow region of morphospace, whereas during the Late Ordovician, the family expanded into both a novel region of morphospace and one previously occupied by earlier forms. Comparison with cranidial patterns reveals a coordinated shift in morphology while highlighting important differences between the two structures. Pygidial disparity remains constant through time, while cranidial

disparity decreases significantly. Moreover, cranidia occupied the region of morphospace corresponding to more streamlined morphologies early in their history, whereas pygidia did not explore it until the Late Ordovician, suggesting that these structures were subject to different constraints and followed decoupled trajectories through time. Rather than reflecting decreasing disparity associated with ecological specialization, the evolution of Remopleurididae appears as a mosaic pattern of morphological change, with pygidia exhibiting greater morphological lability.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:05–14:10.

Exploring the correspondence between the brain and the endocranial cavity in sauropsids

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Sauropsids (including reptiles, birds and their relatives) are incredibly diverse, displaying extreme variation in life history, thermoregulation and brain size. Because brain tissue almost never fossilizes, casts of the endocranial cavity (endocasts) are essential to study neuroanatomy in extinct taxa. Unlike birds, which almost entirely fill the endocast with neural tissue, non-avian sauropsids fill proportionally less of this cavity with brain, resulting in lower brain-endocast correspondence (BEC). Brain size and morphology are therefore poorly represented by the endocast, confounding attempts to study sauropsid brain evolution. Using digital models of brains and endocasts generated from diffusible iodine contrast-enhanced computed tomography scans, we characterise BEC across 50 non-avian sauropsids. We used geometric morphometrics and dense cloud comparison to quantify group-wide BEC variation. We show, broadly, that the cerebrum corresponds closely to the endocast, whereas the optic tectum and cerebellum correspond less well. Small-bodied squamates display a higher-than-expected BEC in the hindbrain, adjacent to the inner ear, likely arising from the constraints of small skull size. Ultimately, this work will facilitate more accurate estimations of brain volume and morphology from fossil endocasts and clarify trends in sauropsid brain evolution, including the origin of the elaborate, neuron-dense avian brain capable of complex cognition.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:35–14:40.

Low background oxygen enabled aerobically selective extinction during the Late Ordovician mass extinction

Pedro Monarrez[1], Evren Arif[1,2], Alexandre Pohl[3], Richard G. Stockey[4], Jood Al Aswad[1], Ryan Yohler[5], Seth Finnegan[5] and Erik A. Sperling[6]

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The Late Ordovician mass extinction (LOME) is unique among the Big Five as the only event strongly tied to cooling, yet no later glaciation produced equivalent losses. Geographic range

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and thermal breadth are established selective factors, but the physiological mechanism linking glaciation to genus-level extinction remains unquantified. Here we test whether aerobic physiology, measured by the factorial metabolic index (MI) under Katian and Hirnantian baseline ocean conditions, predicts extinction selectivity. Mapping 1,155 marine genera onto Late Ordovician cGENIE climate fields, we confirm geographic range and thermal breadth as dominant predictors but find that Katian-baseline aerobic scope is independently significant. Extinction was highest among genera in low-latitude, low-pO_2 shelf environments, those nearest their aerobic limits in a low-oxygen world (~30–40 % PAL), not because cooling reduced aerobic scope, but because they had the least physiological buffer to absorb glaciation-driven habitat disruption. A two-pulse comparison reveals this signal is specific to pulse 1; the Hirnantian shelf's compressed pO_2 gradient (~2.5-fold vs ~20-fold Katian) renders the pulse 2 MI signal fully temperature-mediated. Low Ordovician background oxygen was the critical enabling condition for aerobically selective extinction, potentially explaining why subsequent cooling events produced no equivalent biotic crisis.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:25–14:30.

Mapping stomatal variation in the Cretaceous conifer *Frenelopsis*: insights into ecophysiology and taxonomy

Axel Montigny, Bernard Gomez, Véronique Daviero-Gomez and Christophe Lecuyer
Université Lyon 1, France

The cheirolepidiaceous conifer genus *Frenelopsis* was abundant and highly diverse in European Cretaceous floras. Its branched shoots bear leaves arranged in whorls, each consisting of a long, unsutured basal sheath terminating in two or three free, triangular leaf apices. Taxonomic distinctions within the genus have traditionally relied primarily on qualitative characters, particularly the morphology and arrangement of the stomatal apparatus. Conversely, the spatial distribution of stomatal apparatus and the quantitative variation in their characteristics within individual shoots have never previously been investigated. Here we analyse 50 cuticular specimens of *Frenelopsis* collected from ten distinct French and Spanish localities. For each specimen, stomatal parameters –including stomatal density, stomatal index and stomatal diameter– were measured across 30 sampling areas distributed longitudinally and transversely along the cuticle. For the first time, we provide high-resolution maps of spatial variation in stomatal parameters and compare these patterns among specimens, localities and species. Our results further suggest that post-mortem flattening of shoots can be distinguished from their original three-dimensional orientation in life. Specifically, the observed distribution of stomatal parameters is interpreted as the orientation of leaves, potentially linked to light interception. Finally, we assess the contribution and potential usefulness of quantitative stomatal measurements for the taxonomy of *Frenelopsis*.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:20–14:25.

New organic-walled microfossil assemblage from the 1.8-billion-year-old Rove Formation, Animikie Group, Canada

Sanaa Mughal[1], Daniela Gutierrez Rueda[1], Baptiste Coutret[1], Achyuth Venugopal[2], Zhiquan Li[3], Philip W. Fralick[3], Simon W. Poulton[2], Ross P. Anderson[4] and Kurt O. Konhauser[1]
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Molecular clocks and putative fossils suggest eukaryotes diverged from archaea during the Palaeoproterozoic (2.5–1.6 Ga) or earlier, yet widely accepted fossil evidence for total- or stem-group eukaryotes appears near the Palaeoproterozoic–Mesoproterozoic boundary (~1.78–1.63 Ga), marked by large organic-walled microfossils with complex wall ornamentation and excystment structures. The 1.88 Ga Rove Formation (Animikie Group, Ontario, Canada) directly overlies the famous 1.9 Ga Gunflint Formation, whose diverse microfossil assemblage includes cyanobacteria and enigmatic unicellular forms debated as possible early eukaryotes. Whilst Gunflint's microfossil affinities remain contested, the Rove Formation offers a chance to examine near-contemporaneous organic-walled microfossils preserved in fine-grained siliciclastic rock. We describe a new microfossil assemblage from the lower Rove Formation, recovered from drill core, comprising diverse sphaeromorphs and filamentous taxa with variable wall textures visible under scanning electron microscopy. Differential preservation within the same mudstone layers points to compositional differences among taxa. We formally describe and assign several new taxa, assess their biological affinities and potential eukaryotic status, and integrate these findings with high-resolution palaeoredox proxies (Fe, Mo, V, Re, U) and sedimentological analysis, building on the Animikie Basin's established redox history, to reconstruct the environmental conditions supporting this assemblage during a pivotal interval in eukaryotic evolution.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:00–14:05.

talks

A Chengjiang-like biota from the Early Cambrian of western Canada

Giovanni Mussini*, Francesco Izzo and Nicholas J. Butterfield
University of Cambridge, UK

Burgess Shale–type (BST) fossil biotas, which preserve carbonaceous compressions of non-mineralized organisms, provide the most direct and phylogenetically representative record of the Cambrian radiation of animals. However, Cambrian BST macrofossil biotas remain rare and unevenly distributed in space and time, hindering the recognition of macroevolutionary patterns among their constituent taxa. We describe a BST macrofossil assemblage from the Mural Formation (Cambrian Series 2, Stages 3–4) of Alberta, Canada. The Mural biota, deposited in a muddy shelf environment above storm wave base, comprises abundant vetulicolians and amplectobeluid radiodonts alongside 'soft-shelled' brachiopods, hyolithids, palaeoscolecids, shield-bearing arthropods and tube-dwelling cnidarians. The Mural biota is the first assemblage from western Laurentia comparable in age and phylum-level taxonomic coverage with the exceptionally diverse, broadly coeval biotas of South China, including the Chengjiang biota. Its composition overlaps with that of globally distributed, palaeoenvironmentally distinct Stage 3 to earliest Stage 4 biotas, to the exclusion of younger faunas from neighbouring Laurentian deposits. These results suggest truly global turnover between early and middle Cambrian faunas and fill a major temporal and biogeographical gap among Burgess Shale-type fossil assemblages.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:10–14:15.

Reconstructing the postcranial anatomy and locomotion of ostracoderms using X-ray microtomography

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Ostracoderms are armoured, jawless fishes considered successive branches on the gnathostome stem lineage. As such, they record the stepwise acquisition of definitive gnathostome features, informing our understanding of jawed vertebrate evolution. However, reconstructing their locomotion remains challenging given a lack of suitable living analogues or detailed 3D anatomical data. Recent studies challenge traditional interpretations of ostracoderms as ecologically constrained, demonstrating that headshield morphology can influence hydrodynamic performance and locomotor strategies. Understanding locomotion also requires detailed reconstructions of postcranial anatomy. Using micro-CT, we reconstruct a ~90 % complete tail-trunk of the osteostracan *Cephalaspis*. Although it lacks a tail fin, its exceptional completeness provides a unique opportunity to reconstruct tail-trunk squamation. We reveal a 'platemail-like' morphology, with 17 overlapping, dorsoventrally elongated dermoskeletal flank scales, intersected by associated, similarly shaped ventrolateral scales, and ~18 rhombic dorsal ridge scales. This differs markedly from the heterostracan *Anglaspis*, which has fewer (9), larger, flank scales. *Cephalaspis* and *Anglaspis* occupy different positions on the gnathostome stem lineage, allowing us to investigate whether variation in tail-trunk squamation reflects phylogenetic signal or functional/ecological adaptation. Range-of-motion analyses will allow us to further test locomotor hypotheses, providing insight into tail-trunk evolution and its palaeoecological implications.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:20–14:25.

Gut morphology and preservation in trilobites from the Fezouata Shale

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Trilobite gut remains are rarely preserved, being known from only *c*. 40 species out of the 24,000 described species. The best-known examples of trilobite gut remains come from Cambrian deposits with exceptional preservation. Here we present new information about the trilobite digestive system of six species from the Fezouata Biota (Tremadocian, Early Ordovician) of Morocco. Most of the specimens reported only preserve the digestive tract but specimens from three species show exquisite preservation of paired diverticulae. The digestive tracts are preserved as a two-dimensional film of framboidal iron oxides or as three-dimensional sediment infilled or secondarily replaced structures. Meanwhile, the diverticulae are usually preserved as three-dimensional phosphatized structures with a rim of iron oxides. In addition, a specimen of *Pharostomina* shows a six paired diverticulae in the cephalon and anterior trunk preserved as a carbonaceous compression film. These results provide the first evidence of phosphatization of soft tissues in the Fezouata Biota. The phosphatization shows taxa and tissue selectivity, being only reported in the paired diverticulae of trilobites. Therefore, there is a differential preservation among different parts of the trilobite digestive system with the digestive tracts usually preserved as a sediment infill and the glands as secondarily phosphatized.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:20–14:25.

Lyell in Chicago: a historic collection illuminates a missing chapter in nineteenth century geology

Roy E. Plotnick[1], Pamela McIntyre[2] and Rachel Krick[1]
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From the 17th–24th of June 1841, Charles Lyell visited localities in Wales and the Welsh Borderland and collected specimens representative of the units described in Murchison's *The Silurian System*. This collection travelled with Lyell during his first visit to America that began in July of that same year. The collection was originally intended for the Lowell Institute in Boston. At some point, it ended up in James Hall's possession in New York and then eventually at the Field Museum in Chicago. Although Lyell's travels in America have been extensively discussed, his trip to collect these specimens has never been documented in detail. In addition, the collection has only received passing mention, none of which describe its contents or its current status. Using Lyell's notebooks, we have reconstructed his collecting journey. Contemporary letters shed light on the interactions between Lyell and his American hosts concerning the specimens. As far as possible, we have identified the specimens in the collection, determined their localities, and placed them within the current stratigraphy for the Ordovician and Silurian. This collection played a key role in the nascent efforts to produce a global correlation for those time periods.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:40–14:45.

Three-dimensional mineralized skin in Triassic drepanosaurs from Italy

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The recent discovery of the drepanosauromorph *Mirasaura grauvogeli* has reshaped our understanding of the diversity of the integument in Triassic reptiles, revealing that some species possessed spectacular elongate appendages forming a dorsal crest. Direct evidence of skin, however, remains scarce, hindering our understanding of the anatomy of the integument in drepanosauromorph reptiles. Here we present new data from the analysis of historical drepanosaur specimens from Italy with soft tissues visible as dark-coloured material forming a patchy outline around the skeletons. Four specimens, including the holotypes *Drepanosaurus unguicaudatus* and *Vallesaurus cenensis*, were examined using UV light and an optical microscope. Notably, *D. unguicaudatus* preserves extensive continuous soft tissues only in the caudal region, with evidence of scales of different morphology preserved in three dimensions. Microsamples of soft tissues were analysed using scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS). Preliminary results reveal that the soft tissues are composed of calcium and phosphorous, indicative of preservation via calcium phosphate mineralization. Cross-sections of selected samples show at least two distinct layers, suggestive of epidermal and dermal tissues. Our study provides novel data on the taphonomy of soft tissues of important fossil specimens, with implications for our understanding of drepanosaurs' integument.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:10–14:15.

DinoSAW experimental biomechanical system: testing the cutting efficiency of ziphodont teeth in theropod dinosaurs

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The medio-laterally compressed, recurved and serrated (ziphodont) teeth of many extinct theropod dinosaurs resemble steak knives and were likely efficient at cutting through flesh. Their shapes indicate that optimal cutting would be under a diagonal posterior motion. However, no study to date has quantified the cutting performance of theropod ziphodont teeth, especially in a dynamic posterior pulling motion – previous studies focused on vertical puncturing. Crucially, vertical puncturing only engages serrations on one edge (the mesial edge), while the proposed diagonal pull-cutting motion should engage serrations on both the mesial and distal edges. Here we develop an experimental biomechanical system, the DinoSAW system, to test the cutting efficiency of diagonal motions and compare with that of vertical puncturing. Our results show that diagonal pull-cutting significantly reduces resultant forces compared to those recorded for vertical puncturing. This reveals that simulating motions that are in line with the curvature of the tooth, engaging both serrated edges, drastically reduce resistance forces and improve cutting efficiency. This offers insights into the possible motions associated with feeding in extinct theropod dinosaurs and the directions of mechanical loads under more biologically and behaviorally realistic scenarios.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:15–14:20.

Taste of change: floral turnover and the restructuring of herbivore communities before the K-Pg extinction in the Hell Creek Formation

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Latest Maastrichtian ecosystems are central to debates surrounding dinosaur diversity and ecological resilience prior to the Cretaceous–Palaeogene (K-Pg) mass extinction, yet the influence of floral turnover on herbivore communities remains poorly understood. Here we reconstruct plant–herbivore trophic networks for the Hell Creek Formation (USA) using integrated palaeofloral and vertebrate data spanning the final two million years of the Cretaceous. Taxon-level interactions between plants and herbivores were reconstructed using a functional trait-based framework incorporating plant growth height and palatability, herbivore feeding height and browsing selectivity, and inferred oral-processing capabilities. Our results reveal substantial restructuring of understory vegetation through time, with marked changes in the relative diversity of herbs, shrubs, and ferns across successive megafloral zones. Changes within these intensively browsed vegetation strata coincide with shifts in herbivore community structure, niche partitioning and resource overlap. Broad-spectrum megaherbivores remained comparatively resilient, with *Edmontosaurus* emerging as the most connected herbivore interacting with the broadest range of plant resources. Conversely, intermediate selective browsers, including nodosaurids and some pachycephalosaurids, experienced greater niche compression and resource overlap. Rather than uniform ecological decline, our results indicate vegetation-

associated reorganization of latest Maastrichtian ecosystems, with changing understory composition restructuring herbivore communities prior to the K-Pg extinction.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:25–14:30.

An ichnological bridge between two radiations: diverse trace fossils from the middle–late Cambrian of North Wales

Yorick P. Veenma* and Neil S. Davies
University of Cambridge, UK

The Cambrian Explosion and Great Ordovician Biodiversification Event are two major phases in the early diversification of marine ecosystems, but the later Cambrian interval that separates these episodes remains comparatively poorly resolved. The knowledge gap associated with this interval, which includes the so-called 'Furongian Gap', is particularly pronounced in the trace fossil record, even though ichnological evidence has been central to reconstructing the two radiations. In North Wales (UK) the Mawddach Group provides an expanded record of the intervening Miaolingian and Furongian epochs, capturing the progradational shallowing of the Welsh Basin in a varied slope-to-shoreface transect. The group is shown to contain one of the most diverse trace fossil assemblages known from the latter half of the Cambrian Period, including several ichnotaxa not previously documented from this interval. It also preserves gradients in ichnoassemblage diversity, composition, and preservation between different palaeoenvironmental settings. These results are discussed with reference to both older and younger trace fossil records, in order to evaluate how interactions between late Cambrian benthic communities and their substrates compare to earlier Cambrian and Ordovician ichnological regimes. Overall, the rich trace fossil assemblages of the Mawddach Group expand the empirical record from within the Furongian Gap and improve our understanding of evolutionary trajectories between the major Cambrian and Ordovician radiations.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:15–14:20.

Beyond the cuticle: hidden internal anatomy in Mesozoic terrestrial arthropods

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Fossilized internal soft anatomy of arthropods is predominantly known from Cambrian marine Burgess Shale-type deposits, providing critical insights into functional morphology, ecology and phylogeny. However, internal anatomy is rarely documented in compression fossils from younger terrestrial deposits, limiting our understanding of the anatomical innovations associated with the diversification of arthropods on land. Here we reveal widespread preservation of internal anatomy across the respiratory, digestive and reproductive systems in insect and crustacean fossils from the Jurassic Yanliao and Early Cretaceous Jehol biotas of China. These internal structures are largely indistinct under visible light but are conspicuously revealed by fluorescence imaging, with fluorescence showing consistent taxon- and tissue-specific patterns. The preserved anatomy provides otherwise inaccessible organ-level detail, permitting direct comparisons among taxa and

reconstruction of their functional biology. Our findings uncover an overlooked archive of internal anatomy in terrestrial arthropod fossils, demonstrating that carbonaceous compression fossils preserve substantially richer anatomical information than previously recognized, and expanding the fossil evidence available for investigating arthropod evolution on land.

Thursday 10th December, Session 6c, Mathematical Institute L3, 14:05–14:10.

Pliocene ecosystems at Chinchilla (Queensland, Australia): insights from large herbivores

Oscar E. Wilson[1], Caitlin Syme[2] and Julien Louys[3]

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The Pliocene was a period of ecological change in Australia, with a trend towards aridification, grassland expansion and faunal modernisation. Critical to understanding the Australian Pliocene is the exceptionally rich Chinchilla local fauna (southeast Queensland). Large (>2 kg) herbivores are well represented in the fauna, with at least 30 taxa. We applied three techniques to reconstruct the palaeoenvironment at Chinchilla. Taxon-based reconstruction using tree kangaroo occurrences (using Dendrolagus as an analogue for Bohra) supports a wet, tropical forest environment, with 69% tree cover and mean annual precipitation (MAP) of 2,800 mm yr^{-1}. Conversely, new dental ecometric models using community bunodonty in modern Australasian herbivores suggest an open, dry environment for Chinchilla, with just 4 % tree cover and MAP of 463 mm yr^{-1}. Dietary inference for the herbivores of Chinchilla, using mesowear angles measured from wear facets and dentine valleys, indicates niche differentiation, modulated by body mass. The large diprotodontids (*Euryzygoma*, *Euowenia*) had shallow mesowear angles (>117°) reflecting grazing, while some macropodids (*e.g. Protemnodon*, *Sthenurus*) had sharp facets, with mesowear angles indicative of browsing (<106°). The diversity of dietary ecologies at Chinchilla is consistent with a heterogeneous habitat, highlighting the potential role of diet as a universal trait in palaeoenvironmental reconstructions.

Thursday 10th December, Session 6b, Mathematical Institute L2, 14:05–14:10.

Biotic succession and palaeoenvironmental change in the Jiufengshan record of the Jehol Biota, Northeast China

Yan Xue[1,2,3]*, Daran Zheng[1,2], Xiangdong Zhao[1], Xiao Teng[1], Xin Zhang[4], Peihan Liu[1,2], Siyu Song[1,2], Rui Fang[1,2] and Gang Li[1]

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The lower part of the Jiufengshan Formation exposed at Shiyoukuangtun (*c.* 124.3–121.5 Ma), northern Great Xing'an Range, northeastern China, preserves an important non-core record of the Jehol Biota. Two organic-rich shale intervals interbedded with mudstones and tuffs yield fish, insects, plants and diverse clam shrimps. Integrated palaeontological, geochemical and mineralogical analyses are used to assess biotic and environmental change. The clam shrimp fauna comprises *Eosestheria aff. middendorfii*, *E. cericula*, *E. naketaensis*, *E.* cf. *opipera* and *Diestheria jeholensis*. Their distributions define three stages: an initial

Eosestheria-dominated assemblage; a *Diestheria*-bearing stage following the disappearance of two *Eosestheria* taxa above the lower shale; and a renewed *Eosestheria-Diestheria* assemblage beginning with the upper shale. The shales contain up to 10.75 wt.% TOC and substantial algal-derived organic matter. FeHR/FeT ratios (>0.22; mostly >0.38), Fepy/FeHR ratios (<0.7) and Mo-U enrichment indicate dominantly anoxic, ferruginous conditions. Clay-mineral and weathering proxies suggest changing catchment input without increased detrital supply during shale deposition. Exploratory PCA explains 70.7 % of the variance on its first two axes and partially separates the assemblage stages, suggesting that faunal turnover coincided with environmental reorganization. These results support productivity-preservation coupling involving algal organic-matter supply, limited detrital dilution and ferruginous anoxia.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:30–14:35.

