Progressive ***Pal***aeontology 2017

LEICESTER

1st - 3rd June

Abstract Booklet

WELCOME

Hello and welcome to Progressive Palaeontology 2017 in Leicester! We are delighted to host this annual gathering of up and coming palaeontological minds from around the world, bringing together exciting new research that spans the wide breadth of our field. We hope that you will find this to be an engaging and stimulating scientific conference, and we hope you enjoy your stay in this historic city.

Leicester, and the surrounding Leicestershire, has a rich palaeontological pedigree. *Charnia masoni*, discovered in Charnwood Forest in 1958, was the first Precambrian macro-organism to be described. You'll be able to see the *Charnia* holotype and other spectacular fossils from around Leicestershire in the fantastic Dinosaur Gallery at the New Walk Museum during the Icebreaker reception.

The conference is held within the Department of Geology, which boasts a wide spectrum of geological interests. Research from the Palaeobiology, Palaeoenvironments and Palaeoclimates group alone spans the entire Phanerozoic, with research ranging from pioneering techniques using tooth microwear to constrain diets of a plethora of extinct organisms, disgusting work studying the effect of taphonomy on the fossil record, novel techniques using small shelly fossils to constrain Cambrian environmental conditions and cutting edge research investigating the human impact on the geological record, defining a new period of Earth's history: the Anthropocene.

Your *ProgPal* 2017 committee have endeavoured to convene a lively and thought-provoking meeting and we hope you enjoy your time here. This conference would not have been possible without our numerous benefactors. We would like to thank all those who have supported us, either financially or by giving up their time, to help make *ProgPal* 2017 possible; particularly the Palaeontological Association and the University staff and students who have assisted us. Finally, we'd like to thank all of you, the delegates, for attending. *ProgPal* is a marvellous, fun and friendly forum for post-graduates to meet and demonstrate their research. We hope your experience in Leicester at #ProgPal17 will keep up this proud tradition.

The Progressive Palaeontology 2017 Organising Committee:

Tom, Jordan, Yasmin, Chris, Michael & Thomas

The Palaenotological Association

Reg. Charity No. 1168330

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

Membership is open for students for just £15 a year. In return, members receive the Association's newsletter, online access to the PalAss journals *Palaeontology* and *Papers in Palaeontology,* a discount on Field Guides and eligibility for Association awards and grant schemes including the Postgraduate Travel Fund.

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

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

Dr Jo Hellawell
Executive Officer, The Palaeontological Association

COMMITTEE

Co-chair - Jordan Bestwick

Jordan is a second year PhD student investigating the diets of pterosaurs (Mesozoic reptiles which flew above the heads of dinosaurs). Away from the PhD, Jordan is your typical nerd, immersing himself in all things Star Wars, Doctor Who and Spider-man.

Co-chair - Tom Hearing

Tom is a third year PhD student at the University of Leicester and the British Geological Survey. His research focuses on examining Cambrian marine environments, mostly through micropalaeontology. However, it's not all work and Tom also enjoys occasional kayaking and swing dancing.

Finance Officer - Yasmin Yonan

Yasmin is a graptolite from the Early Silurian, currently in her second year of a PhD examining anthropogenic ocean sediments and how plastics can be identified in the stratigraphic column. Outside of university she enjoys drawing, climbing and evolving really fast into charizard. Her preferred mode of transport is longboard.

Secretary - Chris Nedza

Chris is a first year PhD student arriving somewhat late to the palaeo party having first completed a degree in photography. Research interests include the diet and diversification of early mammals, and is currently working on pigmentation in early vertebrates. Don't let him near your fish…

Field Trip Officer - Michael Morton

Michael is a second year PhD student studying the sedimentary processes involved in the deposition of Russian mudstones and their source rock potential. After hours he enjoys the sweet amber nectar of traditional real ale and rambling in the national parks of Britain. Alternatively you'll find him tinkering with his car or slapping a burger on the BBQ.

Social Media Officer - Thomas Clements

Thomas' PhD focuses on taphonomy and rotting carcasses in order to understand the proceses of fossilisation. He loves Lego, playing hockey and is a little too obsessed with cephalopods.

Volunteers - William Crabbe, Robert Goodall, Jonathan Lees, Emily Mason, Leah Nolan and Muhammad Aqqid Saparin

VENUE

ProgPal 2017 is being hosted in sunny* Leicester. Birthplace of Walkers crisps, the UK National Space Centre and package holidays from Thomas Cook. Leicester is a vibrant and fun city that has hit the headlines in recent times. An archaeological team, led by the University of Leicester, unearthed the remains of King Richard III, the last Plantagenet King of England, from a car park in the city centre. The RIII visitor centre is well worth visiting and is only a 15 minute walk from the university. Those of you from planet Earth may also be aware of the success the small local football team had last season… Leicester City won the Premier League against overwhelming odds of 5000–1! This was a famous sporting triumph that shook the world media and, indeed, the surrounding area – Leicester University's 'VardyQuake' team employed a seismometer network to record the magnitude of celebrating fans – a literally ground shaking experience!