Testing the phylogenetic affinities of Archaeocyatha and Chancelloriida within a comprehensive morphological framework of Porifera

Linjun Zou*, Davide Pisani and Philip C. J. Donoghue
University of Bristol, UK

The phylogenetic position of Archaeocyatha and Chancelloriida are important for understanding early sponge evolution, yet their placement is complicated by contrasting interpretations of skeletal and soft-body anatomy. Evaluating these affinities requires a morphological framework that captures diversity across major sponge lineages and permits comparisons with other metazoans. Here we assemble a morphological matrix of 350 discrete characters, expanding the representation of demosponge diversity and morphology within a comparative metazoan framework. Focal sampling includes 55 extant sponge species, 8 other fossil sponge taxa, 6 chancelloriid taxa, and 13 archaeocyath taxa. Bayesian phylogenetic analyses compare four fossil schemes. Each scheme retains the extant comparative sample and is analysed without topological constraint and under two alternative constraint conditions. Preliminary results recover broadly consistent relationships among the major sponge lineages and place archaeocyaths within Porifera, whereas chancelloriid placement varies among analytical conditions. Ancestral states of selected morphological characters are also reconstructed under alternative topological constraints to explore their evolutionary implications. These analyses provide a revised morphological framework for sponge relationships and reassess the positions of archaeocyaths and chancelloriids within that framework.

Thursday 10th December, Session 6a, Mathematical Institute L1, 14:00–14:05.

Abstracts of poster presentations

* Candidates for the Council Poster Prize are marked with an asterisk.
Underlined author denotes designated presenter.

Trilobite evolutionary history is organized into six major evolutionary faunas

Jonathan Adrain[1] and Francesc Pérez Peris[2]
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That significant evolutionary faunas were a key aspect of trilobite evolutionary history was first reported in 1998, and the Ordovician faunas discriminated in that study, the Whiterock and Ibex evolutionary faunas, have become widely cited features of the group's macroecology. The original analysis was carried out using four intervals of the Ordovician, with families as the units of analysis and genus counts per interval serving as the data. It is now possible to explore the evolutionary history of the group at high taxonomic and temporal resolutions. We divided the Palaeozoic into 36 sampling intervals (six Cambrian, seven Ordovician, eight Silurian, seven Devonian, five Carboniferous and three Permian). All 168 trilobite families were scored for their species diversity by sampling interval. Species level data were compiled in a relational taxonomic database from the primary literature. The number of accepted formally-named trilobite species is currently 22,254. Hierarchical cluster analysis was carried out, and the results indicate that all trilobite families belong to one of six major evolutionary faunas. The previously discovered faunas were recovered, and a further four major Cambrian patterns were identified. Most of the shifts in dominance between the faunas are associated with major extinction events.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Defining the 'mass' in mass extinctions: inferring the scope and scale of Phanerozoic extinction events

Bethany J. Allen[1], Baran Karapunar[2], Eileen Straube[3], Ádám Kocsis[4], Elizabeth M. Dowding[4], Matthew Clapham[5], Roger Close[6], Emma M. Dunne[7], William J. Foster[8], Jenny McGuire[9], Daniele Silvestro[10], Andrej Spiridonov[11], Steve Wang[12], Rachel C. M. Warnock[4], Zhen Xu[13], Junxuan Fan[14], Wolfgang Kiessling[4] and Danijela Dimitrijević[4]
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The majority of species ever to have lived are now extinct. Many of these extinctions occurred during mass extinction events, intervals in Earth history when extreme environmental perturbation pushed the biosphere to its limits. Canonically, five mass extinctions have been identified in deep time, but defining mass extinctions is not straightforward – do these events clearly diverge from the 'background' evolutionary processes of the Phanerozoic? We review current knowledge about mass extinction events, using state-of-the-art methodologies to tackle sampling bias in the fossil record. We explore the importance of different facets of biosphere perturbation in defining an extinction event,

including extinction magnitude, duration, selectivity and geographic extent. We highlight key methodological innovations that may improve our understanding of mass extinctions in future. Finally, we advocate that the fossil record is key to understanding the relationship between environmental change and extinction, essential context for making predictions as biodiversity faces anthropogenic threats.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Insect miniaturization from a palaeontological perspective: a review of wing morphology in fossil microwasps

Sergio Álvarez-Parra
Instituto Geológico y Minero de España (IGME-CSIC), Spain

Miniaturization, defined as an evolutionary trend towards extremely small body size, has evolved independently across insect lineages and is generally interpreted as an adaptive response to ecological pressures. In winged insects, miniaturization is often accompanied by highly specialized wing morphology, including reduced venation, modified wing shape and marginal setae. However, the evolutionary and ecological drivers of these adaptations remain poorly understood, particularly in fossil taxa. Here I review miniature insect groups to investigate insect miniaturization and flight dynamics from a palaeontological perspective, focusing on the relationship between wing specialization and ecological adaptations such as parasitoidism and pollination. Hymenoptera, which encompass remarkable morphological and ecological diversity, constitute the primary model system. Additional miniature representatives of other insect orders will be examined to assess potential cases of convergent evolution. Integrating fossil and extant taxa, this research will investigate the relationship between wing morphology, flight performance, and ecological adaptation from the Cretaceous onwards. Particular emphasis will be placed on reconstructing the palaeobiology of fossil groups, whose biology is often inferred primarily from phylogenetic relationships. By identifying morphological and functional adaptations that may have no modern equivalents, this research aims to provide new insights into the evolutionary history of insect miniaturization. The author is supported by Juan de la Cierva Grant JDC2023-052016-I funded by MCIU/AEI/10.13039/501100011033 and ESF+. It is a contribution to the projects CIGE/2026/23, funded by Generalitat Valenciana, and PID2022-137316NB, funded by MICIU/AEI/10.13039/501100011033 and by ERDF/EU.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

When the Obolus Sea turned black: ecosystem collapse during the Alum Oceanic Anoxic Event

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The Miaolingian–Tremadocian Alum Shale of Baltoscandia records an extraordinary interval of regionally persistent oxygen depletion lasting almost 30 million years. The Alum Oceanic Anoxic Event (AOAE) developed within a semi-enclosed epicontinental

basin, where restricted circulation, high productivity and water-column stratification promoted dysoxic to anoxic bottom waters. However, its palaeontological record reveals a dynamic rather than permanently stagnant basin, with repeated episodes of oxygenation and major ecological change. During the Furongian and early Tremadocian, the northeastern basin margin in Estonia and Ingria supported extensive shallow-water shoals containing enormous accumulations of organophosphatic linguliform brachiopods, forming major phosphorite deposits. Continued transgression eventually drowned these ecosystems beneath black shales. We suggest that flooding and reworking of phosphatic shell accumulations released bioavailable phosphorus, promoting eutrophication, algal productivity and oxygen consumption. This accompanied replacement of shallow-water benthic communities by low-diversity assemblages characteristic of the Olenid Biofacies. The Baltoscandian record illustrates how transgression, phosphorus recycling, restricted circulation and tectonic instability interacted to drive prolonged eutrophication and ecological restructuring across the Cambrian–Ordovician transition.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Shark fins through time: exploring the diversity of galeomorph body configuration

Manuel Amadori[1], Eduardo Villalobos-Segura[1] and Jürgen Kriwet[1,2]

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Elasmobranch fishes, including sharks, rays and skates, represent an ancient and evolutionarily significant vertebrate lineage, providing key insights into early gnathostome evolution. Here we present a comprehensive comparative assessment of fin arrangement across extant and fossil galeomorph sharks, focusing on patterns of fin position and body configuration. Representative members of every extant galeomorph family and the best-preserved fossil specimens were considered for this comparison. Our preliminary comparisons reveal unusual fin configurations among fossil galeomorph taxa, some of which have no known equivalents among extant representatives of the same orders. These findings suggest that morphological diversity and/or disparity in body configuration may have declined within some galeomorph lineages through time. At the same time, the recognition and interpretation of such unusual configurations have important implications for assessing the morphological variability of established taxonomic groups, particularly when these configurations are known exclusively in fossil taxa. However, integrating these patterns into an evolutionary framework requires further comparative investigations of both fossil and extant galeomorphs with detailed assessments of fin position and configuration. Such approaches will contribute to disentangle patterns of morphological evolution and disparity, as well as provide a more comprehensive understanding of the evolution of galeomorph body configurations in deep time.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Putative pterosaur (*Cryodrakon boreas*) manus-only tracks in a multitaxic tracksite from the Dinosaur Park Formation (Campanian)

Sarah C Ashby*[1], Phil R Bell[2], Vicky L Boult[1], Caleb M Brown[3,4,5] and Brian J Pickles[1]
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Discovered in 2024 this pterosaur trackway from the Dinosaur Park Formation (DPF), Alberta, Canada, represents the first evidence of pterosaur locomotion preserved within Dinosaur Provincial Park (DPP). Forming part of the multitaxic Skyline Tracksite, these prints represent the earliest well dated, azhdarchid footprints in North America (75.6 Ma). The trackway comprises four consecutive crescent shaped impressions, measuring 14-16 cm long and 4-7 cm wide, extending over ~8.3 m with a trackway width of ~50 cm. Their spatial arrangement suggests production by a single individual during a single locomotor event. Remarkably, this manus-dominant trackway occurs within a pes-dominant dinosaur tracksite and may provide insights into forelimb loading during terrestrial locomotion. The trackmaker shared this surface with ceratopsians, ankylosaurs, tyrannosaurs and a small theropod, offering a rare snapshot of this dynamic Late Cretaceous ecosystem. Pterosaur tracks are rare in North America, particularly those attributable to azhdarchids, the last surviving pterosaurs of the late Cretaceous. The location, dating, and large print size suggest likely affinity with *Cryodrakon boreas*, whose holotype derives from the same formation. This set of prints shares similarities with the ichnotaxa *Haenamichnus*, which is also assigned to a large azhdarchid trackmaker, and large tracks assigned to *Pteraichnus*.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

New macroevolutionary insights into the Middle Triassic neopterygian radiation

Emma Ayres and Michael J. Benton
University of Bristol, UK

The Permian–Triassic mass extinction (PTME) devastated aquatic life, clearing the way for the Mesozoic Marine Revolution and subsequent establishment of modern aquatic ecosystems. Neopterygians are the most diverse group of extant fish and they radiated substantially throughout Triassic, but the details of this diversification remain obscured by an incomplete fossil record. Rock successions from South China hold exceptional records of the recovery from the PTME, including the first neopterygian radiation, but these focus exclusively on the marine realm. Some European deposits, like the Otter Sandstone from England, provide information on early neopterygian evolution in freshwater habitats. Macroevolutionary analyses conducted on both marine and freshwater datasets of total-group Neopterygii from the entire Triassic establish some key aspects of their diversification. The neopterygian morphological radiation was more temporally nuanced than previously acknowledged. Neopterygians began to become smaller and deeper-bodied before the extinction and continued doing so into the Triassic, seemingly unimpacted by the PTME. Freshwater realms may have served as refugia of neopterygian diversity, affecting the evolution of Triassic marine lineages. It appears that the PTME did not severely affect neopterygians, nor did it suddenly ignite their Triassic radiation. Instead, it allowed them to continue and amplify pre-extinction evolutionary trajectories.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Extinction: sink or swim? Metabolism and survival in fossil fishes across the K-Pg boundary

Emily Ball[1,2]*, Gary L. Stringer[3], Clive N. Trueman[1], Richard J. Twitchett[2] and James D. Witts[2]
[1]University of Southampton, UK; [2]Natural History Museum, London, UK; [3]University of Louisiana at Monroe, USA

Mass extinctions represent major episodes of ecosystem change, yet their effects are highly selective, with taxa differing in their susceptibility to extinction. The physiological traits underlying this selectivity remain poorly understood. Metabolic rate has been proposed as a potential driver of extinction vulnerability, reflecting differences in energetic and oxygen requirements, but existing studies provide conflicting evidence. Fossil fishes provide a valuable system for investigating this relationship because their extensive otolith record preserves physiological signals across taxa with contrasting extinction outcomes. Here we investigate whether metabolic physiology was associated with survival across the Cretaceous–Palaeogene (K-Pg) extinction in fossil fish. We hypothesize that taxa that survived the extinction will exhibit lower metabolic signals than those that became extinct. We use stable isotope compositions of fossil otoliths from Maastrichtian and early Danian deposits of the southern Western Interior Seaway to compare taxa with contrasting extinction outcomes. Otolith $\delta^{13}C$ is used as a proxy for metabolic activity, while $\delta^{18}O$ provides complementary information on environmental conditions. Determining whether metabolic physiology contributed to extinction selectivity may provide new insight into the physiological factors shaping fish evolutionary history, while traits associated with resilience to environmental change may provide context for understanding vulnerability in modern fish communities.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Variation in the three-dimensional structure of stereom in articulate crinoids

Charles Bates[1,2]*, Luke A. Parry[1], Philip C. J. Donoghue[3] and Imran A. Rahman[1,2]
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The extensive taxonomic and morphological diversity of Echinoderms – both modern and extinct – is underpinned by their unique skeletal microstructure: an intricate network of trabeculae and pores known as 'stereom'. Stereom displays remarkable plasticity, varying in scale and organization even within a single skeletal element. This variation has been linked to biological function (*e.g.* muscle attachment), phylogenetic relatedness, and even environmental conditions. Characterization of stereom structure has traditionally been carried out using electron microscopy, with tomographic methods only recently being adopted. Even then, three-dimensional analyses have largely focused on single skeletal elements, with comparisons being drawn, at most, between closely related species. We are assembling the largest tomographic stereom dataset to date, with extant representatives from both major lineages of articulate crinoids, the Isocrinids (sea lilies) and Comatulids (feather stars). With this, we aim to quantitatively assess large-scale trends in stereom structure within the group and, ultimately, improve our understanding of the role stereom has played in the evolutionary success of Echinoderms.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Furongian (Upper Cambrian) faunas from the Montagne Noire: new data and palaeobiogeographical implications

Enzo Birolini[1]*, Yves Candela[2], David A. T. Harper[2,3], Bertrand Lefebvre[1] and Daniel Vizcaïno[4]
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Long perceived as an interval of quiet transition or one marked by a diversity crisis (the Furongian Biodiversity Gap), the Furongian Series (upper Cambrian) is characterized by major environmental fluctuations and significant modifications of benthic and planktonic ecosystems, which anticipated the Great Ordovician Biodiversification Event. This work focuses on the following key issue: to what extent do the faunas of the Val d'Homs Formation (southern slope of the Montagne Noire, France) allow for a reconsideration of late Cambrian marine biodiversity and its palaeobiogeographical implications? The study is based on an integrated analysis of more than 600 macroinvertebrates collected during field campaigns and from the extensive collection of the last author(arthropods, linguliform brachiopods and echinoderms), complemented by the examination of ichnofossils and palynomorphs (acritarchs). To overcome Variscan tectonic deformation, a mathematical retrodeformation method was applied to restore the initial morphology of the fossils. The identification, for the first time in the Montagne Noire, of the cosmopolitan agnostid *Homagnostus* obesus allows a Paibian Age to be assigned to the Val d'Homs Formation. The trilobite fauna is entirely revised (including the reassignment of species to the genera *Andrarina* and *Onchonotellus*) and a new species is described, marking the first record of the genus *Langyashania* in France. The strong provincial affinities of the 'Bois des Pradels' assemblage with coeval faunas from East Asia (China), Spain and Scandinavia (Norway, Sweden) challenge the concept of strict Gondwanan provincialism, while highlighting global dispersal pathways at the end of the Cambrian.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

An alluvial floodplain assemblage of Early Cretaceous ornithopods and theropods in Bexhill-on-Sea, East Sussex

Tone Blakesley[1]*, Misha Whittingham[1], Paige E. dePolo[3], Luke Mander[1] and Stephen L. Brusatte[2]
[1]The Open University, UK; [2]University of Edinburgh, UK; [3]Liverpool John Moores University, UK

The Early Cretaceous aged Wealden Supergroup (*c.* 141–119 Ma) has yielded a variety of dinosaur footprints over 180 years across Southern England. These include ornithopod, theropod, thyreophoran and sauropod trackmakers. The most extensive and earliest reported trackways occur in intertidal platforms at Bexhill-on-Sea – few of which have been systematically mapped before succumbing to erosion. Here we describe and map an extensive series of 260 dinosaur footprints in the Late Valanginian (*c.* 134-132 Ma) Tunbridge Wells Sand Formation at Bexhill-on-Sea using photogrammetry. The trackways occur across multiple horizons of siltstones deposited in a terrestrial, low-energy alluvial floodplain setting, in proximity to vegetation. We assign these tracks to three main morphotypes, most likely representing large iguanodontian ornithopods and a small indeterminate theropod. Such a density of trackways provides clear evidence of time-averaged milling behaviour as dinosaurs travelled without localized palaeogeographic constraint in all directions. Collectively, these trackmakers provide evidence of how dinosaurs behaved in open environments during the Early Cretaceous and a workflow for preserving vulnerable soft sediment tracksites.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Evolutionary patterns in a diverse group of trilobites: morphological disparity and phenotypic trends in Asteropyginae

Anya Blanshard*, Juned Zariwala and Marcello Ruta
University of Lincoln, UK

Trilobites were among the most morphologically diverse arthropods of the Palaeozoic, with over 20,000 described species spanning the entire era. Within this diversity, the Devonian subfamily Asteropyginae is notable for its extreme cephalic and pygidial morphologies, including exaggerated spines and highly derived cephalic outlines, exemplified by taxa such as *Walliserops*. Despite this, previous work has largely focused on cephalic shape alone or compared cranial and trunk evolution across broad trilobite groups, leaving patterns of morphological evolution within individual subfamilies poorly explored. Here we investigate phenotypic disparity and evolutionary rates in both cephalic and pygidial morphology within Asteropyginae, testing whether extreme morphologies are associated with shifts in evolutionary tempo. Using outline-based morphometric analyses, we quantify shape variation across a wide range of asteropyginid morphologies and assess morphospace structure, disparity, and principal axes of variation for both anatomical regions. These data are integrated with a phylogenetic framework to estimate lineage-specific rates of morphological evolution. Both cephala and pygidia occupy a broad and complex morphospace, with major axes of variation capturing pronounced changes in outline elongation, spine development and regional expansion. Evolutionary rates vary substantially across the subfamily, with taxa exhibiting the most unusual morphologies – such as *Walliserops* and *Heliopyge* – showing markedly elevated rates of evolution relative to more conservative forms. These results demonstrate that asteropyginid trilobites underwent highly heterogeneous evolutionary dynamics, and that exceptional morphological novelty is closely associated with accelerated evolutionary rates. Our findings highlight the importance of subfamily-level analyses for understanding how extreme forms arise during arthropod evolution.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Understanding the complexity of the extinct triradial body plan: a morphometric analysis of *Tribrachidium*

Tory Botha[1,2]*, Mary L. Droser[3], Diego Garcia-Bellido[2,4] and Emma Sherratt[2]
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Nilpena Ediacara National Park (South Australia) preserves over 200 specimens of *Tribrachidium heraldicum* and 95 specimens of the newly described *Tribrachidium gehlingi* within the fossiliferous Ediacara Member. We use rotational geometric morphometrics to quantify the morphological variation within each species and the differences between the two. Both species were found to be morphologically different from one another, forming distinct groups within the morphospace. Analysis of the symmetric and asymmetric shape components revealed that both species present limited deformation, suggesting they consisted of a fairly resistant material. Growth appears to have been comprised of various interacting allometric relationships that maintain a consistent overall morphology for both species, possibly constrained by its suspension feeding mode.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

The metabolic index through deep-time: a Phanerozoic analysis of temperature and hypoxia tolerance

Tim Breeze[1]*, Clive N. Trueman[1], Cooper M. Malanoski[2], Erin E. Saupe[2], Benjamin J. W. Mills[3] and Richard G. Stockey[1]

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The metabolic index was developed to explore how the synergistic interaction of temperature and oxygen supply impact the geographic range and habitats of modern marine ectotherms. This metric has been used to investigate the roles of ancient ocean warming and deoxygenation in mass extinctions and other key events in the Phanerozoic fossil record. Palaeobiological applications of the metabolic index to date utilize observations of modern marine species and assume that species' metabolic sensitivities are fixed and do not evolve due to environmental change. This project seeks to test these assumptions by exploring the metabolic index through the lens of the fossil record. We use stage-by-stage Earth system model simulations spanning the Phanerozoic and integrate these with a Phanerozoic fossil occurrence dataset of ancient marine ectotherms. We combine modelled temperature and O_2 concentrations from the palaeo-rotated locations of fossil occurrences to estimate the temperature and hypoxia tolerances of fossil taxa. This approach enables us to generate a new, uncertainty-bound compilation of estimated metabolic parameters across a range of taxonomic groups and geologic time. We use this dataset to explore whether the distribution of metabolic index traits in deep-time resembles that in modern species and how these traits have changed through time.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Biogeography and diversity of fossil spores from the Devonian of Gondwana

Harold Bridger[1], Jason Hilton[1], Charles H. Wellman[2], Zhen Xu[3] and Henry Sussem[1]

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The Devonian represents an important interval in floral territorialization and globalization. Using palynological data from more than 150 discrete biostratigraphic units across 50 localities in Gondwana, Britain and the Armorican Terrane (present-day Western Europe), a spatiotemporal framework for Devonian floras has been developed. Plant spores undergo a more rapid diversification in the Lower Devonian than has been previously suggested, including a potential mid-latitude origin for progymnosperms in the Emsian. We find support for at least three distinct biogeographic provinces from the Middle Devonian onwards, including evidence of endemic floras in the Armorican Terrane. Armorica serves as a potential refugium for 'rhyniophytic' plants (Rhyniopsida, Trimerophytopsida and basal Polysporangiophyta) due to its geographical isolation, concurrent to the disappearance of these groups elsewhere. Spore diversity appears unaffected by Middle-Upper Devonian marine anoxia, whereas increased turnover into the Famennian is likely a result of the Late Devonian Mass Extinctions.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Small but intriguing: the unusual growth dynamics of the dwarf '*Candiacervus*'

Teresa Calderón[1], George Lyras[2] and Alexandra van der Geer[1]
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Insular faunas are particularly fascinating, where island ecological conditions have led to remarkable morphological and physiological adaptations, resulting in bizarre forms such as dwarf and giant species. The Pleistocene Cretan deer genus *Candiacervus* provides an example, evolving into contemporaneous, differently sized morphotypes with body mass ranging between ~28 and ~245 kg. We performed histological analysis on 24 femora from dwarf *Candiacervus* of different age stages to obtain detailed information on growth dynamics and life-history traits. Bone tissue was interrupted by growth marks in all femora. However, the arrangement of the growth lines did not follow the common vertebrate pattern. Instead, most specimens exhibited a splitting pattern in the inner growth marks, resulting in double or multiple lines, hindering the interpretation of growth periods. These unusual findings raise more questions than answers regarding the *Candiacervus* growth pattern: could phylogeny underlie this pattern? Could it be related to the changing climatic conditions throughout the Pleistocene? Could this pattern be the result of an ontogenetic component (heterochrony) related to insularity? Could it be explained by a shift in biomechanical loadings associated with dwarfism? Further analysis of the other *Candiacervus* morphotypes and other insular taxa will be key to understanding this intriguing growth pattern.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

From land to sea: disparate macroevolutionary dynamics in terrestrial and marine artiodactyls

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The aftermath of the end-Cretaceous mass extinction witnessed the vacancy of most large-vertebrate marine niches, which allowed one of the most remarkable shifts in mammalian evolutionary history: the transition of mammals to marine lifestyles. From terrestrial ancestors, mammals invaded marine environments at least seven times, with cetaceans (Cetacea, Artiodactyla) representing one of the earliest mammalian lineages to evolve aquatic adaptations. Here we investigate how ecological transitions and biotic and abiotic variables affected diversification rates in artiodactyls, using a birth-death neural network model and partial dependence plots to visualize variable effects. Aquatic artiodactyls show higher speciation and lower extinction rates, consistent with an evolutionary advantage of the transition to a new adaptive zone. While aquatic lineages diversified faster during cooler Cenozoic periods, terrestrial ones followed the opposite path. Artiodactyls' marine radiation was thus driven by macroevolutionary rules distinct from those governing their land-dwelling relatives. Despite the differences in maximum size among lineages, which may be related to energetic costs of thermoregulation in water, larger species exhibited lower extinction rates in both terrestrial and marine environments. This deep-time pattern contrasts with present-day observations, in which large body size is generally associated with lower population densities, slower reproductive rates and increased vulnerability to extinction.

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High-resolution mapping of an *in situ* Upper Carboniferous fossil forest (Brymbo, Wrexham)

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Brymbo Fossil Forest was discovered in 2003 during reclamation works on the old Brymbo Steelworks site near Wrexham, North Wales. Initial excavations of the Upper Carboniferous (Moscovian) fossil forest, designated an SSSI, revealed hundreds of *in situ* fossils of calamatian horsetails and arborescent lycopods in life position, along with hundreds of prostrate calamites, theorized to be washed in by currents. Live excavations began at Brymbo in 2025 in a dedicated building erected over a portion of the site. This has provided the opportunity to study spatial relationships between the *in situ* fossils on the upper sandstone surface, a unit of the Brymbo cyclothem interpreted as a catastrophic series of inundations. This study looks at the spatial relationships, bearings, dips, dip angles and sedimentary structures of *in situ* (in life position and those deposited by other means) fossils for palaeoenvironmental and palaeobotanical insights, as well as information for the small-scale reconstruction of a Carboniferous fossil forest, giving a more in-depth understanding of these environments. Further, the statistical significance of the data collected is analysed in R.

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Evolution and adaptation of the dinosaur naris

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Olfaction plays a crucial role in the survival and behaviour of vertebrate animals. As narial soft tissues are not preserved in fossil vertebrates, we have limited knowledge of dinosaur olfactory capabilities and their evolutionary trajectories. This study investigates the evolution of narial size and shape in dinosaurs across geological time, taxonomic groups and ecological niches. We hypothesize that dinosaur narial size and shape is partially controlled by environmental parameters. For 200 Mesozoic dinosaur species, we recorded 2D linear and area measurements to quantify the size of the narial opening and used 32 landmarks and geometric morphometric methods to quantify its shape. Principal components analysis was used to map narial shape into a morphospace. Our initial results find statistically significant differences in relative narial area between herbivorous and both carnivorous and omnivorous dinosaurs in the Jurassic and Cretaceous. Ceratopsidae exhibits significantly divergent narial variation relative to all other dinosaurian clades. Dinosaurs living at higher (palaeo)elevations show significantly different relative narial areas, and distinctive morphospace occupation, to dinosaurs from lower elevations. Analyses utilizing palaeo-aridity, dinosaur habitat proxies, and inferences of olfactory acuity derived from endocasts are ongoing.

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Evidence of neurocranial pneumaticity in a Late Triassic archosaur with dinosaurian affinity

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The vertebrate braincase or neurocranium exhibits a complex internal architecture including pneumatic spaces. These offer significant insights into the functional and evolutionary aspect of the cranium. Cranial pneumaticity, particularly within the braincase, is well documented for the derived archosaurian clades, whereas their presence and development within the early-diverging archosaurs remains comparatively scarce. An isolated, partially preserved braincase was recovered from the Upper Triassic Tiki Formation of the Rewa Gondwana Basin of India. Comparative anatomical analysis with other vertebrate braincases indicates that it belonged to an archosaur, with several morphological features pointing towards a dinosauromorph affinity. X-ray micro-computed tomographic slices of the braincase reveal passages for several cranial nerves, open spaces and pneumatic cavities. Among these, the open spaces are preserved as the anterior tympanic, median pharyngeal and basisphenoid recesses within the braincase. A distinct canal extends from the region of the vestibule towards the basicranial floor, approaching the contact between the basioccipital and parabasisphenoid. The partially preserved endosseous labyrinth constitutes an elongated cochlear duct similar to the late-diverging archosauromorphs. The internal cavities provide evidence for reconstructing evolution of neurocranial pneumaticity in the Late Triassic archosaurs and enhances our understanding of morphological disparity of braincases within the Late Triassic dinosauromorphs.

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UnEarthing the social worlds of palaeobiological research: heritage, legality, and pluralistic approaches to ethics

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Recent years have witnessed widespread debates and, in many cases, institutional and organizational rifts when it comes to questions of research ethics in palaeobiology – particularly those concerning the sourcing of fossil specimens from various sites around the world. Underpinning these conflicts are the different cultural registers and valuations, socio-political contexts and economic systems through which many fossils must move before being incorporated into research programmes. Researchers are thus increasingly called to confront the assumed universal values of natural science against localized value systems, which do not always align with institutional norms and research agendas. Here we present findings from the interdisciplinary project Amber Worlds (ERC: AMBER) which incorporates perspectives from social anthropology, the philosophy of science, and legal studies as they pertain to the complexities of acquisition and use of palaeobiological materials as seen 'from the ground up'. With comparative mention to ongoing work in Myanmar, China and Latin America, we highlight one project case study – Lebanon and its fossil resources – to exemplify collaborative palaeobiological and social scientific approaches. We demonstrate an interactive element of our research communication, as we share a prototype 'fact sheet' for researchers to incorporate pluralistic legal and ethical frameworks into their research design and execution.

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The marine vertebrate fauna and palaeoenvironment of the Kellaways Formation (Wiltshire, UK)

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The UK is renowned for its excellent marine reptile fossil record, particularly its Jurassic record. Despite the long study of these deposits, there are still some that remain poorly understood, a key example of this being the Lower Callovian aged Kellaways Formation, which has been neglected due to its limited exposure. During systematic excavations of the Kellaways Formation at Cerney Wick, Wiltshire, we recovered new specimens through field collection and bulk sieving of sediment samples. The recovered fauna consists of plesiosaurs, pliosaurs, thalattosuchians, chondrichthyans and osteichthyans, including some possible new taxa. Here we report these new specimens, while further considering specimens that were historically collected from the county, to allow comparison between the Kellaways and Oxford Clay faunas. The most notable difference is the apparent absence of ichthyosaurs in the Kellaways Formation, given they are relatively common in the Oxford Clay. To further investigate the palaeoenvironment, we sampled throughout the section at Cerney Wick for palynomorphs and nannofossils, which can be compared against known assemblages. Overall, the new data will enable us to provide comments on the palaeoecology of the Kellaways Formation in Wiltshire, while providing new insights into a poorly understood time in the global vertebrate fossil record.

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Two decades of declining academic career prospects in UK palaeontology

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Securing a permanent palaeontological academic post in the UK is increasingly seen as a mythical achievement for early career researchers (ECRs), yet a 2018 analysis of Progressive Palaeontology presenters found 44 % of UK palaeontology PhD students secured permanent posts, far exceeding UK STEM norms. Here we tracked 629 UK-based palaeontologists using public data across 20 years (2004–2024). The 2004–2008 cohort represents a 'golden spike', an anomalously favourable interval for ECRs entering permanent academic positions. Since then, academic retention of PhD graduates has fallen dramatically, with three boom-bust intervals tracking the 2008 financial crisis, post-2010 funding erosion, and post-pandemic sector fragility. Employment rates varied between annual cohorts, suggesting PhD timing relative to economic shocks may be as influential as individual academic output for long-term career trajectories. Our data

mirror the US decline in jobs and funding and coincides with the UK University funding crisis, felt especially in Earth Science departments. These figures likely understate the current trajectory given the lag between funding cuts and job losses. We urgently call for investment in coordinated, longitudinal employment tracking by our learned societies to inform advocacy alongside realistic, evidence-based career information for PhD students entering this turbulent employment period.

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Spatial scaling of diversity in Phanerozoic marine animals

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Understanding how the spatial structure of biodiversity changed through the Phanerozoic is critical for understanding how biodiversity itself was assembled through deep time. To date, however, no study has systematically quantified how diversity–area relationships varied through the Phanerozoic, or which spatial scales were most important for driving overall biodiversity change. Here we use Bayesian hierarchical distributional models to quantify genus-area relationships (GARs; both local–global, and within well-sampled geographic regions) for Phanerozoic marine animals. Validating empirical patterns against simulations generated using spatially-explicit neutral models demonstrates that local-to-global GARs cannot be reliably inferred due to incomplete spatial coverage, but that GARs within well-sampled regions are generally reliable. Through time, GAR intercepts within regions mirror trends previously documented at regional scales, including an abrupt increase across the Cretaceous–Palaeogene boundary. GAR slopes do not change systematically through the Phanerozoic, but become shallower following the end-Permian and end-Cretaceous mass extinctions. Steeper GAR slopes are statistically associated with the presence of reefal environments, suggesting that such regions may have hosted higher beta diversity. Our results show that at local- to regional scales, the spatial scaling of diversity has not systematically changed throughout the Phanerozoic.

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Reinvestigating *Ventarura lyonii*, the last plant species described from the Rhynie cherts

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Ventarura lyonii is an early Devonian plant species that is only known from the Windyfield chert in Scotland, a deposit nearby and very similar in age and preservation quality to the famous Rhynie chert. *V. lyonii* is a zosterophyll, an extinct, paraphyletic group of lycophytes that were the dominant plant group in the Early Devonian. This species is one of a small number of zosterophylls preserved with 3D tissue preservation, and therefore allows insight into the morphology and anatomy of this extinct group of important early land plants. The species was first described in Powell *et al*. (2000) from fragmentary remains observed using standard light microscopy. Here we present initial results from a reinvestigation of *V. lyonii*, using confocal laser scanning microscopy (CLSM) to examine

fine anatomical features. This will provide the basis for an understanding of fundamental anatomical traits of the zosterophylls, such as water and sugar conduction, allowing the impact these early vascular plants had on early terrestrial ecosystems to be understood in greater detail.

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Revisiting the preservation of chloroplasts in the mid-Miocene Clarkia biota

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The mid-Miocene Clarkia biota (USA) is an assemblage of fossils preserved in exquisite detail in clay-rich sediments. Among the wide diversity of organisms found in this deposit, plant fossils were reported to retain residual pigment colour, but also to preserve intact chloroplasts and mitochondria with sub-micrometre detail. Although such a level of detail is exceptional, the intact organelles in these fossil leaves have not been investigated since an initial study in the 1980s. Furthermore, the preservation of ultrastructures in senescing leaves remains difficult to understand. Therefore, the high-resolution taphonomy and preservation mode of these organelles remains to be elucidated. Here we have observed fossil leaves preserved as carbonaceous compressions, but also covered by diatom masks at certain localities and with occasional siderite mineralization. However, no permineralization or cementation was reported, which is unique to leaves in which the chloroplasts are preserved. To go further, we will prepare extant senescing leaves and fossil leaves from the Clarkia biota for tissue fixation and TEM analysis. The preservation of the internal structures will be compared between extant senescing leaves and fossil leaves from two Clarkia localities.

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The recurrence principle: a proven link between evolutionary convergence and predictability

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The extent to which evolution is predictable has been subject to continued debate. Previous narrative assertions of macroevolutionary predictability or unpredictability can be viewed as hypotheses, requiring formal mathematical models, proof and specific statements of requirements, either way. However, there is a route forward in that unpredictability of macroevolution is potentially falsifiable if models can be formulated that successfully predict key features. One such feature is evolutionary convergence, the repeated evolution of the same states. It has been both suggested, and disputed, that convergence is somehow connected to predictability. So, how, precisely, are they linked? I will demonstrate mathematical proof that formally connects convergence and predictability via, what I will call, the recurrence principle. This will show how fundamental probability theory can be extended to facilitate evolutionary prediction and elucidate its relationships to convergence. Application across theoretical examples and an Eon-scale case study of the palaeoenvironmental record, focusing on reef evolution, will illustrate implications of the recurrence principle for the stability of Earth's ecological states.

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A new mitrate (Echinodermata, Stylophora) from the Fezouata Shale (Lower Ordovician, Morocco) and the origin of the Anomalocystitidae

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Stylophoran echinoderms are a class of Palaeozoic echinoderms that diversified during the Cambrian. Severely affected by the Hirnantian mass extinction, only a few clades survived into the Silurian and Devonian. Among them, the family Anomalocystitidae represents probably the most successful and diverse of these long-ranging clades, which originated in the Ordovician and are attested to at least until the Middle Devonian (Givetian). Their origin, however, remains poorly understood: the morphology of the oldest described anomalocystitid, *Diamphidiocystis regnaulti* from the late Darriwilian of the Czech Republic and France, is already highly derived, suggesting an earlier diversification. Over the past 25 years, particularly abundant and diverse stylophoran remains (more than 30 taxa) have been found in the Lower Ordovician of the Zagora area (Central Anti-Atlas, Morocco). In the upper part of the Fezouata Shale (?*Baltograptus jacksoni* Zone, middle Floian), two localities have yielded numerous specimens of a new mitrate. Its morphology displays a mixture of apomorphies typical of anomalocystitids (*e.g.* a pair of posterior spines) and plesiomorphic characters (*e.g.* a right infracentral area, lateripores) shared with basal mitrocystitids (*e.g. Aspidocarpus*) but lost in anomalocystitids. This new taxon thus documents a key evolutionary transition, with the transformation of two posterior marginals into articulated spines.

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Palaeoecology of the Devonian 'button coral' *Microcyclus* (Anthozoa: Rugosa) and its recent functional analogues

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Corals show considerable phenotypic flexibility in response to environmental conditions. As a result, similar morphologies evolved independently in various modern and extinct taxa. One distinctive, recurring body plan, the 'button coral' morphotype, characterizes the Palaeozoic free-living solitary rugose coral genus *Microcyclus*. This study examines Middle Devonian *Microcyclus* assemblages from two sites in southeastern Morocco: the carbonate-ramp succession of Madène el Mrakib and the fore-reef succession of the Aferdou el Mrakib reef, which was periodically affected by reef-derived mass-flow deposits. Based on morphological analyses and comparisons with modern Scleractinia from similar environments, we evaluate the habitat preferences, life-history strategies and possible degree of auto-mobility of this genus. The small discoid corallite, protruding septa, and apparent preference for low-sedimentation settings suggest that *Microcyclus* was adapted to living on the sediment surface in soft-bottom settings. Among modern free-living scleractinians, *Cycloseris boschmai* and *Cynarina macassarensis* appear most comparable morphologically, with the latter notable for the presence of an epitheca, a feature also found in rugose corals. Morphological evidence indicates that *Microcyclus* was likely a lithosessile organism capable of excavation from small amount of sediments. Funded by National Science Centre, Poland, grants 2022/47/B/ST10/ 00205 to MJ and 2019/33/B/ ST10/00059 to BB.

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The palaeoneurology of the Triassic cynodont *Diademodon tetragonus* unveiled through computed tomography

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Computed tomography (CT) has provided non-destructive avenues for revealing endocranial structures in fossil cynodonts for over two decades. However, palaeoneurological studies remain taxonomically biased, with early-diverging gomphodontians being comparatively understudied, limiting our understanding of neurosensory evolution across the cynodont radiation. Here we present a modern reassessment of the palaeoneurology of *Diademodon tetragonus*, a gomphodontian cynodont from the Middle Triassic of Gondwana. CT segmentation enabled three-dimensional reconstructions of the brain endocast, inner ear, nasal cavity and associated neurovascular structures, including the maxillary canal. These are compared within a broad comparative framework spanning basal cynodonts to more derived gomphodontians, probainognathians and mammaliaforms. The morphology of *Diademodon*'s inner ear is consistent with sensitivity to low-frequency sound. Relatively small olfactory bulbs suggest diurnality, and are distinctly separated by a median sulcus, a feature typical of derived cynodonts. Maxillary canal morphology indicates a snout adapted for direct tactile interaction with the environment rather than whisker-based sensing. Ontogenetic comparisons further suggest that *Diademodon* may represent one of the earliest occurrences of parietal foramen closure during growth within Cynodontia. These features indicate that *Diademodon* exhibits a largely basal cynodont sensory organization, while also displaying characteristics typically seen in more derived forms, supporting a gradual evolution of neurosensory morphology.

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Testing the *Limulus*–trilobite locomotion analogy

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Trilobite locomotion has traditionally been reconstructed from exoskeletal morphology, trace fossils and comparisons with extant horseshoe crabs, particularly *Limulus polyphemus*. Despite their superficial exoskeletal similarities and benthic lifestyles, studies of limb flexibility in *L. polyphemus* and *Olenoides serratus* suggest distinct limb functions. Here we isolate the effect of interlimb coordination by applying two locomotory regimes to the same three-dimensional *Limulus* model. The first reproduces natural limb trajectories and timing from video recordings. The second reorganizes successive limb movements following the metachronal-wave equations developed for trilobite locomotion, without modifying appendage morphology or body configuration. The two regimes produce contrasting biomechanical outputs. Natural *Limulus* locomotion is strongly heteronomous, with walking legs and the posterior pushing leg performing distinct mechanical roles and generating discontinuous shifts in support. By contrast, the imposed metachronal regime distributes propulsion sequentially along the appendage series, producing a more continuous, posteriorly propagated pattern of support and a more uniform transfer of force to the substrate. Our results suggest that locomotory performance depends critically on interlimb coordination. *Limulus* should therefore be considered a partial functional analogue rather than a direct locomotory model for trilobites, with implications for reconstructing substrate interaction, trace production and neuromechanical control.

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Diving beetles (Coleoptera: Dytiscidae) through time: uncovering their ancient origin and pulsed diversification

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Predaceous diving beetles (Dytiscidae) are among the best-known and most extensively studied beetle groups. Despite their remarkable extant diversity, their fossil record remains highly fragmentary and unevenly sampled, limiting our understanding of their evolutionary history and diversification through geological time. To address these limitations, we applied the Bayesian Brownian bridge model, an approach particularly suited to clades with incomplete fossil records. Although initially developed to estimate clade origination times, this model can also be used to investigate origination and extinction dynamics while accounting for biases caused by uneven fossil sampling. Using a carefully curated dataset of fossil species occurrences comprising 155 species across 41 genera of Dytiscidae, we estimated the age of origin of the family and the origination times of individual genera represented in the fossil record. Our results indicate that Dytiscidae originated either during the Late Triassic, approximately 220 million years ago, or during the Early Jurassic, around 190 million years ago. These estimates are consistent with several recent time-calibrated phylogenies and provide further evidence for an ancient origin of the family.

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Tubes, fronds, and something in between: newfound Ediacaran fossils from Newfoundland

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The Ediacara biota records early experiments with large, multicellular eukaryotic life. Its earliest record occurs in deep-water siliciclastics of Newfoundland, Canada, but this exceptional fossil record contains a ~1,000-m stratigraphic and evolutionary gap between the pre-Gaskiers 580 Ma macrofossil *Colinetia* (a disc with an attached tube-in-tube structure) in the Mall Bay Formation and more complex, post-Gaskiers 571 Ma fronds in the upper Drook Formation. This gap raises questions about how biological complexity arose in the Ediacaran. We report >250 specimens of a new taxon in the middle Drook Formation. Most specimens comprise a centimetre-scale disc with eight lobes surrounding a central lobe. Six specimens preserve morphologically similar discs, each attached to a centimetre- to decimetre-scale triangular extension composed of parallel, unbranched tubes that twist clockwise into a cone with millimetre-scale orthogonal subdivisions. Tubes emanate from lobes in the communal holdfast, and their arrangement may have supported an erect posture. The new taxon may represent a colonial relative of *Colinetia*, but with a modular architecture similar to younger Ediacaran fronds. New U-Pb dates place the taxon between 580 and 571 Ma, filling a major gap in early Ediacaran evolution. We interpret the new taxon as an early step toward biological complexity.

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Be curveful: the omission of wing curvature and its consequences on pterosaur flight performances across the Mesozoic era

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Pterosaurs were the first vertebrates to evolve powered flight. Despite decades of debate, the degree of curvature of the trailing edge of the wing, formed by the membranous brachiopatagium, has been under-studied in biomechanical analyses due to taphonomic biases. The impact of wing curvature on the possible flight capabilities of pterosaurs has never been explicitly investigated, which consequently hinders our understanding of their possible locomotory and foraging ecologies across the Mesozoic. This study assesses how uncurved wing reconstruction distorts interpretations of aerodynamic performance and macroevolutionary signals. We quantified curvature-free wing outlines of 211 known pterosaur species using a theoretical morphospace approach based on elliptical Fourier analysis. Pteranodontia and Ornithocheiromorpha are disproportionally affected by high aerodynamic stresses and highly flexible wings due to the omission of realistic trailing-edge curvature. Conversely, Anurognathidae and Rhamphorhynchidae showed negligible sensitivity toward uncurved wing reconstruction. This pattern is driven by ecological niches rather than phylogenetic relationships. Functional morphospace occupation increases across the Mesozoic, but it is accompanied by a decline in Pareto optimality toward the Cretaceous, independent of uncurved wing sensitivity. Collectively, this clade-dependent stress limit and ecologically-structured performance demonstrate that wing curvature must be considered for accurate palaeobiological inferences across Pterosauria.

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Carbonaceous compression and tissue-specific organic signatures in the Qingjiang Biota

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The Qingjiang biota (Cambrian Stage 3, South China) represents one of the most pristine Burgess Shale-type (BST) deposits, preserving exceptional soft-tissue fidelity with minimal post-depositional thermal or weathering alteration. Despite over a century of research, the primary BST taphonomic pathway remains debated. Here we present results from high-resolution elemental mapping of Qingjiang fossils spanning diverse phyla and tissue types. Our data demonstrate that carbonaceous compression constitutes the dominant preservation mode, whereas authigenic mineralization processes, including pyritization, phosphatization, and aluminosilicification, play negligible roles. Preliminary observations further reveal that residual carbon concentrations vary systematically among tissue types in patterns that appear to reflect original biochemistry rather than differential decay resistance. Although detailed results are forthcoming, these tissue-specific carbon signatures suggest a molecular taphonomic control on preservation fidelity. These findings refine BST taphonomic models and offer a promising chemical framework for evaluating the anatomical authenticity of Cambrian soft-bodied fossils.

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Deep burrowing behaviour in trilobites: taphonomic insights

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Cruziana has been an extensively studied ichnogenus, which is generally attributed to trilobite activity and therefore offers valuable insights for reconstructing their burrowing behaviour. Most commonly, *Cruziana* is preserved at the bottom of strata as positive bilobate traces (convex hyporeliefs). This is interpreted as being the result of an epibenthic movement. However, in the Armorican Quartzite of the Iberian Peninsula (Puertollano, Central Spain), this ichnogenus occurs preserved as furrows on strata tops (epireliefs) as well as full reliefs. In addition, a meniscate infill (very rare in the ichnogenus) can also be observed, which would suggest a deeper bioturbation. The study of these kinds of preservation for *Cruziana* provides new insights for further understanding underrepresented ecological niches for trilobites. This work aims to identify distinct movement patterns in dense *Cruziana* assemblages through quantitative analysis of photogrammetric models. By combining spatial distribution, orientation, sinuosity, curvature, width, superposition and 3D relief, we seek to move beyond qualitative descriptions and assess whether these traces record random movement, directed displacement, localized searching, feeding activity or successive phases of substrate use. Our results suggest a deeper infaunal behaviour, which might have been the result of foraging in shallower environments where decantation of organic matter did not occur.

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Ontogeny and variability of an early Vallesian bovid (Boselaphini) from CCN20 (Vallès-Penedès Basin, NE Iberian Peninsula)

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Neogene bovids from Europe are generally well represented in the fossil record, yet the genera and species recorded around the late Aragonian/early Vallesian transition remain difficult to distinguish and their phylogenetic relationships are still debated. New fossil material from the early Vallesian (Late Miocene, MN9, ~11.2 Ma) locality of Creu de Conill 20 (CCN20; Vallès-Penedès Basin, northeastern Iberian Peninsula) provides an opportunity to reassess the taxonomy of Boselaphini (Bovidae: Bovinae) during this interval. The assemblage, provisionally attributed to *Miotragocerus* aff. *pannoniae*, comprises numerous cranial remains, including horn cores, dentognathic and postcranial elements. The exceptional representation of individuals at different ontogenetic stages makes it possible to almost completely reconstruct the sequence of horn-core growth and development. The CCN20 bovid is characterized by long, nearly straight horn cores with

marked mediolateral compression, brachyodont teeth (smaller than those of both the late Aragonian *Miotragocerus monacensis* and the Vallesian *Miotragocerus pannoniae*), molarized lower premolars, and metatarsals displaying a moderately developed lateral groove. Owing to its abundance and broad ontogenetic representation, the CCN20 sample constitutes an excellent framework for investigating both intraspecific variation and growth-related morphological changes in extinct boselaphins, and may ultimately merit the description of a new species. Funded by PID2024-159434NB-I00 and PID2023-151089NB-I00 (MICIU/AEI/10.13039/501100011033 and FEDER, UE); CERCA Programme/Generalitat de Catalunya; Deptartament de Cultura (ARQ001SOLC-241-2025 (14311 CU00050)) of the Generalitat de Catalunya; Beatriu de Pinós 2022 BP 00265 to MP, Joan Oró-FI 2023 FI-3 00396 to SS and 2024 FI-3 00112 to SGA.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

The Brymbo Fossil Forest, a new Upper Carboniferous (Moscovian) Konzentrat-Lagerstätte

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The Brymbo Fossil Forest geological SSSI (North Wales, UK) is an *in situ* carboniferous forest consisting of Lycopod tree-stumps with stigmarian root-systems, standing Calamites thickets, abundant pteridosperm fossils and preserved animal remains. The site is partially covered by a building that allows year-round excavation and study by a team of students and volunteers while also being publicly accessible as a unique natural history attraction. The Upper Carboniferous (Moscovian) sediments exposed within Brymbo Fossil Forest represent palaeoenvironments associated with an equatorial coal-forming, umbral rainforest in association with river deltas, meandering river systems and catastrophic flood plains. Careful excavation of portions of the site between 2024-2026 has allowed the collection of spatial data that helps us better understand some of the finer elements of these dynamic, successive ecosystems and how plants and animals respond to a changing environment over geological time. Here we present sedimentological, palaeontological and palaeoecological evidence which (when coupled with the sheer density, quality and scientific importance of the fossils on site) supports the designation of the site as a Konzentrat-Lagerstätte.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

New possibilities for the UV-visible-near infrared investigation of fossils

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Palaeontologists regularly exploit the luminescence of minerals, driven by crystal lattice properties, defect centres and activator ions, as well as that of certain organic compounds, to reveal fossil features invisible or only weakly visible to the naked eye. UV photography remains the primary approach, but techniques based on luminescence under visible-light excitation, including visible-light fluorescence and laser-stimulated fluorescence, are increasingly used to uncover hidden details in a wide range of fossils. The most recent development, multispectral imaging, enables the acquisition of dozens of reflectance and

luminescence images spanning wavelengths from the ultraviolet to the near-infrared. This approach has successfully enhanced morphological contrasts and revealed previously undetected features in fossil arthropods, cephalopods, sponges, vertebrates and plants, while also providing information on the composition and preservation of fossil tissues. In this presentation, I will briefly introduce the latest developments of multispectral imaging, including the portability of the system for data acquisition campaigns in museum collections and galleries, and its coupling with UV-vis-NIR emission spectroscopy to investigate the origin of luminescence signals. These developments will be illustrated by recent case studies spanning a diverse range of palaeontological and experimental taphonomy applications.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

The marine influence on the Latest Cretaceous North American terrestrial ecosystems and the impact on community structure.

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The latest Cretaceous of North America is among the most well studied Mesozoic terrestrial ecosystems. It documents an apparent dinosaurian diversity decline before the Cretaceous mass extinction, correlated with the regression of the intercontinental Western Interior Seaway (WIS). Here we analyse disparity in the environment, climate, flora and herbivorous fauna of ecosystems in relation to the WIS retreat. We find that environmental and depositional disparity within terrestrial ecosystems can be attributed to the influence of the WIS. Localized heterogeneity caused by the WIS likely influenced dinosaurian community dynamics, habitats, and drove localized diversity. Regression of the WIS resulted in the affected ecosystems having lower hadrosaurid but increased ceratopsian diversity due to changes in habitats. Hadrosaurs favoured more lowland habitats, whereas ceratopsians preferred more upland habitats based on occurrence and isotope data. Diverse terrestrial habitats associated with the WIS likely facilitated different life histories within hadrosaurs and ceratopsians. Increased pachycephalosaurid diversity within the Hell Creek Formation may be attributable to a contemporaneous decline in hadrosaurid diversity due to ecological dietary competition at different feeding heights during ontogeny. This study supports the influence of the marine systems on terrestrial fauna, alongside the abiotic factors affecting their life history and diversification.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Ecological and environmental influences on the evolution of cranial morphology in Mesozoic Archosauromorpha

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This study examines the evolution and allometric scaling of the orbit and naris in archosauromorph skulls, and tests how variation in these structures relates to ecology

and environment. Studies of extant archosaurs have linked orbit and naris dimensions to ecological and physiological factors, but whether similar relationships exist within extinct archosauromorphs remains unclear. We analysed two-dimensional measurements from 650 Mesozoic archosauromorphs and evaluated the effects of diet, locomotion, biotope, and environmental temperature, accounting for body-size and phylogeny analysed using Bayesian mixed effect models. Results reveal a strong negative allometric relationship between skull and orbit lengths; in contrast naris length exhibits positive allometry with substantial ecological variation. Ecological influence on orbit length is limited, with orbit scaling being conserved despite extensive ecological diversification. Whereas naris length was more responsive to ecological pressures, with diet, biotope and locomotion displaying differences in the scaling of naris length. These differences identify a contrast in the evolutionary dynamics of two major cranial openings, suggesting that macroevolutionary diversification in archosauromorphs is shaped by a combination of conserved allometric constraints and ecologically driven modification of the skull. These responses highlight how regions of the skull contributed unevenly to morphological diversification across 200 million years of evolution.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

From brick to bones: microvertebrates of the Wealden, Clockhouse Brickworks, Surrey

Thomas J. Henderson[1], Joseph Thompson[1], Elizabeth Cook[1], Christopher J. Duffin[1,2], Peter A. Austen[3], Claudia Hildebrandt[1], Tim Tomkinson[1] and Michael J. Benton[1]

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The Wealden of southern England is one of the most historically famous sites. That isn't surprising considering the impressive dinosaur fossils found, including *Iguanodon* and *Baryonyx*. An often-understudied aspect of these sites is their microfossil assemblage. Here we describe a previously poorly described site: Clockhouse Brickworks, Surrey. Home to a diversity of Hauterivian sharks, bony fish, lizards, turtles, crocodiles and more! This, along with sedimentological data, allows us to assess the palaeoenvironment and describe the specific taphonomy of this site. This is all supported by a food web showing the interaction between each genus, demonstrating complexity. We also compare the presence of taxa across multiple Weald sites from mainland UK to help describe temporal trends from the Valanginian to the Barremian.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Visualizing the Rhynie chert plant community in 3D

Alexander J. Hetherington[1,2,3], Harufumi Nishida[4,5], Aya Kubota[4,6], Nao Kawagoe[4], Ryo Taniguchi[1], Matthew Humpage[1], Sophie Burne[1], Shintaro Sasaki[7], Yusuke Takeda[8], Mehmet Oguz Derin[9] and Yasuhiro Iba[7]

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The Early Devonian Rhynie chert is our earliest exceptionally-preserved terrestrial ecosystem and provides direct evidence for a rich diversity of plant, animal, fungal,

nematophyte and microbial life at the dawn of life on land. However, technological constraints have limited our ability to characterize the form of large plants and the ecosystem as a whole. Here we overcome this limitation with a high-throughput, automated serial grinding approach termed digital fossil-mining. Using this technique we visualize a large 157 cm^3 volume of the ecosystem across scales spanning anatomy to entire plants. This approach allows us to describe gross morphology of the Rhynie plants in unprecedented detail and shed new light on the evolution of plant rooting systems.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Skeletally immature ichthyosaur skulls inform on ontogenetic dietary shifts and the palaeoecosystem at Strawberry Bank

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[1]University of Bristol, UK; [2]The University of Manchester, UK

Ichthyosaurs dominated the Jurassic oceans and several species often coexisted. However, limited evidence exists for interspecific and ontogenetic dietary niche partitioning. As such, we still understand little about what changes occurred in feeding behaviour as ichthyosaurs matured. Here we perform 3D reconstruction and finite element analysis on two exceptionally well-preserved ichthyosaur skulls from the Strawberry Bank Lagerstätte of Ilminster, England: an infant *Stenopterygius* sp. and a juvenile *Hauffiopteryx typicus*. The infant experienced higher stress and lower estimated bite forces. We compared our results to finite element models from a previous study: a sub-adult *Stenopterygius quadriscissus* skull and a juvenile *H. typicus* skull. The *Stenopterygius* sp. infant bore higher stress with a lower bite force yet had more efficient force transfer than the sub-adult. We conclude that feeding mode was likely similar throughout life history, with infants and juveniles feeding on softer and smaller prey. Both of the *H. typicus* specimens performed similarly in relation to size; we predict *H. typicus* had a diet of small, soft fish and squid. Overall, our results indicate minor ontogenetic niche partitioning in ichthyosaurs, though these differences are far more apparent between extremely young ichthyosaurs and those that are close to or at skeletal maturity.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

A new horseshoe crab (Xiphosura: Limulidae) from the Middle Jurassic of England

Richard J. Howard
Natural History Museum, London, UK

Fossil horseshoe crabs (Euchelicerata: Xiphosura) belonging to the single extant family Limulidae are exceedingly rare in Great Britain with only three examples previously recorded, ranging from the Carboniferous to the Jurassic. A new and unusually preserved limulid is reported and described here from the Middle Jurassic Inferior Oolite Group of Ketton Quarry, Rutland in England. Referred to *Mesolimulus* sp., the specimen occurs as a three-dimensional external mould imprinted in equal-grained pure oolitic limestone. Though the mould has collapsed in places, both the prosomal shield and the thoracetron are present as well as surprisingly fine-scale features such as the right lateral compound eye, making it the best preserved British limulid fossil.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Cenozoic crinoids from Taiwan reveal tectonically driven marine passive dispersal

Chia-Hsin Hsu[1,2]*, Yueh-Sheng Chung[3] and Chien-Hsiang Lin[2]
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Plate tectonics are a major driver of terrestrial biogeography, but their role in shaping dispersal in marine systems remains poorly resolved. Stalked crinoids provide an unusual test of this problem because their Cenozoic faunal turnover in the western Pacific has long been interpreted as the tectonically mediated arrival of Southern Hemisphere faunas into Asian waters, yet this hypothesis remains poorly constrained because the late Cenozoic western Pacific fossil record is sparse. Here new Plio-Pleistocene isocrinid crinoids (Metacrininae) from two localities in Taiwan are reported, representing the youngest crinoid fossil record known in Asia and closing a key late Cenozoic gap in the Pacific history of stalked crinoids. Integrating these fossils with published occurrences and palaeocoordinates reconstructed from global plate models, we compared the latitudinal dispersal rate of Metacrininae with plate motion and showed that its Cenozoic dispersal was governed first by plate motion and later by its oceanographic consequences, challenging the traditional view that marine passive dispersal is driven solely by ocean circulation.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Functional convergence through ontogenetic divergence in two arthropod guts separated by 500 million years

Alejandro Izquierdo-López and Dongjing Fu
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Ontogenetic patterns are one of the main factors that determine trait morphology across deep time evolution. The fragmentary nature of the fossil record, added to incomplete preservation, however, usually prevent carefully reconstructing these patterns, especially for complex or internal traits. We compare the function, architecture and ontogenetic mode of an internal organ, the arthropod midgut gland, between exceptionally preserved Cambrian naraoiids (Artiopoda) from the Qingjiang Formation (China) and extant phyllosoma larvae (Decapoda, Pancrustacea). Both groups have evolved a branching structure that maximizes its length, surface area and other functional variables within the constrained space of their flattened cephalon, potentially due to a similar planktonic-benthic lifestyle, but achieved through different ontogenetic modes. Naraoiids follow a non-centralized pattern in which growth depends on constant branch subdivisions, a largely unstable pattern that leaves wide space unfilled. Instead, phyllosoma have a central branch that forces daughter branches to grow laterally; their growth depends on fewer subdivisions that lead to a more stable and space-filling efficient growth. This case shows that non-selective processes like ontogenetic modes can constrain the architecture and efficiency of complex traits, but that evolution can circumvent these constraints to achieve convergent functions even after hundreds of millions of years.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Breaching the walls: an interlocking durophagous apparatus in a stem arthropod

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The Cambrian explosion was followed and fuelled by increasing complexity of animal ecosystems and trophic interactions. The ensuing evolutionary 'arms race' led to evolution of a variety of complex defensive and predatory adaptations, including exoskeletons and corresponding means of bypassing them. Here we present the first known durophagous apparatus in the arthropod stem group. A new genus of radiodont from the early Cambrian (Series 2) Mural Formation of Alberta, shows a set of gnathobase-like structures (GLS) bearing a set of conical, thick and interlocking spines, much more robust than the curved and thinner GLS spines of other radiodonts. This morphology may have allowed the animal to break highly sclerotized or biomineralized exoskeletons, and may be linked to W-shaped healed scars found in several Cambrian trilobites. Our descriptive (including 3D modelling) and phylogenetic results suggest that GLS evolution and differentiation within Radiodonta was a key factor in shaping their role in the earliest food networks. They likely allowed radiodonts to explore new niches, like durophagy, beyond the reach of more plesiomorphic arthropod mouthparts.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

The sensory toolkit of the early terrestrial predator, *Palaeocharinus* (Trignotarbida, Arachnida), from the Rhynie cherts (407Ma)

Beau Jones[1], Alexander J. Hetherington[1,2,3], Ryo Tanaguch[1]i, Laura Cooper[1] and Rachel Wood[1]
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The Rhynie chert (~407 Ma) in Scotland, a Devonian hydrothermal hot spring system, contains the most complete early terrestrial ecosystem on Earth. The animal biota of the Rhynie chert contains a taxonomically diverse group of arthropods with exceptionally preserved morphological features preserved in a precipitated silica sinter. Study of the microscopic sensory structures of the Rhynie arthropods (sensilla) provide valuable information on the behaviours of these animals – filling the geologic gap where complex sensory behaviours appear in deep time – and the ecological relationships between these organisms and their modern relatives. New high-resolution imaging of Rhynie chert arthropod microstructures with confocal laser scanning microscopy (CLSM) – a newly applied technique of non-destructive 3D microscopy – provide the most detailed descriptions of these vastly important microstructures in the predatory trigonotarbid arachnid, *Palaeocharinus rhyniensis*. Here we present a new workflow for screening and applying non-destructive 3D imaging to both modern and historical Rhynie chert thin section collections. Exploring both digital and confocal microscopy in conjunction with 3D reconstruction, we assess the external and internal structures within the delicate limb sensilla of *Palaeocharinus*. Our results reveal a complex mechano- and chemo-receptive sensory toolkit in early Devonian Palaeocharinid trigonotarbids. Descriptions of internal cuticular sensilla canals and external slit sensilla allow us to posit the functions of limb sensilla in navigating early terrestrial habitats, sexual selectivity, and predatory behaviours. This study elucidates our understanding of early terrestrial sensory adaptations, providing valuable data regarding the longevity of arachnid sensilla in deep time. Additionally, this research strengthens the case for revising historical palaeontological material with

new visualization techniques in order to improve our understanding of arthropod origins and evolution.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

From fire and water: assessing ecosystem structure in coastal Mesozoic ecosystems using the Wessex Formation as a case study

Harry Jones[1]*, Zak Lewis[2], Chance Guest[3], Tristan Moran[4], Josh Gunn[1], Dino Chu[1], Petter Nordenhaug[5], Thomas J. Henderson[2], Steven J. R. Allain[6] and Cassius Morrison[7,8]

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The Wessex Formation, UK, is a Lower Cretaceous sedimentary deposit famed for its diverse dinosaurian fauna. Despite yielding various taxa, many fossils from this formation are either temporally separate or stratigraphically unconstrained. We used literature to generate a list of fossil occurrences, before constraining each occurrence to its respective horizon to mitigate the impact of time averaging non-contemporaneous faunas. We identified 'bed L9' to be adequate for palaeoecosystem reconstruction due to sufficient sampling of taxa that can confidently be assumed to be sympatric. The similarly aged 'bed 5c' of the Upper Weald Clay Formation was also found to be well sampled with sympatric fauna, making it a valid horizon to investigate as a comparative ecosystem. By establishing trophic interactions between coeval fauna and flora, we determined different ecosystems within the Wessex. We used the R package Cheddar to generate food webs for each ecosystem, enabling comparisons between them. Preliminary results suggest that ornithischians had a different and reduced impact on ecosystems compared to sauropods and apex predator dinosaurs (*Neovenator* and spinosaurids) due to reduced ecological interactions, partially due to gregarious behaviour. Apex predator behaviour may have required some group behaviour to prevent smaller members from being consumed by other predators.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Triassic ammonoids of Pakistan: reconstructing Tethyan palaeobiogeography and marine biodiversity

Mian Sayed Khan

University of Swabi, Pakistan

The Triassic represents a pivotal interval in ammonoid evolutionary history, marked by rapid marine ecosystem recovery following the end-Permian mass extinction. Although the Tethyan seaway played a vital role in this diversification, the palaeobiogeographic importance of ammonoid faunas along Gondwana's northern margin remains insufficiently synthesized. The Triassic succession of Pakistan – particularly the Salt Range – contains one of the region's most crucial ammonoid records, yet it is rarely discussed within the broader Tethyan framework. In this study, we compiled Pakistan's published Triassic ammonoid record to analyse temporal variations in taxonomic diversity, biostratigraphic distribution and palaeobiogeographic affinities. Focus is placed on the exceptionally well-documented Early Triassic faunas of the Salt Range, which serve as high-resolution

reference standards for correlations across the northern Indian margin. We compared these faunas with those from the Himalaya, Tibet, India, Iran and Oman to evaluate provincialism, dispersal and marine connectivity. Pakistan provides an essential palaeontological window into post-extinction marine ecosystem reorganization. Integrating taxonomy, biostratigraphy and palaeobiogeography, this review contextualizes Pakistan's Triassic ammonoids within global evolutionary recovery and highlights priorities for future research on Tethyan ammonoid evolution.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Reconstruction of the diagenetic sequence of the Sarvak Formation type section based on textural relationships and petrographic evidence

Kiana Kiarostami and Masoomeh Sohrabi Mollayousefi
Islamic Azad University, Iran

The Sarvak Formation is an important carbonate unit of the Zagros Basin and a major carbonate reservoir in Iran. The Sarvak type section is located in Tang-e Sarvak in the southern flank of Bangestan Anticline (northwest of Behbahan). Following deposition, the succession was affected by various diagenetic processes. Identifying these processes and determining their relative timing are essential for distinguishing primary depositional features from post-depositional modifications and reconstructing the diagenetic history. In this study, prepared thin sections were examined using a polarizing microscope. Petrographic analyses were conducted to identify diagenetic processes, textural relationships, formation mechanisms and diagenetic environments. The results indicate that the Sarvak Formation experienced diagenesis in three main environments: marine, meteoric, and burial settings. The identified processes include dissolution, dolomitization, cementation, micritization, mechanical compaction, stylolitization, dissolution-related veinlets and fracturing. Textural relationships and petrographic evidence were used to establish the relative sequence of these processes. Overall, the present characteristics of the carbonate succession resulted from the interaction between primary depositional features and several stages of post-depositional alteration. Reconstruction of the diagenetic sequence provides a better understanding of the textural evolution and diagenetic history of the Sarvak Formation and helps clarify the complex post-depositional evolution of this carbonate succession.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

The fate of supposed plesiosaur vomit from Jurassic delta deposits offshore Norway

Dirk Knaust
Equinor ASA, Norway

Regurgitalites (fossilized vomit) have been recognized as such for a century, but only recently have they become better understood and systematically described. Centimetre-sized clumps containing tightly packed skeletal material of invertebrates (*e.g.* bivalves, serpulids and crinoids) and plant fragments are reported from well-core material offshore Norway. They occur in numerous wells with continuous cores through Middle to Upper Jurassic (Bathonian to Oxfordian) siliciclastic successions. The clumps mainly occur in

delta-front deposits with records of salinity fluctuation due to incoming freshwater. This contrasts with their composition, consisting of stenohaline forms. The tight fabric, diverse composition, co-occurrence of fractured and complete organisms, and etched margins are consistent with an interpretation as regurgitalites. Delta-front environments are dynamic systems with a high sedimentation rate and frequent bioturbation. Consequently, the gastric pellets are subject to reworking and alteration, resulting in their disintegration or incorporation into burrows. An evaluation of potential producers of the regurgitalites – based on functional morphology and stomach content – infers that Cryptoclididae are most likely (although Hybodontiformes cannot be ruled out), which agrees with their abundance and stratigraphic distribution in the basin. Accordingly, these long-necked plesiosaurs were bottom-feeding on offshore epi- and infauna and regularly egested undigestible food remains nearshore, where it became preserved and modified.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Upper Cretaceous bivalves of Western Kyzylkum, Uzbekistan

Robin Knight
Natural History Museum, London, UK

This preliminary study of the Upper Cretaceous bivalves of western Uzbekistan is based on the sedimentary/stratigraphic logs produced by Dr Chris King and fossils collected by Dr Noel Morris in the late 1990s. The bivalve fauna inhabited nearshore palaeoenvironments within the proto-Paratethys, a Late Cretaceous epeiric sea formed by eustatic sea-level fluctuations in conjunction with early Himalayan orogen tectonic activity. This formed shallow basins due to subsidence behind an active forearc region, which acted as a control on marine incursion from the Tethys based on sea-level, leading to the formation of complex, dynamic Upper Cretaceous seafloor palaeoenvironments. This is reflected in the distinct, short-lived and highly-localized bivalve faunas recorded at different localities and stratigraphic levels. This research begins to explore how sea-level change and terrestrial inputs (fresh water and sediment) due to tectonic activities affected the bivalve fauna, using specific families as environmental proxies: open marine recorded by inoceramids; brackish conditions by trigoniids; oysters as euryhaline indicators. Other taxa of interest include an early appearance of *Crassatella* (possible insight into generic origin), a late appearance of *Neocrassina* (refugia faunal component) and the presence of *Glycymeris*/*Limatula* (distinct palaeoenvironmental signals). The faunal changes may prove useful in regional stratigraphic framework refinement.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Early Spathian conodont radiation assessed through a multiproxy approach

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Conodonts were marine vertebrates that survived the end-Permian mass extinction and underwent repeated phases of radiation and diversity loss during the environmentally dynamic Early Triassic. One of the most pronounced turnovers occurred across the Smithian–Spathian boundary (SSB; *c.* 249.3 Ma), coinciding with major climatic and sea-level changes. Constraining the timing, potential drivers and evolutionary pathways of the subsequent early Spathian radiation is commonly limited by the temporal resolution of the stratigraphic record. Owing to high sedimentation rates, the Smithian–Spathian

succession at Pastun (Kashmir) provides an expanded record that enables an integrated analysis of conodont evolution, microfossil assemblages and microfacies. The strata contain abundant and diverse microfossils, including foraminifers, ostracods, gastropods, echinoids, crinoids, conodont elements, and teeth of chondrichthyans and osteichthyans, deposited in a shallow-marine setting. The positive carbonate $\delta^{13}C$ excursion associated with the SSB and early Spathian spans approximately 15 m of the section. Preliminary results indicate that characteristic Spathian conodont taxa became established by the end of the $\delta^{13}C$ excursion, documenting rapid faunal reorganization following the SSB crisis and providing a high-resolution framework for tracing early Spathian conodont diversification.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Inside a trilobite gut – the digestive anatomy and feeding in *Deanaspis goldfussi* from synchrotron data

Lukáš Laibl[1], Valéria Vaškaninová[2], Jakub Rantuch[2], Jana Bruthansová[3] and Petr Kraft[2]
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Knowledge of trilobite digestive systems provides important insights into their anatomy, feeding and physiology, yet preserved digestive tracts and associated organs are exceptionally rare in the fossil record. Here we present a uniquely three-dimensionally preserved digestive tract of the trilobite *Deanaspis goldfussi* from the Upper Ordovician Letná Formation of Bohemia. The specimen was scanned at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France. The digestive tract is a relatively simple, continuous tube extending from the posterior glabella to the end of the pygidium. Beneath the glabella, it expands ventrally into a voluminous, unusually bell-shaped crop connected to the mouth by a markedly narrow oesophagus. The mouth itself was positioned slightly posterior to the hypostome. A pair of large digestive glands is attached dorsally to the posterior part of the crop. Along the gut, the infill is partitioned into short, pellet-like segments with a distinct concentric internal structure, strikingly resembling gut contents enclosed by a peritrophic membrane in extant mandibulates. Both the crop and intestine contain sediment and remains of hard-shelled organisms, providing direct evidence of the feeding strategy of this specialized trilobite.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Beak performance: convergent evolution of beaks underpins the adaptation of herbivory in dinosaurs

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Herbivory is a key strategy permitting access to previously inaccessible resources. It has evolved multiple times, in >50 % of dinosaur species (in ornithischians, sauropodomorphs, and such unlikely groups as theropods). This success depended considerably on the ability to procure and process plant matter, resulting in a vast variety of skull and jaw morphologies. However, one key innovation is prevalent in all groups (except derived sauropodomorphs): the acquisition of an edentolous beak. A number of beak shapes have evolved in different herbivorous dinosaur groups thought to reflect different feeding styles and specializations. Here we test the hypothesis that despite the seemingly large diversity of skull shapes in herbivorous dinosaurs, beaks were morphologically and functionally

constrained; that similar shapes have evolved multiple times convergently; and that convergence in beak shapes led to competition between herbivorous dinosaur groups. Using a combination of geometric morphometric analysis (GMM), diversity analysis, and biomechanical modelling, we quantified beak morphologies for over 100 species across six major groups and assessed the functional and evolutionary implications. Our results demonstrate that three general beak morphotypes evolved convergently in unrelated species. These morphofunctional specializations led to niche partitioning in ornithischian and theropod herbivores, but only to limited competition between groups.

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Collections and taphonomic bias of Silurian trilobites in the Lapworth Museum of Geology, Birmingham, UK

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The Lapworth Museum of Geology holds important collections of Silurian trilobites from the Much Wenlock Limestone Formation at Wren's Nest, Dudley. These collections and their specimens were likely affected by collection biases introduced by private collectors as well as by a variety of taphonomic processes. The extent to which these collections and their constituent fossils were affected by these biases is assessed amongst the Holcroft and Ketley collections of the Museum. Analysis suggests that collection biases have led to overrepresentation of rare species, a focus on collecting more complete, articulated trilobite specimens and possibly a bias towards smaller fossils, which masks palaeontological information. Taphonomic biases were harder to identify, but may have impacted which associations were most strongly represented within the collections. These findings have important implications for the use of older museum collections in palaeontological research, showing that a variety of factors important to understanding fossil localities (such as trends in body size and specimen completeness) may be significantly affected by the collection bias, to the point where data from these collections will be radically different to the original locality.

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Using tooth whorls to elucidate the ancient evolutionary origin of the tooth attachment system

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Despite interest in the origins of vertebrate tooth patterning and dental tissues, debates continue over the origins of the periodontium (attachment tissues). Identifying the homologs of mammalian cementum, periodontal ligament (PDL), and alveolar bone, remains challenging; however, tooth whorls present the unique opportunity to study periodontal tissues in early gnathostome dentitions with no intervening contributions from the jaws. We therefore studied periodontal histology in fossil tooth whorls from stem and crown chondrichthyans and osteichthyans and compared these to extant elasmobranchs. Stem chondrichthyan tooth whorls possess a bone tissue derived from each tooth generation and a Sharpey's fibre-rich cementum that intermixed with dentine, forming what was previously referred to as 'osteodentine'. Newly attached teeth show a suture

line between the tooth and the whorl base, highlighting the presence of a transient PDL tooth attachment. Modern chondrichthyans also possess cementum along the tooth bases, derived from surrounding mesenchymal cells. Synchrotron-CT scans of a sample of fossil osteichthyan teeth and tooth whorls show similar dental tissues, but also the capacity for tooth resorption and shedding. We conclude that a three-part periodontium is an ancient gnathostome feature and that evolutionary shifts in mineralization and resorption capacities have allowed gnathostomes to evolve diverse dentitions.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Sailing to Gondwana: multiple waves of spinosaurid dispersal to the southern continents

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Spinosaurid theropods had a relatively widespread distribution during the Cretaceous; however, biogeographical analyses have been limited due to their fragmentary nature and uncertainties in spinosaurid phylogeny. We conducted a biogeographical analysis of Megalosauroidea, with a focus on Spinosauridae, using the R package BioGeoBEARS across several phylogenetic hypotheses to test probable dispersal patterns. The best-fit models suggest that spinosaurid evolutionary history was influenced by geodispersal, followed by narrow and widespread vicariance, as well as regional sympatry between co-occurring taxa. Within Spinosauridae, we find evidence for at least two dispersals from Europe into Africa and South America, and at least one dispersal from Europe into Asia. We also consider more fragmentary spinosaurids in a non-phylogenetic context to constrain the timing of these dispersal events. Based on existing palaeoclimate data, spinosaurids generally appear to inhabit high mean annual temperature (~25–35 °C) semi-aquatic habitats, a preference that appears more constrained than in other contemporary theropods. These results may imply that spinosaurid dispersal potential was constrained by a combination of strict environmental and climatic preferences, as well as geographical barriers. These proposed migratory obstacles might explain their mysterious absence from North America, Antarctica and Australia.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

A 'thoracosaur' crocodyliform from the latest-Cretaceous freshwater deposits of western North America

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The terminal-Cretaceous Hell Creek Formation, and adjacent 'Lancian' units, have been intensively sampled due to sustained interest in understanding biodiversity collapse and

recovery patterns across the Cretaceous–Palaeogene extinction event. Crocodyliforms represent a diverse component of this fauna but remain understudied with respect to other contemporary tetrapods. In order to better constrain the taxonomic composition of the crocodyliform assemblages, we examined specimens of a large, undescribed longirostrine taxon from the northern Great Plains of North America. These fossils include highly fragmentary skeletons from the Hell Creek Formation of Montana and South Dakota, USA, and isolated teeth from the Frenchman Formation of Saskatchewan, Canada. The material presents characters diagnostic of the 'thoracosaurs' *Thoracosaurus* and *Eothoracosaurus*, documenting the first record of this group from non-marine deposits. This 'Lancian thoracosaur' taxon potentially offers additional evidence for the persistence of the Western Interior Seaway immediately preceding the K–Pg mass extinction, and supports a more nuanced perspective on the ecology of 'marine' reptiles. It remains intriguing that the Lancian thoracosaur is seemingly absent post-Cretaceous considering the persistence of thoracosaurs elsewhere during the early Paleocene, with one possible explanation being a local extirpation relating to the K–Pg extinction event.

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Quantitative assessment of community structure of fossil forests from the Devonian to Jurassic periods

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Forests have profoundly shaped terrestrial ecosystems, climate and environment since their emergence in the Middle Devonian. Although extensive palaeobotanical studies have provided qualitative insights into their evolution, the community structure and dynamics of fossil forests remain poorly quantified. Here we quantitatively assess 38 pre-angiosperm fossil forests from the Devonian to Jurassic based on forest composition, canopy height, tree density, biomass, stand structure and spatial pattern. Our results show that canopy height increased twice, during the Late Devonian–Early Carboniferous and the Middle Triassic–Late Jurassic; biomass peaked in lycopsid-dominated Devonian–Carboniferous forests before stabilizing at levels comparable to extant forests after the Middle Triassic; tree density was highest in Devonian–Carboniferous forests and approached modern levels following gymnosperm dominance in the Middle Triassic; and spatial patterns remained predominantly aggregated, similar to extant forests. We identify four evolutionary stages: Initial Forest (Eifelian–Frasnian), characterized by diverse composition, moderate biomass and density, and low canopy height; Geocarbon Forest (late Famennian–early Permian), dominated by lycopsids with maximum biomass and density; Dawn Forest (middle Permian–Early Triassic), with increased canopy height but reduced biomass and density; and Preset Forest (Middle Triassic–Late Cretaceous), characterized by gymnosperm dominance and increased canopy height.

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The external and internal anatomy of the cervical vertebrae of the sauropod dinosaur *Lingwulong shenqi* and its implications for pneumaticity in Diplodocoidea

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Lingwulong shenqi, from the Middle Jurassic of China, is the stratigraphically earliest known diplodocoid sauropod dinosaur. Recovered either as a dicraeosaurid or an earlier-branching diplodocoid, it extends the spatiotemporal distribution of Diplodocoidea and implies multiple unsampled ghost lineages. Given that it is known from most of the skeleton, *Lingwulong* also possesses substantial morphological information, but only limited data have been published so far. Here we present detailed anatomical data on the cervical vertebral series of *Lingwulong*, both externally and internally, via CT scanning. Our analysis reveals greater morphological variation along cervical vertebral series than previously recognized, including bifid and unbifurcated neural spines. *Lingwulong* possesses deep fossae that penetrate the vertebral corpus, but the internal bone is dense and spongious, indicating a 'procamerate' condition. Our review of the pneumatization of cervical vertebrae of diplodocoids, based on published and newly collected CT-scan data, indicates that the condition in *Lingwulong* is most similar to that of the early-branching diplodocoid *Haplocanthosaurus* and dicraeosaurine dicraeosaurids, differing from the 'polycamerate' to 'camerate' condition that characterizes most other diplodocoids. These new data will help to elucidate the phylogenetic relationships of *Lingwulong* within Diplodocoidea, as well as shed light on the evolution of pneumaticity in the clade.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Disruption of the mats: evaluating ecosystem shift and the first extinction pulse in Late Ediacaran

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The terminal Ediacaran Period (~550–539 Ma) witnessed the first major extinction of complex life and the collapse of the matground ecosystems that had characterized the Proterozoic. The Shibantan Lagerstätte (~550–543 Ma) in South China provides an exceptional record of this transition, preserving both Ediacara body fossils and an expanding suite of metazoan trace fossils. To assess the role of biotic effect in the ecological upheaval, we quantified ichnofossil bedding-plane densities and spatial distributions within the Shibantan Member. Our results reveal a pronounced stratigraphical increase in bedding-plane bioturbation intensity, with ichnofossil coverage rising from <10 % to 20–40 %, accompanied by increases in size and complexity. Density isopleth maps illustrate the heterogeneous patterns of *Lamonte*, *Streptichnus* and *Helminthoidichnites* across surfaces. This rise in metazoan activity correlated with declining diversity and reduced spatial coexistence of sessile Ediacara taxa. These patterns indicate that metazoan bioturbators acted as ecosystem engineers, fragmenting microbial mats and destabilizing the substrate conditions essential for the coeval Ediacaran biota. This study identifies a

correlation between matground disruption by early bilaterians and the first extinction pulse, underscoring the role of biotic replacement and ecosystem engineering in driving one of the most profound ecological revolutions in Earth history.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Quantifying the quality of the non-hominin hominoid fossil record and elucidating geological and anthropogenic biases

Rosie May Lock and Daniel Cashmore
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Hominoidea is the primate superfamily comprising all apes, extinct and extant, including the tribe which led to *Homo sapiens*, Hominini. Variation in fossil specimen completeness through time and space can bias our understanding of Hominoidea evolution. Here we quantify the completeness of the non-hominin hominoid fossil record using the skeletal completeness metric (SCM) and character completeness metric (CCM). These metrics calculate the total skeletal proportion of a specimen and the proportion of phylogenetic information preserved in a specimen, respectively. Hominin fossils were excluded for this preliminary study and, so far, data for 90 % (53) of the remaining species has been collected. Initial findings show that most species have poor skeletal preservation, but relatively informative character preservation. Unlike all previously assessed tetrapod groups, hominoids lack specimens at >80 % completeness, which may reflect palaeoenvironmental preservation bias. 70 % of all non-hominin hominoid fossil occurrences are teeth, 14 % are cranial bones and only 16 % are postcranial. Just 25 % of species are represented by postcranial specimens, which is likely hindering our understanding of hominoid locomotory evolution. Only minor fluctuations in mean completeness through geological time are observed, but significant spatial variation, with African and European localities withholding more favourable preservation and a greater variety of bone types.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Insights into the Ediacaran–Cambrian transition from cherts and phosphorites of South China

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The boundary between the Ediacaran and Cambrian represents a critical transition in Earth history defined by major changes in the biosphere. Sedimentary successions in South China provide an important window into this transition through the occurrences of fossiliferous chert and phosphorite deposits. In particular, these intervals contain exceptionally preserved microfossils, including small shelly fossils and acritarchs, that offer an opportunity to investigate both the evolutionary and stratigraphic significance of earliest Cambrian communities. Microfossils preserved within these deposits can provide insight into the emergence and diversification of early Cambrian organisms, as well as changes associated with a major community turnover relative to preceding micro-assemblages. Documentation of their occurrence and distribution can also yield valuable, high-precision biostratigraphic constraints for Ediacaran–Cambrian successions in South China, ultimately contributing to broader correlations with sections elsewhere. Here we

will examine microfossil assemblages from deposits across South China to further explore their capability for understanding early Cambrian evolutionary and biostratigraphic patterns. By combining palaeontological data with sedimentological, stratigraphic and geochemical information, this work seeks to assess how exceptionally preserved microfossils can improve our understanding of the Ediacaran–Cambrian transition in South China and globally.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Bentiaba: a southern hemisphere perspective on Maastrichtian marine ecosystems

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The Maastrichtian marine fossil record at Bentiaba, Southern Angola, is among the most complete assemblage known from the Southern Hemisphere. New stratigraphic and sedimentological analysis of the 80 m-thick Mocuio Formation reveals facies changes (bioturbations, carbonate-cemented sandstones, sandstone bed thickness and presence of fossil hash layers) associated with a shallow marine environment, reflecting variable detrital input, shifting environmental conditions and sea-level fluctuations. Building on published records of marine reptiles and by incorporating new shark and bony fish material, we refine the vertebrate biostratigraphic communities and chronological framework of the sequence. Spanning most of the Maastrichtian, it documents a faunal turnover, associated with the mid-Maastrichtian Event, marked by inoceramid extinction and shifts in *Squalicorax*, Ginglymostomatidae, Myliobatiformes, *Enchodus* and mosasaur communities. The scarcity of calcareous fossils throughout the section is attributed to local acidification of coastal environments linked to high organic matter flux, as documented in comparable Maastrichtian phosphatic deposits in Morocco. At Bentiaba, however, rare internal moulds of gastropods and scaphopod along with sporadic remains of horn corals and echinoderm provide evidence of a shallow-marine benthic community. Together, these results establish Bentiaba as a key reference for the Southern Hemisphere Maastrichtian, offering new insights into Late Cretaceous Ocean biotic dynamics. Fieldwork funded by ISEM at SMU, and research by Fundação para a Ciência e Tecnología (GeoBioTec UIDB/04035/2020 supporting AM, RP, CS, and Fellowship 2022.11517.BD supporting AM).

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A for acrodonty: the ambiguity of acrodonty amplified by agamid acrodontans

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Tooth implantation is an important morphological character in lepidosaurian (lizards and their kin) phylogenies. Acrodonty, apical positioning of the tooth relative to the jaw, is a key character of extant chameleonid and agamid lizards (Acrodonta), and is important in referring fossil material to Rhynchocephalia. However, tooth implantation in some 'acrodont' reptiles has recently come under scrutiny, raising concerns around its

taxonomic and phylogenetic utility. To address this, we conducted a histological survey of extant acrodontan lizards and found that agamids demonstrate ontogenic shifts in tooth implantation, where newly erupted teeth are pleurodont (attached to the labial wall of the jaw), even in the posterior, supposedly acrodont teeth. Posterior teeth then transition to a superficially acrodont implantation geometry following dentine deposition and bone remodelling through ontogeny. Conversely, chameleonids are unambiguously acrodont throughout life. This highlights problems with the use of implantation geometry as a morphological character, and in our understanding of the evolutionary history of groups where implantation geometry plays a vital role in classification (*e.g.* rhynchocephalians). Geometry is insufficient to describe tooth implantation, and characters should be constructed based on discrete morphologies in newly erupted posterior teeth to codify it accurately.

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Preliminary finite element analysis of the internal structure of two distinct azhdarchoid jaws from the Kem Kem Group of Morocco

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The mid-Cretaceous Kem Kem Group of southeastern Morocco has yielded abundant fragmentary pterosaur bones, many preserving their internal structure in high detail. Here we present a preliminary finite element analysis (FEA) on two fragmentary, microstructurally distinct cf. *Apatorhamphus* jaws. They were CT-scanned, processed via Dragonfly and Geomagic Design X, and subjected to finite element simulations in Ansys, modelling various biting scenarios. One specimen exhibits thickened lateral margins, complex trabecular systems and numerous neural foraminae. The other shows constant bone wall thickness, well-spaced simple isolated transverse trabeculae and fewer foraminae. Under applied loads of 25–50 N, Von Mises stress is well distributed in both cases. Very low values occur throughout the thickened lateral margins, while the stress is most efficiently dissipated through the trabecular systems. The maximum stress is concentrated in unreinforced areas near the dorsal margin and around foraminae. Simplified models lacking endosteal structures lead to significantly higher stress, showing the extent of the structural reinforcement. These analyses quantify the stress dissipation associated with simple or dense trabeculae, as well as cortical thickening, showing varied microarchitectural configurations enhancing biomechanical performance. This study provides a framework for evaluating different microstructural adaptations of azhdarchoid pterosaur jaws under mechanically demanding feeding strategies.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Global fossil biases, unequal impacts: mammalian faunas are differently distorted across climates

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The fossil record is inherently incomplete, but incompleteness may do more than reduce the amount of biodiversity we observe: it may systematically distort its ecological and

geographical structure. While preservation and sampling biases have been extensively studied, we still know little about whether they affect biodiversity differently across climates and continents. Here we use the global distribution of extant terrestrial mammals as a known baseline and simulate major filters affecting the fossil record, including geological availability, geographic range size, body size, spatial sampling and taxonomic sampling. By progressively reducing sampling completeness, we quantify which components of present-day biodiversity would remain visible if the living world were transformed into a fossil record. We show that biodiversity loss is not climatically random. Tropical, temperate and arid regions lose proportionally more species than cold environments, generating systematic distortions of biodiversity across climatic space. We further evaluate how this selective loss alters the taxonomic composition recovered within climatic regions and across continents. Carnivorans and artiodactyls become disproportionately represented relative to their original contribution to mammalian diversity, whereas the high diversity of bats and primates characterizing present-day ecosystems is poorly recovered. Our results suggest that the fossil record is not simply an incomplete version of past biodiversity, but a selectively transformed one. These transformations can fundamentally alter our perception of how biodiversity was distributed across climates, which taxonomic groups dominated different environments, and how many species were able to occupy and persist under different climatic conditions. Recognizing these climate-dependent biases is therefore essential for reconstructing the ecological structure of past biodiversity from the fossil record.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Silent past: biogeographic gaps in the Cenozoic fossil archive

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Exposed sedimentary rocks are unevenly distributed across space, interfering with our ability to reconstruct the spatial and temporal dynamics of past climates and ecosystems. In this study we quantified the extent of 'lost' informative areas – regions where sedimentary layers from the past 66 million years are not presently exposed – and assessed gaps across climate zones and geological time bins. Using Chorlton's global geological map, we reconstructed the distribution and depositional ages of exposed sedimentary rocks, and linked these with palaeoclimate simulations from the HadCM3 model, classified under the Köppen–Geiger system. This framework allowed us to compare the distribution of palaeoclimates predicted by HadCM3 for each time bin with the distribution of climates represented only by currently exposed rocks of that interval. We further integrated fossil occurrence data from the Paleobiology Database to evaluate mismatches between climatic coverage in the geological and fossil records. Our results indicate that more than 72 % of past continental areas across the Cenozoic lack accessible sedimentary rocks, implying a substantial loss of information about past biodiversity. Of the remaining 28 %, exposed sediments are disproportionately derived from regions that experienced tropical, temperate and arid climates, while deposits from cold and polar climates are underrepresented. The fossil record, in contrast, shows distinct biases, with a particularly large proportion of

fossils originating from past temperate environments, likely reflecting excavation effort. These findings underscore the need to account for geographic and climatic biases when interpreting macroevolutionary trends, biodiversity patterns and species' responses to climate change.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Ecological functional stability in the dinosaurian fauna of the Upper Jurassic Morrison Formation, USA

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The Upper Jurassic Morrison Formation spans 7-9 million years and is dominated by a diverse dinosaurian fauna. However, despite extensive sampling, palaeoecosystem dynamics remain poorly understood. Taxonomic turnover can be decoupled from ecological functional diversity (EFD), as different species can fulfil the same role, as seen within Cenozoic mammalian assemblages. To test EFD and its stability through time, we analysed the dinosaurian fauna of 15 spatiotemporally distributed quarries within the Morrison Formation that could be identified as representing an ecosystem, *i.e.* temporally co-occurring taxa, to provide an alternative macroecological perspective. Taxa were characterized by ecomorphological traits of mass, dietary guild and locomotion. Quarries were placed in six stratigraphic 'zones', allowing for a test of ecosystem structure throughout the Morrison Formation. Zones 2-5 showed stable EFD, despite taxonomic differences, while Zone 6 is distinct. This may represent a genuine ecological shift, or sampling bias. Within the dinosaurian fauna, environment changes have limited to no influence on EFD, yet sampling biases cannot be ruled out. This study shows the potential to assess ecosystem structure independent of taxonomic turnover and the persistence of ecological functionality through deep time within vertebrate assemblages.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Distribution and preservation of *Kimberella quadrata* from the Ediacara Member, South Australia

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The fossil *Kimberella quadrata* is one of the most morphologically complex members of the soft-bodied Ediacara Biota. *Kimberella* and its trace fossil, *Kimberichnus teruzzii*, are largely known from the White Sea region of Russia, where *Kimberella* occurs abundantly. *Kimberella* occurs rarely in the Flinders Ranges area of South Australia, previously identified almost exclusively from float material. Here we leverage previously collected specimens and 51 body fossils recently uncovered on a single bedding surface at Nilpena

Ediacara National Park to examine *Kimberella* and *Kimberichnus* from the Ediacara Member of South Australia. We find that body and trace fossils are widely distributed across a variety of shallow water facies throughout the Ediacara Member. Consistent with specimens from the White Sea region, larger *Kimberella* are preserved with reduced vertical relief compared to smaller ones, demonstrating preferential deformation of larger *Kimberella* during burial that reflects a fluid-filled construction. We find that the orientation between concurrently preserved *Kimberella* and *Kimberichnus* provides evidence that the direction of motility and feeding were decoupled and that *Kimberella* likely moved primarily with its anterior end forwards. All data are consistent with a Lophotrochozoan affinity for *Kimberella* and the possibility of this taxon representing a stem-group mollusc.

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Myology and microraptorines: exploring the functional capabilities of paravian wings

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The evolution of flight in birds is one of the most iconic and important major evolutionary transitions in the history of life. However, to reach the extensive diversity of birds alive today, powered flight endured numerous experimental phases throughout its early evolution. One of these being a four-winged body plan, as exemplified by the small yet charismatic microraptorines. Whilst the role of their four wings in gliding flight has been modelled in different ways, how they undertook proposed powered flight has received less attention. This study aims to reconstruct the forelimb musculature of the microraptorines to inform the functional capabilities of the wings and its implications on flight capability and style. To do so, preserved soft tissues were observed under laser-stimulated fluorescence and ultraviolet light alongside assessment of osteological details. The shape, size and position of muscles in the wings of select genera were then identified and mapped, allowing for the rotational, extensional and moment arm capabilities of the wings to be reconstructed. Resultant measurements found that *Microraptor* exhibited extensional and rotational capabilities comparable with early birds. This study sheds light on the evolution of this enigmatic clade of dinosaurs and their flight origin story. Our results serve as a step towards a wider integrative analysis of the flight evolution of microraptorines, and the resultant implications for the wider paravian clade.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

The evolution of pentaradial symmetry in echinoderms

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Symmetry is an integral aspect of organismal biology, which is reflected in the construction of the fundamental animal body plans that emerged during the late Neoproterozoic–Cambrian. Echinoderms are a model group for investigating the evolution of symmetry in

animals; they are unique among bilaterians in displaying pentaradial symmetry as adults and their fossil record includes bilateral, asymmetrical, triradial and pentaradial forms. It has been proposed that echinoderms evolved pentaradial symmetry as an adaptation to a sessile suspension-feeding mode of life. To test this hypothesis, we digitally reconstructed a range of Cambrian echinoderms, capturing the full range of morphologies and symmetry types observed in the group. We placed these models in a virtual fluid environment and used a fully coupled computational fluid dynamics and discrete element method (CFD-DEM) simulation to accurately track food particles and quantitatively assess feeding performance. The results shed light on the origin of the pentaradial body plan and has implications for the evolution of symmetry in animals more broadly.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Fantastic beasts and where to find them at fossil festivals

James McKay
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As a palaeoartist (winner of the Marsh Palaeoart Award 2026) I have worked with the PalAss outreach team since 2013 at dozens of fossil festivals (*e.g.* Lyme Regis Fossil Festival) creating artwork to engage children in palaeontology. The activity involves children 'discovering' bones from prehistoric animals and reconstructing them into a drawing of their very own fantasy prehistoric creature, which they colour, scientifically name and present to the artist, along with information about its habitat, diet *etc.* I then create a piece of original palaeoart based on their drawing and ideas, which is gifted to the child as a souvenir of the activity. Here I present my experiences of working with the PalAss outreach team, creating prehistoric artworks 'live' under pressure, and will give some evaluation of what the children have gained from the activity. Be prepared for some bizarre discoveries!

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Variable effects of endocranial volume on sulcal lengths in the mammalian Order Carnivora: a quantitative analysis

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Gyrification, or the degree of folding and sulci on the surface of the brain, generally increases as mammalian brain size increases. However, few analyses have quantitatively assessed the influence of brain size on individual sulcal length. The diverse mammalian order Carnivora is an ideal group to study the relationship between brain size and sulcal length. Here we examine the relationship between endocranial volume (ECV) and the lengths of the lateral, cruciate and suprasylvian sulci in virtual endocasts of 33 extant species representing eight carnivoran families. We include three fossil taxa: the carnivoramorph *Quercagyle angustidens*, the amphicyonid *Gustafsonia cognita*, and the machairodont *Homotherium serum*. Virtual endocasts were measured using micro-CT scans in 3D Slicer. PGLS regressions reveal a significant positive relationship between ECV and the lengths of both the suprasylvian and cruciate sulcus in extant carnivorans. In contrast, the lateral sulcus is not significantly correlated with ECV. *Quercygale* and *Gustafsonia* have lateral sulcus lengths similar to those observed in a range of extant

carnivorans with much larger ECVs. Despite the expectation of increasing gyrification with increasing brain size, our findings suggest that the influence of brain size on sulcal length is not uniform across sulci.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

New detailed palaeogeographical maps for the last 1 billion years

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Palaeogeographical maps track the movement and dispersal of the continents, the growth and erosion of mountains, and the depth and structure of the oceans over deep time. In this way they fundamentally underpin a wide range of research across the palaeo-sciences. But most maps are still not freely available, and the methods of their production can be difficult to interrogate or reproduce. This results in large differences between maps, with limited scope to quantify and address these. These limitations led us to develop a new set of maps which we present here and in a linked publication. Our maps are procedurally generated from an established plate tectonic model using an open source algorithm that calculates topographic change across different plate boundaries, as well as large palaeontological and geochemical datasets that allow us to estimate continental flooding. The maps produce global topography, bathymetry and shorelines in 1x1 degree resolution every million years from 1Ga to the present, and are validated by their cumulative production of the present day global elevation, and reproduction of preindustrial climate when used as a boundary condition in the HadCM3L general circulation climate model. The maps themselves, and the full source code, are presented freely to the community, and a large set of climate model simulations linked to the maps is in progress for open release. We hope these maps will help others to further their investigation of the palaeontological, palaeobotanical and palaeoclimatic record, and we are also interested to use emerging datasets to further assess and develop the maps themselves.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Plant-sediment interactions in early terrestrial ecosystems: evidence from the Devonian record of the UK

Annabelle Moger-Taylor* and Neil Davies
University of Cambridge, UK

The palaeobotanical record can be fragmentary due to the taphonomic biases of plants residing and being buried in oxidizing environments. However, an extended record of ancient plant life is afforded by sedimentary signatures. The above-ground parts of plants may produce vegetation-induced sedimentary structures (VISS: phenomena that reflect the interaction of plants and hydrodynamic forces) and below-ground parts may create root-related structures. However, these phenomena remain under-reported because VISS are most known from Carboniferous and younger strata, and rooting may be cryptic. Here we explore the archive of plant-sediment interactions related to the Devonian flora of the UK, enhancing the record of early terrestrial ecosystems and their evolution during this interval. We illustrate a variety of previously unrecognized VISS and rooting structures, and discuss the recognition and differentiation of the latter. By taking a holistic look at the Devonian record, plant rooting structures are shown to increase in depth, branching and

density throughout the period, across an increasing range of palaeoenvironments, reflecting expanding conditions that early plants could tolerate and influence. From the VISS record, plants capable of influencing hydrodynamic processes existed from at least the Lochkovian, but the intensity of these interactions, and their biogeomorphic influence, increased through the interval.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

The brain and sensory organs of *Shuyu* galeaspid

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Previously, fossil intracranial anatomy of early vertebrates has been inferred from the endocast of cranial hard tissues, although a *Shuyu* galeaspid specimen showed variations within the braincase. *Shuyu* specimens imaged by synchrotron radiation microtomography were re-segmented and identified two main phases of infilling. The first phase of fine-grained sedimentation preserves the shape of the soft tissues within the neurocranium at the time of infilling. The second phase of coarse sediment surrounds the neurocranium. These findings support a large organ in the nasohypophysial cavity surrounding the nasal orifice and occupying the olfactory bulbs and nasal sac. Close association to the oronasal artery supports this being an olfactory organ. The brain shape is preserved with diagenetic infilling within the fine-grained sediment. A discrete anterior cerebral artery in the right orbital cavity challenges the structure of the venous sinus which has been assumed to dominate the orbital cavities. Finally, the rostral notochord tip position just posterior to the hypophysial recess is consistent with findings in osteostracans. Critically, this interpretation highlights the value in documenting how preservations are justified to be soft tissue.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Intra-regional changes in Cambrian trilobite functional diversity during a post-extinction radiation

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The ‘Sinsk Event’ was a global mass extinction that occurred at ~ 513.5 Ma and constitutes the termination of the canonical Cambrian radiation of bilaterian metazoans. This study examines spatial and temporal changes in the functional, taxonomic and phylogenetic diversity of one of the most significant and emblematic invertebrate groups to emerge during the Cambrian – the trilobites – and compares these patterns between two regions profoundly impacted by the Sinsk Event: the Siberian Platform and South China cratons. This poster presents the initial findings of this project with a focus on spatial changes in trilobite taxonomic and functional diversity on the Siberian Platform before, during and after the Sinsk mass extinction.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Gaultness me! Reconstructing the palaeoecology and palaeoenvironment of the Gault Clay (Albian, Cretaceous) of South England

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The Gault Clay (Albian, Cretaceous) has been studied in multiple areas of South East England, chiefly on the Isle of Wight and at Folkestone. Building upon this framework, this study aimed to answer the question of what taxonomic assembles inhabited the region and how their environment appeared. To achieve this, the major localities of the Isle of Wight and Folkestone were visited, collecting varied assemblages of taxa before cleaning, preparing and identifying them. Both the Folkestone Museum and Dinosaur Isle on the Isle of Wight were visited to study their collections of Gault Clay species. From this research and surrounding literature, the water depth was identified to be on average around 150 m deep at 27-30°C. Ammonites and belemnites were found to be the most common pelagic invertebrate fauna, gastropods and bivalves were the most common benthic invertebrates, and several groups of marine vertebrates were present in the environment including ichthyosaurs and plesiosaurs. These results indicate that South East England was a warm, shallow sea capable of supporting coral, diverse invertebrate life, and forming an intricate food web for large marine vertebrate reptiles to flourish.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

A predator-prey arms race in the Mesozoic oceans

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The Mesozoic Era (252–66 million years ago) saw a major restructuring of marine ecosystems, characterized by a transition from predominantly benthic Palaeozoic communities towards more diverse, mobile marine faunas. This faunal turnover is often associated with the emergence of the Mesozoic marine revolution (MMR), a proposed period of evolutionary escalation between shallow-marine predators and their prey, characterized by increasing predation pressure and the development of defensive adaptations. Although the MMR is traditionally linked with the Late Jurassic and Cretaceous, its timing and underlying drivers remain debated, as some studies suggest it originates in the Triassic after the Permian Triassic mass extinction devasted Palaeozoic ecosystem structure. This study investigated whether the diversification of predators influenced the diversification of prey during the Mesozoic. To test this, origination and extinction rates of gastropods and bivalves were compared using cross-correlation analyses to test for temporal links between predator and prey diversity dynamics. Analyses also examined different bivalve ecological guilds, assessing whether gastropod diversification was associated with increased diversification among motile and infaunal bivalves, as predicted by the escalation hypothesis. These results provide new insights into the role of biotic interactions in shaping evolutionary dynamics that underpinned the development of modern marine ecosystems.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

How environmental conditions correlate with exceptional preservation in the Middle Cambrian depositional systems of Montana

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The middle Cambrian rocks of southwest and central Montana, USA, preserve a diverse assemblage of co-eval environments. These rocks exhibit highly variable fossil preservation, with many sections containing no fossil material, and one locality, Nixon Gulch, hosting rare soft-bodied fossils and better-preserved trilobites. Here we present new stratigraphic context, paired with geochemical redox proxies, total organic carbon (TOC) concentrations and mineralogical measurements, to reveal how palaeoenvironmental conditions relate to the opening of a unique taphonomic window at Nixon Gulch. Twelve stratigraphic sections were measured across southwestern and central Montana; eight sections were sampled for sedimentary geochemistry and mineralogic analysis. The Nixon Gulch fossil horizon was deposited in a depocentre, as indicated by the thickness of the fossiliferous interval relative to the same horizon in adjacent sections. The fossil beds at Nixon Gulch also show elevated TOC concentrations compared to other stratigraphic sections, indicating favourable conditions for greater accumulation or preservation of organic matter. No sections show evidence of redox-sensitive trace-metal enrichments (uranium, molybdenum, vanadium), indicating likely oxic to dysoxic conditions. Moderate CIA (Chemical Index of Alteration) and high ICV (Index of Compositional Variability) values in other stratigraphic sections indicate that sediment sources were weakly weathered and compositionally immature, but the Nixon Gulch fossil horizon has some of the most compositionally mature and heavily weathered sediment, likely indicating increased clay content. Combining these lines of evidence provides a holistic view of the various environments present in the middle Cambrian of Montana and how environmental factors interact to allow for the preservation of soft-bodied fossils.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Mineralogical records of complex microbial activities from the 1.8 Ga Duck Creek Formation, Western Australia

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The late Palaeoproterozoic strata host a global peak of iron formation deposition. Although a genetic link between the iron formations and microbial activities has been proposed, the identity of the microbes and the role they played in the iron deposition remain debated. Here we present a microfossil assemblage from chert samples in the ~1.8 Ga iron formation-bearing Duck Creek Formation, Western Australia. The assemblage mainly comprises filamentous microfossils preserved in growth position, exhibiting features comparable to those of younger cyanobacterial mats. Three preservational patterns are found associated with different sedimentary textures: preservation by hematite with rare goethite and stilpnomelane, forming cross-laminations in an intraclastic sample; preservation by iron-oxide minerals (goethite, hematite, maghemite and magnetite) and kerogen, with siderite grains wrapping the filaments observed in both cases, forming flat laminations and domal stromatolites; and preservation by kerogen with occasional pyritization, forming flat laminations. While previous studies attribute the preservational variation to late diagenetic alterations, we tentatively interpret

the mineralogical records as reflecting a complex microbial community consisting of oxygenic photoautotrophs, iron-oxidizing bacteria, dissimilatory iron-reducing bacteria, and sulphate-reducing bacteria, with each playing a distinct role in iron cycling.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Trichopherophyton teuchansii: getting to the root of their extinction

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The zosterophylls are an enigmatic group of early terrestrial plants. Once globally widespread, they underwent a rapid and total extinction by the end Devonian, in contrast to their close relatives the lycopsids that diversified and persist to modern day. A theory for their decline is competition with lycopsids, whose evolution of true vascular traits including roots and leaves provided an evolutionary advantage. The majority of zosterophyll remains are flattened, adpression fossils, limiting analytical techniques for exploring this. The Rhynie chert Lagerstätte in Scotland preserves the only known examples of 3D, cellular preservation of the zosterophyll *Trichopherophyton teuchansii*. Using a novel approach called digital fossil mining has allowed specimen reconstruction without the loss of morphological information typical of conventional techniques. Preliminary results indicate *Trichopherophyton* did not evolve true roots as they lack several diagnostic features including root caps. Their structure is distinct from both extant and extinct lycopsids including the co-occurring *Asteroxylon mackeii*, informing on the stepwise acquisition of rooting systems within lycophytes. Additional reconstructions of their entire rooting systems, sporangial arrangement and circinate tip development have allowed for the most complete reconstructions yet of this ancient plant as well as it's resolution in the wider lycophyte clade.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Late Oligocene–late Miocene fossil camels from the John Day Basin, north-central and eastern Oregon

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The camels from the John Day Basin in central Oregon have long been confused and misidentified, both because they are rare and highly fragmentary, and because North American camelid systematics has been chaotic for over a century. With the new revision of North American camels, it is now possible to correctly identify the higher quality specimens. Contrary to the internet and all the literature for over a century, there are no fossils referable to the Orellan-Whitneyan High Plains camel *Paratylopus* anywhere in the late Oligocene-early Miocene John Day Formation. In the Arikareean (Turtle Cove and Kimberly members of the John Day Formation), the most common camel is the nothokemadine *Gentilicamelus sternbergi*, which has been placed in many invalid

genera over the past 150 years. From the latest Arikareean Haystack Valley Member and stratigraphically higher members, we describe a new genus and species of long-nosed floridatraguline. This is the first published occurrence of the floridatragulines outside the Gulf Coast region and Central America, from Florida to Texas to Mexico to Panama. The enigmatic camel from the John Day Formation that was long misidentified as "*Paratylopus*" *cameloides* is actually a primitive protolabine, now assigned to *Michenia cameloides*. It is rare but found in the late Arikareean to Hemingfordian parts of the section. Overlying the John Day Formation is the middle Miocene (Barstovian) Mascall Formation. It yields camel fossils referable to *Procamelus occidentalis* and is the type locality of *Miolabis* "*transmontanus*" (now *M. fissidens*). The late Miocene (Hemphillian) Rattlesnake Formation at the top of the John Day section yields fossils of the giant camel *Megatylopus gigas*, and the lamine *Pleiolama vera*.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

The morphological disparity of trilobite biofacies within the Middle Ordovician of Laurentia

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Throughout the Middle Ordovician, taxonomic diversity drastically increased in an event known as the GOBE, and evidence suggests that trilobite morphological disparity saw a similar increase. However, it is the exact allocation of this diversity that remains in question. Previously, we assessed the geographic distribution of disparity within Laurentia using collection data from the Paleobiology Database, clustering collections by geographic distance and comparing the resulting morphospaces. This revealed little difference within the geographical disparity of Laurentian trilobites during this interval. For this study, the trilobite collections were clustered according to their composition, resulting in four clusters (*i.e.* biofacies). Similar to the previous geographically-based clusters, these biofacies showed little differentiation in morphospace occupation and in morphological disparity. However, the most dominant and characteristic taxa do follow a lateral, partially-overlapping trend, occupying differing regions within the morphospace. This pattern indicates that disparity is allocated between dominant taxa of biofacies, while less common taxa in all biofacies occupy similar portions of the morphospace. Our results, therefore, suggest that during the GOBE, the morphological diversity in Laurentia was partitioned following the ecological structure of the assemblages (differences in niche) rather than pure geographic structure (dispersal limitation).

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Quantifying the swimming and floating performance of extinct arthropods

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Many arthropods have evolved to inhabit the water column since the origins of this diverse clade in the Cambrian period, over 500 million years ago. However, identifying extinct taxa as water-column inhabitants requires integration of lithological and palaeobiogeographic evidence, with inferences from functional morphology and

comparisons to modern analogues. Here we present two complementary quantitative approaches for testing whether extinct macroscopic arthropods occupied the water column. The first investigates the drag and lift generated by *Tuzoia* carapaces, combining outline morphometrics with computational fluid dynamics. Although variation in carapace shape affected drag and lift forces, the inferred hydrodynamic performance is more consistent with a lifestyle close to the seafloor. The second introduces a novel approach to estimating trilobite density, focusing on the 'bubble-head' Silurian trilobite *Deiphon*. If *Deiphon*'s bubble was filled with lipids of a similar density to that found in some modern arthropods for buoyancy and energy, this animal had a specific gravity within the range of modern 'armoured hovering' zooplankton, which may represent a novel approach for adult trilobites to occupy the water column.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Who's a good fossil? Exploring the functional limits of skull evolution in domestic dogs, wild canids, and their fossil relatives

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Dogs, 'man's best friend', showcase a staggering array of skull shapes, resulting from human-driven selection. This diversity contrasts with wild species, where natural selection shapes skulls in response to selective pressures, favouring traits associated with increased fitness. Previous research has captured the morphological breadth achieved under these evolutionary forces; however, we do not fully understand how it impacts skull function. We investigate how variation in skull shape among domestic dog breeds impacts their feeding biomechanics, relative to extant and extinct canids. Using linear metrics, we calculated proxies for feeding performance in the skulls of 150 domestic breeds, 20 wild, and 10 fossil caniforms. Results reveal greater variation in biomechanical proxies among dog breeds than extant wild canids. This was primarily driven by extremes in domestic skull morphologies, especially brachycephalic (short-faced) forms, which exhibited distinct functional profiles that prioritize relatively stronger predicted bites for a given skull size. Interestingly, we observed this pattern (albeit less extreme) in fossil caniforms, specifically those belonging to 'bone crushing' Borophaginae. By contrasting artificial and natural selection in past and present contexts, we provide a glimpse into how functional constraints influence the evolution of form and function in nature and govern limits of vertebrate cranial evolution.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Quantifying the impact of exceptional preservation on Early Ordovician community ecology

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Exceptional preservation provides rare insight into the morphology and diversity of soft-bodied organisms, but its effect on reconstructions of ancient community ecology is poorly quantified. This project assesses how exceptional preservation enhances our understanding of the ecology of the Early Ordovician Fezouata Biota of Morocco by comparing exceptionally and conventionally preserved assemblages within sites. Community structure

is quantified using taxonomic diversity, specimen abundance, and estimated biovolume within ecological niches. Taxon-specific biovolumes were calculated from specimen measurements using geometric models, while differences in ecological composition were evaluated using paired tests, contingency analyses and multinomial logistic regression controlling for site. We find that exceptionally preserved assemblages occupied broader ecospace than conventionally preserved assemblages and differed in niche composition. Among >6,000 specimens from sites preserving both components, feeding mode remained strongly associated with preservation after accounting for site. Biovolume-based analyses similarly identified significant differences between preservation modes, demonstrating that exceptional taxa influence reconstructions of physical community structure. These results show that conventionally preserved sites capture a systematically restricted subset of Fezouata community structure. Therefore, exceptional preservation not only increases recorded diversity; it changes the apparent occupation of ecospace. Consequently, conventional preservation-based reconstructions may misrepresent the structure of marine ecosystems in the GOBE.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

New palaeoecological data on iberian palaeomerycids (Artiodactyla, Ruminantia) in the context of Miocene climatic changes

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The Miocene period is characterized by two significant climatic changes that determine the evolution of terrestrial ecosystems: the Miocene Climatic Optimum (MCO), a double warming peak event, and the subsequent Middle Miocene Climatic Transition (MMCT), defined by progressive cooling and the expansion of the Antarctic ice sheets. The Ebro Basin, in the north-east Iberian Peninsula, contains key sites that document these environmental shifts. Here we examine the palaeoecology and adaptive responses of the palaeomerycid *Tauromeryx turiasoensis* from the Tarazona site (14.5 Ma, biozone Db, MN5) using dental micro- and mesowear. This procedure provides important information about dietary preferences and the resources available to *Tauromeryx* during the MCO-MMCT transition. The results suggest that *Tauromeryx* had a significant browser component, but also showed flexibility in diet. It would have incorporated high levels of abrasive vegetation in an attempt to adapt its diet to the seasonal availability of resources. Data support the presence of a patchy-vegetation mosaic ecosystem in Tarazona, characterized by abundant shrub/woody-dominated vegetation interspersed with open, dry areas. Our findings highlight the value of ruminant palaeodiets for reconstructing past environmental and climatic conditions, as well as for assessing the adaptive responses and survival strategies of mammals in the face of climatic crisis.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Climatic specialization and evolutionary time shape small-mammal diversity at the global scale

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Small mammals are widely used as palaeoenvironmental and palaeoclimatic proxies because of their close association with environmental conditions and their sensitivity to climatic change. However, the extent to which small mammals are climatically specialized at the global scale, and whether this specialization is associated with their evolutionary history, remains poorly understood. Here we analysed 4,231 species of Rodentia, Chiroptera, Eulipotyphla and Lagomorpha, combining global species distributions, the Köppen–Geiger climate classification and phylogenetic information. Species were classified as climatic specialists when restricted to one of five major climatic zones, and as superspecialists when restricted to one of 30 climatic subzones. We found that 39 % of species are climatic specialists, of which 49 % are superspecialists, revealing that climatic restriction is widespread across small mammals. Climatic specialization varied among taxonomic groups and geographical regions, with particularly strong representation of murid specialists and superspecialists across tropical, arid and temperate regions. At the family level, a higher proportion of superspecialist species was associated with increased diversification rates, particularly in lineages characterized by shorter lifespans and smaller geographical ranges. However, diversification rate did not directly explain present-day species richness. Instead, family age emerged as the main predictor of species accumulation, supporting a time-for-speciation effect. These results show that climatic specialization and evolutionary time capture different dimensions of small-mammal diversity: specialization is associated with diversification dynamics, whereas evolutionary time primarily explains species accumulation. Beyond their macroevolutionary implications, these findings provide a global ecological framework for interpreting the small-mammal fossil record and reinforce the importance of explicitly considering climatic specialisation when using fossil assemblages to reconstruct past environments and climatic change.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Bigger fish to fry? An analysis of the Edmondia marine band of Brymbo, North Wales

Adam Roberts
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This research project revolves around reconstructing the palaeoenvironment and analysing the trophic interactions of a unique outcrop of the Edmondia marine band within the Upper Carboniferous Pennine Coal Measures Formation located in Brymbo, North Wales. The Upper Carboniferous of the UK shows great fluctuation in sea level, and this is represented in the geology by multiple fluctuating layers of fluvial sandstone and marine mudstone. For centuries these mudstone bands have only been used by the coal industry as they can be used to indicate the position of a coal seam, and as such the fossils contained in these bands have been historically ignored; however, systematic bulk sampling of an outcrop of the Edmondia Marine Band in North Wales has revealed a previously unknown palaeoenvironment. This shallow marine ecosystem has been shown to contain basal

tetrapodamorphs such as rhizodontids and megalichthyids, in a diverse mixture of multiple genera. Brachiopods and bivalves, unique for this time in the Palaeozoic, and a multitude of palaeoniscoid fish with evidence of predation from tetrapodomorphs they shared their environment with. This ongoing study demonstrates the unique palaeoenvironment represented by the marine bands of the Upper Carboniferous.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

The internal anatomy of Heterostraci: systematic digital reconstruction and description

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Ostracoderms (armoured jawless fish) are vital to our understanding of the stepwise acquisition of jawed vertebrate characters along the gnathostome stem-lineage. Within this group, the Osteostraci and Galeaspida have yielded detailed anatomical insights into their internal anatomy; by contrast, the internal anatomy of Heterostraci, the most diverse ostracoderm group, remains poorly understood. Despite more than 150 years of investigation, our understanding of heterostracan internal anatomy remains fragmented; characterized by isolated anatomical descriptions, conflicting interpretations, and comparisons with anatomical analogues that are often poorly constrained. Consequently, fundamental questions concerning respiration, locomotion, and sensory organization remain unresolved. To address this deficiency, here we undertake a systematic description and characterization of the internal anatomy impressions of Heterostraci. Forty-five detailed photogrammetric models have been built based on 15 fossil specimen genera of Heterostraci from collections across the globe. In doing so we have demonstrated the utility of modern texture-free 3D approaches in the identification and quantification of ill-defined anatomical structures that have been previously contentiously reconstructed over more than 150 years of research. The preliminary interpretations presented here demonstrate the potential of this approach to clarify longstanding anatomical uncertainties and provide new foundations for research into heterostracan anatomy, functional morphology, and evolution.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

A new Ediacaran chancelloriid with a sparse scleritome from the Avalon Assemblage of Newfoundland

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The Chancelloriidae are a family of obconical, saccate organisms of uncertain phylogenetic affinity, characterized by a thin integument bearing calcareous sclerites. Previously considered restricted to the Cambrian Period, chancelloriids are here reported from older strata. In this study, a new genus and species of chancelloriid is described and figured on the basis of four large specimens recovered from the Ediacaran Avalon Assemblage of Newfoundland, Canada. The new taxon is assigned to Chancelloriidae based on its obconical shape, sparse sclerites, and an ornamented integument sufficiently thin to preserve the morphological details of underlying taxa. It is distinguished from other chancelloriid

genera by prominent apical lobes surrounding the apical orifice, the dimensions of the integumental platelets, and a low density of sclerites. This discovery extends the temporal range of chancelloriids back into the Ediacaran, offering new constraints on the early diversification of this enigmatic clade during the dawn of complex animal life.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

El Soplao amber: a remarkable window into low-latitude resinous forests during the Cretaceous Resinous Interval

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The Early Cretaceous El Soplao Konservat-Lagerstätte (Cantabria, northern Spain) provides an exceptional window into resinous forests during the 54-million-year Cretaceous Resinous Interval (CREI), during which extraordinary resin production, accumulation and burial took place. Dating to the Albian, El Soplao deposit formed during the first of two major resin-production peaks recognized in the CREI, the Albian-Cenomanian and Santonian-Campanian, and represents one of the richest Cretaceous amber localities in Europe. More than 1,500 amber inclusions document a diverse arthropod community and preserve direct evidence of behaviours and ecological interactions rarely accessible in the fossil record, including predation, parasitism, pollination and arthropod-vertebrate associations. Fossils from the amber-bearing sediments complement this record, shedding light on the depositional environment in which the resin accumulated. Plant remains, charcoal and evidence of fossilized resin-sap emulsions provide further insights into the resin-producing conifers and the environmental conditions surrounding resin production. El Soplao amber documents a coastal forest ecosystem during a major transition in terrestrial ecosystems, when angiosperms were diversifying within ecosystems still largely dominated by gymnosperms. Its combined taphonomic, sedimentological and palaeobiological evidence renders El Soplao Konservat-Lagerstätte invaluable to explore terrestrial Cretaceous biodiversity and the ecological and environmental processes within resinous forest ecosystems. This work is a contribution to the project PID2022-137316NB, funded by MICIU/AEI/10.13039/501100011033 and by ERDF/EU.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Complex sensory organs of Ediacaran cnidarians

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The Ediacaran was a time when metazoans arose, 635–539 million years ago. These organisms often looked like leaves, pillows or mats; many of them did not possess organs, absorbing nutrients directly from the water or from bacterial mats on the bottom. During the later Cambrian explosion, with its diversification into all phyla we know today, spectacular visual organs, such as complex compound eyes, had evolved, triggering this evolution and prey-and-predator systems. With rising oxygen levels, the Ediacaran seemed to be a starting point for developing sensory organs. In cnidarians, we find some of them present in unaltered form still today. We describe simple mechanoreceptive organs and

primitive light sensory structures. But we also find a complex mechanoreceptive organ in principle constructed like the equilibrium organ of vertebrates, based on the same old genes, and we find even a simple lens eye, as typical for many small invertebrates of today. While the balance organ helps to stabilize the organism's position in a turbulent environment, the small eyes open a window to the outer world, establishing orientation, and suggesting initial decisions about where to go and where not to go – a basis for the establishment of conscience.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Morphological plasticity in benthic foraminifera during Palaeogene warming

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Microfossils provide a powerful archive for investigating organismal responses to past climate change. We investigated whether the magnitude, rate, and duration of warming influenced morphological plasticity in two long-lived deep-sea benthic foraminifera, the epifaunal *Nuttallides truempyi* and the shallow infaunal *Oridorsalis umbonatus*. We explored whether these taxa resisted environmental change or responded and, if so, whether they recovered or adapted. We analysed 1,337 specimens from seven ocean drilling sites spanning 600–3,600 m palaeodepth, using X-ray microtomography to quantify test diameter, surface area, volume, chamber number and derived surface-area-to-volume and chamber-number-to-volume ratios. During the rapid Paleocene–Eocene Thermal Maximum (5–10°C) and Eocene Thermal Maximum 2 (3–5 °C), both species exhibited reversible dwarfing at peak stress, although the magnitude of this response was independent of warming amplitude. Morphological plasticity was geographically and bathymetrically heterogeneous, possibly reflecting depth-linked differences in habitat and food availability driven by surface ocean processes. In contrast, diameter, surface area and volume during the prolonged Early Eocene Climatic Optimum did not recover to pre-event values within the study interval, suggesting long-term ecological or evolutionary adaptation rather than short-term plasticity. These observations offer a deep-time perspective on biological resilience and vulnerability amid ongoing global warming.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Brach to the future: soft-tissue preservation in Silurian brachiopods

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The Herefordshire Lagerstätte (Sheinwoodian–Homerian, Wenlock, Silurian) of the Welsh Borderlands is renowned for high-fidelity, three-dimensional preservation of soft tissues in organisms that are known primarily from their mineralized remains as well as entirely soft-bodied taxa. Over 30 species have been described across groups including arthropods, echinoderms and annelids. Despite this, many specimens remain unstudied, and the full potential of this exceptionally preserved assemblage is yet to be realized. Only one brachiopod, *Bethia serraticulma*, has been formally described, along with its epifauna, which includes the putative stem-group brachiopod *Drakozoon kalumon*.

Here we investigate the diversity and anatomy of previously undescribed brachiopods from the Lagerstätte. Using serial-grinding optical tomography and synchrotron X-ray phase-contrast tomography, we reconstruct several specimens, including a second rhynchonelliform from the Silurian with a pedicle. We also present the first linguliform from the Lagerstätte preserving a pedicle, chaetae and lophophore. These specimens expand the known anatomical diversity of Palaeozoic brachiopods and provide new evidence for the evolution and functional morphology of the pedicle and feeding apparatus. Their exceptional preservation demonstrates the importance of soft-tissue data for reconstructing early brachiopod biology and reveal an anatomical diversity otherwise inaccessible from the fossilized shell.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Morphology and Evolution of Early Ecdysozoans

Martin R. Smith[1], Alavya Dhungana[1], Bo Yang[1,2], Nathan Chan[1], Jaime Rodriguez Diez[3], Jie Yang[4], Xiaoyu Yang[4] and Xiguang Zhang[4]

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Palaeoscolecids, the armoured worms of the Cambrian seafloor, have been allied with priapulans, with nematomorphs, with panarthropods, and deeper within Ecdysozoa; each position carries markedly different implications for the early evolutionary history of the moulting animals. A holistic morphological matrix of 182 ecdysozoan taxa and 427 characters does not resolve this uncertainty: but a novel method that links phylogenetic support to individual characters identifies groups of traits that pull palaeoscolecids towards different phylogenetic placements. Sclerotized epidermal projections are identified as traits with particular phylogenetic potential. We document the occurrence of nested sclerotized elements across palaeoscolecids, panarthropods, and phosphatized ecdysozoans from the earliest Cambrian. The repeated occurrence of this purportedly idiosyncratic character raises deeper questions about the phylogenetic utility of distinctive character traits. To explore this question, we show how evolutionary models can be extended to distinguish evolutionary gains from losses, and from transitions of form. Applied across 69 empirical datasets, these models demonstrate a pervasive evolutionary trend towards secondary losses, potentially explaining the erratic distribution of 'diagnostic' characters across the ecdysozoan tree.

Wednesday 9th December, Poster Session 1, Mathematical Institute, 12:30–13:00.

Integrating microfossils and palaeoenvironmental data from Late Ordovician Lagerstätten localities for ecosystem reconstruction

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Small carbonaceous fossils (SCFs) are fragile organic microfossils that provide evidence of small, non-mineralized organisms, providing a key window into ancient ecosystems. Recent studies on SCFs, mainly from Cambrian clastic palaeoenvironments, have illuminated early animal diversification; however, fewer studies have examined SCFs in Ordovician rocks or considered their environmental context. Northern Manitoba in Canada yields carbonate

strata preserving non-mineralized macrofossils, deposited over a short time interval during the Late Ordovician (Katian). We developed a method to extract SCFs from carbonate samples and applied it to collections from two of these sites: Cat Head and Airport Cove. To date, over 6,000 microfossils have been counted from 10 stratigraphic intervals at Cat Head and over 540 microfossils from Airport Cove. These collections will be the basis for statistical analyses of SCF diversity across stratigraphic successions at each locality. Rock samples from each interval were also analysed using microfacies analysis to correlate sedimentological changes and fossil assemblages. Integrating these data, we will reconstruct these Ordovician ecosystems and relate changes in diversity and environment. Future application of these methods at other sites will establish a more accurate representation of life during the Great Ordovician Biodiversification Event, while emphasizing the significance of SCFs in carbonate systems.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

The royal fish? Multiple possible fates for historical sturgeon catches in Britain

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Historical archives contain important information-content for informing species conservation and reintroductions. Here we investigate a unique historical archive spanning the fourteenth to twentieth centuries – royal records – and assess its relevance for understanding sturgeon *Acipenser* spp. exploitation and extirpation from the British Isles, where sturgeon are now being considered for reintroduction. Sturgeon were declared a 'royal fish' by the English monarchy in 1324, meaning sturgeon caught in British waters were legally required to be offered to the Crown. We compiled, for the first time, a total of 58 records from the Kew, Berkeley Castle, Windsor Castle, Plymouth and Gloucestershire Archives, from 1303 to 1991. These royal data document the exploitation of sturgeon for at least six centuries, with the last sturgeon reported offered to the Queen in 1991. We extracted information about sturgeon capture localities and seasonality, length and weight, and cost. We also gathered data from an existing extensive newspaper database of sturgeon catches to analyse the outcomes for sturgeon (*e.g.* if sent to the Crown or sold). We then used generalized linear models (GLM) to assess which factors (*e.g.* sturgeon size, distance from Buckingham Palace) most likely influenced sturgeon outcome. This unique historical archive highlights the typology of data that exists for 'royal' species and offers conservation-relevant insights for a potential reintroduction of sturgeon to the British Isles.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Power laws in fossil abundance, cross-recurrence analysis and biostratigraphic correlation of critical events

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The causality of critical evolutionary events is reconstructed by synchronizing or correlated spatially distributed geological sections. Graphical correlation, and its various extensions,

is a general approach for the quantitative stratigraphical correlation based on the first and last appearance events of index species (FADs and LADS), as well as other unique events such as metabentonites or named stable carbon isotopic excursions. The major impediment for the accurate correlation of stratigraphical sections is the incompleteness or, more generally, the complex structure of the fossil record. Here we explore the effects of abundance of conodonts on the precision of correlation through the Late Silurian Lau Even in the Baltic Basin. The detection probability of species varies wildly due to the heavy-tailed nature of abundance distributions. This results in a 'spotty' distribution of rare index taxa and the low consistency of their FADs and LADs at high (tens of Ka) resolution. The correlation using cross-recurrence plots (time ordered self-similarity matrices of similar states) which utilizes the total compositional and temporal patterns of species distributions shows surprisingly high accuracy even in the face of high number of barren samples or large lacunas in fossil detection. This study was supported by the Research Council of Lithuania project S-MIP-24-62.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Protein-templated crystallization of authigenic minerals: a route to the molecular controls on exceptional fossilization

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The fossil record is biased towards organisms with hard parts, so reconstructing the early evolution of soft-bodied life depends on exceptional preservation. In Burgess Shale-type preservation, soft tissues are replicated by kaolinite. We have shown experimentally that decay releases organic acids and then ammonia in sequence, generating chemistry conducive to aluminosilicate precipitation. These precipitates are amorphous, unlike the crystalline kaolinite that possesses the antibacterial properties that arrest decay. We hypothesize that repetitive arrangements of amino acid side chains in protein can template crystalline kaolinite. We tested this with FD-15, a *de novo* protein complementary to the calcite (104) face1. Expressed in *E. coli*, FD-15 directed rhombic calcite at 15 mM $CaCl_2$ and $NaHCO_3$, conditions that otherwise yield metastable vaterite and aragonite, demonstrating polymorph control by templating. Extending this to aluminosilicates, we used deep-learning sequence design to optimize rotamer selection for precise side-chain placement against the kaolinite (001) surface, narrowing ~5,000 designs to 25 candidates now in precipitation experiments. Structure-based proteome searches test whether comparable motifs are widespread across eukaryotes or restricted to particular clades, and hence whether some lineages are intrinsically more likely to fossilize. Together these establish structural motif-to-crystal relationships as a framework for geobiology.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Shapes of the deep: AI-driven shape analysis of fossil and extant dogfish shark teeth

Kim J. Stroben[1]*, Arianna Salili-James[1,2] and Jürgen Kriwet[1,2]
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Quantitative shape analysis is a powerful tool for comparing similar biological forms, as qualitative description alone may not always fully capture taxonomic information. This is especially relevant in palaeontology, where taxa identification is complicated by incomplete preservation. Elasmobranchs have a skeleton which rarely fossilizes and a continuous tooth replacement, resulting in a fossil record dominated by isolated teeth. Therefore, taxa identification within groups that have highly similar tooth morphologies, like Squaliformes (dogfish sharks), is difficult. Here, outline-based elastic shape analysis is combined with supervised and unsupervised classical machine learning to evaluate tooth-shape variation in fossil and extant squaliform sharks. Extant teeth were digitally isolated from micro-CT scans before outlines were automatically extracted from isolated tooth images using computer vision and deep learning tools. Placing fossil and extant teeth in a shared morphospace highlights possible overlaps between fossil and living taxa, as well as clustering patterns in shape variation. Identifying such patterns enables taxonomic identification of isolated fossil teeth and helps evaluate shark diversity over time, while promoting convergence between qualitative descriptions and quantitative shape analysis

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Bearing stress is an impressive 'feet': a comparison of known perissodactyl foot conditions to the unknown anchitheriin foot

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There are two known foot conditions in extant perissodactyls: the monodactyl spring-foot and the polydactyl pad-foot. The pad-foot of living tapirs and rhinos is assumed to be the basal foot condition for perissodactyls, whereas the spring-foot evolved in derived equids. A branching monophyletic group of large, browsing equids, the Anchitheriini, survived alongside grazing equids into the Late Miocene. Anchitheriins have historically been reconstructed with a pad-foot; however, they lack osteological correlates associated with both spring-foot and pad-foot morphology. As such, anchitheriins may have possessed a novel perissodactyl foot condition. This study applies finite element analysis (FEA) and second moment of area analysis to the proximal phalanx of anchitheriins, horses, tapirs and rhinos, to compare anchitheriin foot locomotor stresses and bending resistance to those of spring-foot and pad-foot species' performance. We found that stress results were partitioned by foot condition, with especially low stress present in anchitheriins. Lowest resistance to bending was found in pad-foot taxa and a similar resistance to bending in anchitheriin and spring-foot taxa, despite low stress present in anchitheriins. We interpret this divergence in performance as indicative of a unique perissodactyl foot condition in anchitheriins, perhaps analogous to the unguligrade stance without a spring-foot of extant suids.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

How to make a dwarf elephant: dental allometry in *Stegodon* (Mammalia: Proboscidea)

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Insular dwarfism evolved repeatedly among proboscideans, and *Stegodon* exhibited substantial body-size reduction across islands in Southeast Asia and Japan. However, how body-size reduction affected *Stegodon* dentition remains poorly understood. Here we investigate dental scaling relationships across *Stegodon* to examine how tooth morphology varies with body size and how it compares to patterns observed in other insular proboscideans. We compiled linear measurements from dental specimens representing a range of *Stegodon* taxa and body sizes to assess scaling relationships. Preliminary analyses reveal strong and generally conserved relationships among linear dental dimensions. Relationships between crown length and enamel thickness, and between crown width and lamellar length, remain broadly consistent across body-size groups. In contrast, complexity-related traits diverge more. Extreme dwarf taxa possess comparatively higher plate counts for equivalent crown lengths, while continental forms generally exhibit wider and thicker ridges. The clearest differentiation is observed in hypsodonty: extreme dwarfs consistently show elevated hypsodonty indices, whereas continental forms remain predominantly brachydont. These results suggest that dwarfing in *Stegodon* was not simply proportional reduction. While fundamental dental dimensions retain conserved scaling relationships, dental complexity and hypsodonty diverged with body size, offering insight into the morphological pathways underlying insular dwarfism in *Stegodon*.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Development of the mandibular arch sinus in *Alligator mississippiensis* and its evolutionary implications for non-avian theropods

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Many non-avian theropods exhibit osteological signatures of a paratympanic sinus system but tracing homologies throughout the clade is difficult due to variable expressions of sinuses in surrounding bones. Developmental studies in extant archosaurs (birds and crocodylians) are crucial for understanding their evolutionary history but remain limited. The mandibular arch sinus – pneumatic extensions into the quadrate and articular – is understudied in crocodylians and only recently described in birds. Multiple pneumatic foramina in the quadrate obscure the diverticulum's origin and relationship to the foramina. We present mandibular arch sinus development in embryonic *Alligator mississippiensis* using three-dimensional reconstructions from contrast-enhanced CT data. We find that development of a discrete posterior extension, extending into the articular at a later stage, is associated with the formation of the two pneumatic foramina on the posterior quadrate surface. These foramina are consistently present among extant crocodylians whereas other quadrate foramina are variable. This suggests the posterior extension may be conserved among extant crocodylians. The posterior extension in *Alligator*, developing before quadrate ossification, occupies a similar location to pneumatic fossae in many non-avian theropods. We compare developmental patterns of a mandibular sinus in *Alligator* and birds, and discuss factors underlying differences in sinus expression across archosaurs.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Beyond resemblance: testing anatomical hypotheses in flattened fossils near the origin of vertebrates

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Exceptionally preserved fossils can reveal soft tissues, but once an animal has been flattened, decayed and chemically altered, identifying those tissues becomes difficult. How can we tell what a structure really was, rather than simply what it resembles? Using Cambrian yunnanozoans as a case study, we test anatomical interpretations by asking whether structures occur in the same place across specimens, retain consistent shapes and internal features, and show evidence of their original composition. This approach supports the interpretation of structures around the pharynx as a cartilagious skeleton, long internal structures as major blood vessels, and repeated paired structures back in the body as kidney-like filtering organs. These examples show that even heavily flattened fossils can preserve reliable information about internal anatomy and how competing interpretations can be tested using independent lines of evidence. This offers a broader way to study the early evolution of complex body systems near the origin of vertebrates.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

The neurovascular system and tooth growth habits in the dentary of *Neovenator salerii* from the Barremian, Wealden Group (Wessex

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Internal craniomandibular canals serve as osteological correlates for thermoregulatory mechanisms and somatosensory systems within the vertebrate head. An intricated neurovascular system is widespread in theropod dinosaurs and its degree of complexity may be used to infer different ecomorphological patterns. Barker *et al.* (2017) described the neurovascular system in the upper jaw of the allosauroid *Neovenator salerii*, concluding that an enhanced facial sensitivity functioned for diverse behavioural schemes and was not necessarily related to a semiaquatic lifestyle. Here we investigated the internal osteology of the left dentary of *N. salerii* (MIWG 6348) through µCT scanning, providing a complete overview of its craniomandibular neurovascular system. Preliminary qualitative results returned an inferior alveolar canal morphologically consistent with that of the upper jaw, characterized by laterally branching, anastomosing canals with an increasing topological complexity towards the snout tip. Additionally, a medial alveolar canal (MAC) is reported in *N. salerii* for the first time. This osteological feature is shared only with a carcharodontosaurian from Uzbekistan. Nonetheless, the MAC in *N. salerii* is more complete and its alignment with the dental alveoli may be relevant in understanding theropod tooth replacement pattern and blood supply to perioral soft tissues.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Skeletal remains of a jalodontid chrondrichthyan from the Upper Triassic Arden Sandstone Formation of Warwickshire, UK

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[1]University of Birmingham, UK; [2]Keele University, UK; [3]Warwickshire Museum, UK

Skeletal fossils of chondrichthyans are exceptionally rare, limiting knowledge of their anatomy, evolution and ecology. The Triassic is particularly important for understanding the transition from Palaeozoic to modern chondrichthyans, yet few Triassic chondrichthyan skeletal fossils are known. Here we use computed tomography to describe six chondrichthyan skeletal fossils from the Carnian (Upper Triassic) Arden Sandstone Formation of Warwickshire, UK, including a partial braincase, jaws, pectoral fin radials, caudal fin hypurals, and dorsal fin basal cartilages. The braincase and jaws are assigned to the jalodontid *Keuperodus brodiei*, previously known only from teeth from the same formation, while the post-cranial remains are tentatively referred to the same taxon. These specimens represent the first articulated chondrichthyan skeletal remains known from the Upper Triassic and the first cranial cartilages of Jalodontiformes. The braincase exhibits basicranial circulation largely embedded within the basicranium, while the elongate jaws resemble those of Palaeozoic phoebodontids. Phylogenetic analysis places *K. brodiei* as a stem-elasmobranch closely related to phoebodonts. Its occurrence in freshwater lake shorelines and associated fluvial channels suggests a freshwater refugium for Jalodontifomes at the end of their stratigraphic range, providing a new example of a Palaeozoic chondrichthyan lineage surviving into the Triassic, forming components of Mesozoic ecosystems.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

More than a century of discoveries: revisiting Portuguese Miocene macroflora research in the Lisbon region

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The Lisbon region, on the western coast of Portugal, preserves a diverse Miocene plant macrofossil record that has been studied for over a century and has provided valuable information on the region's palaeogeography, palaeoenvironmental and palaeoclimate conditions. In this context, a historical overview of the macroflora discovered and studied to date is presented, integrating updated palaeobotanical data with new photographic documentation. The first descriptions of plant fossil macroremains from Lisbon were published in 1881, resulting in the identification of 27 fossil-taxa. Subsequent studies reported all known fossiliferous sites and updated the existing knowledge, recognizing 18 fossil-taxa by 1976. One century after the original study, 34 fossil taxa, including four new taxonomic combinations, were identified based on the investigation of new localities and the re-evaluation of previously described specimens. Following this work, seven additional fossil discoveries from the southern margin of Lisbon were documented in 1999. Based on the literature, this work recognized a total of 47 fossil taxa from the Miocene of the Lisbon region, while the taxonomic combinations proposed in 1981 require substantial nomenclatural revision. This synthesis brings together 145 years of palaeobotanical research and provides an updated overview of the taxonomic history of the Miocene macroflora of the Lisbon region.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

One grain, two microscopes: redefining the taxonomy of *Notothylacites filiformis* using the single-grain method

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Taxonomic identification of fossil pollen and spores is often limited by resolution of light microscopy (LM) and by the difficulty of correlating observations made with different imaging techniques. The single-grain method overcomes this limitation by allowing an individual grain selected and documented under LM to be transferred and re-examined under scanning electron microscopy (SEM). This method preserves the specimen, while revealing surface features that may remain invisible in LM. Combined LM–SEM analysis can distinguish superficially similar morphotypes, separate taxonomic diversity from morphological variation and refine botanical affinities. We demonstrate the value of this approach for revising historical palynological material. Single-grain analysis of Late Cretaceous spores from Czechia revealed previously hidden ornamentation in *Notothylacites filiformis*, supporting its hornwort affinity and helping resolve a long-standing taxonomic problem. Reassessment of the associated material separated the original fossil into the hornwort *N. filiformis* and the new liverwort *Ricciopsis pacltovae*. These examples demonstrate how single-grain analysis can substantially improve taxonomic precision in palaeopalynology.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Morphological variation in carnivoran vertebral shape reflects aquatic adaptation

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The functional and ecological morphologies of the carnivoran vertebral column have been well studied, including the use of individual vertebrae shapes to predict ecology and lifestyle. While aquatic capability is known to influence vertebrae shape, exactly how much vertebral morphology reflects degree of aquatic adaptation is less clear. In particular, the atlas (C1) and axis (C2) of the cervical region have been neglected in most studies even though they may provide important biomechanical and ecomorphological information. We examine the effects of aquatic adaptation on carnivoran vertebral morphology and morphological disparity, and how these vary along the presacral vertebral column. Taking a 3D geometric morphometric approach, we use auto3dgm in 3D Slicer to automatically place landmarks on 3D meshes of 14 vertebral elements (seven cervical, four thoracic, three lumbar) from various taxa (species $n \leq 61$ for each vertebra). After Procrustes alignment, we performed PCAs on each element to visualize these taxa in morphospace, classified by their phylogeny and ecology. Degree of aquatic adaptation is reflected in vertebral shape, with the strength of this signal varying along the presacral column. This is also shown in morphospace occupation, with terrestrial taxa displaying greater disparity than more aquatic taxa.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

The role of sampling bias in the diversity and diversification of anseriform birds through deep time

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The avian fossil record is highly uneven in taxonomic, geographic and temporal coverage, making it difficult to distinguish genuine macroevolutionary patterns from sampling artefacts and to evaluate 'rocks-versus-clocks' discrepancies in the timing of crown-bird divergences. This is particularly relevant for Anseriformes (waterfowl), whose Cenozoic fossil record is comparatively rich but taxonomically and spatiotemporally heterogeneous. We compiled a global occurrence dataset of fossil Anseriformes (~230 species, 588 occurrences) from the Paleobiology Database and primary literature, with standardization of taxonomy, stratigraphic assignments and geographical information. Using coverage-based rarefaction and extrapolation to reconstruct diversity, alongside preservation plus speciation/extinction rates estimated in the Bayesian program PyRate, we assessed how sampling bias influences estimates of richness and turnover. Occurrences cluster in the late Neogene–Quaternary and geographically in Europe and North America. Raw richness peaks in the Pleistocene but closely tracks sampling effort; once standardized, the maximum shifts to the Late Miocene. Speciation and extinction rates remain near-constant across the Cenozoic, while sharp Holocene shifts reflect edge effects rather than biological signal, which we are addressing by incorporating past occurrences of extant species. This work will be extended across Aves and integrated with ecomorphological data to place modern avian biodiversity loss in a deep-time context.

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Who lived at Gray Marjum? Disentangling local ecology from transport in a Cambrian Konservat-Lagerstätte

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The Gray Marjum Biota is an abundant and taxonomically diverse assemblage of soft-bodied Cambrian animals comprising more than 87 species from the Miaolingian Marjum Formation of Utah, USA. As in many Konservat-Lagerstätten, a substantial proportion of this fossil material is thought to have been transported away from where the organisms lived before final burial. The extent to which the assemblage retains a local ecological signal, however, remains unresolved. To address this problem, 7 m of fossiliferous strata at Gray Marjum were sampled at 10 cm intervals to construct a bed-by-taxon community matrix. Q-mode factor analysis was applied to identify recurring compositional groupings among intervals and the taxa characterizing each factor. The taxa characterizing each group was then evaluated using independently recorded taphonomic evidence such as types of tissues preserved, fragmentation and disarticulation. Groups of taxa dominated by taxa whose specimens consistently exhibit little taphonomic damage are interpreted as representing organisms that lived within, or relatively close to, the environment of final deposition. More heavily damaged components are interpreted as carrying a stronger signal of transport. A cyclostratigraphic age model was also used to estimate the duration represented by each 10 cm interval, allowing changes in community composition, taxon abundance and diversity to be investigated through time. This approach provides a quantitative means of separating ecological structure from transport-generated associations

without treating the total fossilized assemblage as a single community. More broadly, it offers a framework for recovering local ecological information from exceptionally preserved deposits in which substantial transport is suspected.

Thursday 10th December, Poster Session 2, Mathematical Institute, 12:30–13:00.

Traditional vs geometric morphometrics in theropod tooth form and function

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The use of elliptical Fourier analysis in palaeobiological research has allowed for the visualization of form variation in complex structure and has replaced traditional morphometric techniques. Teeth are vital in most vertebrates for feeding, with variance in form influencing functional properties. Theropod dinosaurs arose during the Triassic and radiated to occupy a plethora of niches and are highly diverse in tooth form. However, using elliptical Fourier analysis demonstrates large overlaps in theropod tooth form, which contradicts traditional morphometrics studies. We aim to compare elliptical Fourier analysis to traditional tooth measurements using a Bayesian generalized linear mixed model to analyse non-avian theropod tooth form and function. We detected significant differences across most niches when analysing tooth measurements, while only herbivores and carnivores were significantly distinct in elliptical Fourier analysis. Additionally, tooth measurements indicated that increasing tooth tip thickness decreases puncturing and cutting stress, whereas elliptical Fourier analysis displayed the inverse. Traditional morphometrics can be directly attributed to specific aspects of shape, whereas elliptical Fourier analysis captures overall shape variance, resulting in difficulty linking the aspects of form associated with function. Therefore, we conclude that traditional morphometrics is more suitable for studying the relationships between form and function.

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New insights into the Callovian positive carbon isotope excursion from brachiopod geochemistry and microfossils

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The Middle Jurassic represents an important period in the evolution of marine life, marking a global peak in rhynchonellid brachiopod diversity, and major restructuring of marine plankton assemblages. The evolution of brachiopods and plankton has been related to changes in ocean chemistry and climate. However, our understanding of Middle Jurassic environmental conditions and their link to evolutionary events remains poorly understood. This study aims to increase our understanding of the link between Middle Jurassic environmental change and evolution by examining the geochemical composition of well-preserved brachiopods from the Euro-Boreal and Ethiopian province spanning the Bathonian-Callovian stages. We present new carbon, oxygen, boron and strontium isotope records, which are used to reconstruct the carbon cycle, temperature, CO_2 and weathering, respectively. These are used in conjunction with Paleobiology Database microfossil

occurrence data from these provinces to gain a better overall understanding of the impact of environmental conditions on Western Tethys diversity across the Bathonian–Callovian.

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Cnidarian polyps from the basal Cambrian: exoskeletal secretion and construction

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Small shelly fossils (SSF) from the basal Cambrian of China provide a crucial window into the early stages of animal diversification. The Kuanchuanpu Formation (Shaanxi Province) is particularly rich in SSF, including abundant and exceptionally three-dimensionally preserved cnidarians. These are represented by diverse groups of sessile, epibenthic polyps that secreted protective exoskeletons (periderms), including carinachitids, olivooids, hexangulaconulariids, and numerous forms of uncertain affinities. Although generally millimetric in size, carinachitids can reach up to 1 cm in length. Our project aims to investigate how these early cnidarians secreted and constructed their periderms, and to characterize their organic and/or biomineralized composition using SEM, micro-CT, and detailed comparisons with extant polyps, particularly scyphozoan coronates. We focus on the layered architecture of the periderm and its potential homologues in extant cnidarians. A second objective is to clarify the phylogenetic relationships between these early cnidarians and major extant lineages using cladistic analyses, with the broader goal of reconstructing early cnidarian evolution across the Precambrian–Cambrian transition. Finally, we investigate the emergence of exoskeletal features as potential adaptive strategies for feeding, anchoring, and anti-predation in response to major ecological changes in early Cambrian marine ecosystems.

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Quantitative evaluation of feeding performance in the first apex predators

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Radiodonts, the earliest macropredators to flourish during the Cambrian Explosion, exhibited a diversity of feeding modes such as filter feeding, predation and benthivory. The paired frontal appendages are informative to their feeding mechanisms, such as long endites with fine spines in filter feeders versus trident-shaped endites in predators. However, morphology-based qualitative assessment can only provide a rough classification of feeding strategies in radiodonts. Here, computational and experimental analysis provides a methodological basis to assess different feeding strategies of radiodonts, and evaluate how inherent uncertainties such as muscle and material properties impact their biomechanical analyses. A combination of 3D kinematics, finite element analysis and physical experiments using static models was applied to quantify the grasping, crushing and filtering ability of radiodont appendages. Kinematics suggests that flexibility in basal part and appendage morphologies such as large proximal spine greatly affect the feeding behaviour and prey selection, while physical experiments of filtering appendages could examine the influence

of multi-segmented appendages on filtering food, and finite element analysis of raptorial appendages could reveal the importance of morphologies like large spine and uncertainties to crushing ability. This work will reveal the different ways in which radiodonts exploited food resources in the Cambrian.

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Isotopes and teeth: $\delta^{18}O$ paints the picture of the earliest land vertebrate ecosystems

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In this study we present oxygen isotope compositions of fossil teeth from three different species of Late Devonian tetrapods from Latvia, Pavāri site, South Timan, Sosnogorsk site, and North Timan, Volonga River locality. All three localities are associated with diverse fish fauna that we have also sampled. High-precision $\delta^{18}O$ compositions were obtained *in situ* using secondary ion mass-spectrometry and exclusively targeted the enamel, composed of bioapatite most resistant to post-mortem alteration. Secondary and minor element concentrations were mapped using energy dispersive X-ray spectroscopy to assess the preservation state of the targeted fossil tissues. Similarly, we analysed $\delta^{18}O$ in the enamel or enameloid from several contemporaneous fish as a palaeoenvironmental and palaeobiological control. We found that the $\delta^{18}O$ signal in all the fish showed an unambiguous freshwater signal in both Timan sites, even though they had different lifestyles and phylogenetic relationships. Fish from Latvia displayed $\delta^{18}O$ values corresponding to brackish environments, yet consistent within each taxon. The tetrapod signal was quite different, demonstrating the value of isotope analysis for distinguishing ecological-environmental patterns at taxon level, going beyond the collective association of the entire fossil assemblage with a particular environment of deposition to illuminate the actual lifestyles of these animals.

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