ProgPal 2017 is being held in the University of Leicester's Bennett Building which was built in the early 1960s. Named after Frederick William Bennett MD BSc (1858 – 1930), a local surgeon and keen amateur geologist, who, along with subsequent family members, donated large sums of money to the University - specifically the Geology Department. The building is home to the Geography and Geology departments, but more importantly, the only juvenile *Tyrannosaurus rex* in Europe. 'Jane', named after a benefactor of the museum that discovered the skeleton and not the animal's sex, is a cast of the most complete (50%) juvenile *Tyrannosaurus* ever found. 'She' stands at 2.3m tall at the hip, is 6.4m long, weighed around 950kg and was approximately 11 years old at time of death. Part of the 'flying dinosaurs – the origin of birds' exhibition, which has numerous stunning fossils including a Cretaceous feather in which fossil pigments were first discovered. 'Jane' is the mascot and centre point of the department and a firm favourite with visitors and students. She is a keen fan of selfies, although she has very short arms, so you may have to hold the camera!

*Terms and Conditions apply

GETTING HERE

BUS OR COACH

If you are travelling to Leicester by bus or coach you will arrive at St Margaret's Bus Station in the city centre. You'll be able to get a bus from St Margaret's Bus Station to the University:

- The **no.48** bus, operated by Arriva, leaves St Margaret's every 15 minutes and takes about ten minutes to reach the University. (NB. The return journey is the no.47.)
- The **no.80** bus, also Arriva, leaves St Margaret's every 30 minutes and continues past the University to the Halls of Residence in Oadby. When returning, be aware that the 80A operates largely the same route but does not go to the railway station or city centre.

TRAIN

Leicester lies on the London-Sheffield and the Birmingham-Stansted lines. Approximate journey-times and frequencies of trains are:

- From London (St Pancras station):70-90 minutes/four times an hour
- From Birmingham (New Street station): 60 minutes/twice an hour
- From Luton (Airport Parkway station): 60 minutes/hourly
- From Stansted Airport: 2 hours 30 minutes/approximately hourly

You can get to the University on foot in 15 minutes, by turning left outside the station, walking up London Road and then turning right along University Road. From the railway station you can also catch the number 48 or 80 bus service which runs from outside the station to the University.

CAR

The University's postcode is LE1 7RH. You can access the campus via University Road. Parking on campus is very limited but there are several car parks nearby.

TAXI

There is a taxi rank at the railway station and outside St Margaret's bus station. The fare should be between £5 and £12.

PLANE

We are close to several major airports with good bus and train connections to Leicester.

FURTHER INFORMATION

Further information can also be found at the back of this booklet or on the University's maps and directions webpage:

http://www.le.ac.uk/maps

CONFERENCE

Registration

Main registration will take place in the University of Leicester Bennett building foyer from 13:00 - 17:00 on Thursday 1st June and again on the morning of Friday 2nd June. See the back of the booklet for a map and floorplan of the building. Delegates will be able to collect their welcome pack and name badge. Whilst not compulsary, in order to promote communication between delegates, it is advised you wear your name badge whilst in the university buildings.

Icebreaker

The Icebreaker will commence at 18:00 in the Dinosaur Gallery of the New Walk museum. Refreshments will be provided. This is a great opportunity to catch-up with old acquaintances and make new friends, all whilst enjoying the many palaeontological wonders on display at the museum. Afterwards the committee will gladly direct you to any local publican should you wish to continue socialising.

Presentations

Presentations will be held in Lecture Theatre One (G26) of the Bennett building. The entrance to the lecutre theatre is located in the main foyer as you enter the Bennett building (see floorplan at the back of this booklet). Committee members and ProgPal volunteers will be on hand to direct you.

There will be four oral sessions and one poster session. Oral sessions will contain several Full talks, with Lightning talks at the end of each session. Both Full and Lightning talks are eligble for prizes (committee members excluded). Members of the committee will chair and judge the sessions. Full talks are 12 minutes plus 3 minutes for questions, while Lightning talks are 4 minutes with 1 minute for questions. In order to ensure the day runs smoothly we kindly ask speakers to adhere to the schedule and to keep to time.

Posters will be available to view throughout the day on Friday 2nd June in the lower ground floor attrium in the Bennett building. Committee members and volunteers will be on hand to direct you if needed. Alternatively see the floorplan at the back of this booklet. Posters should be A0 portrait and printed in advance. Posters can be put up on the Friday morning or alternatively in the first coffee break, and then removed at the end of the day. Adhesive will be provided. The designated poster session is at 15:00 on the Friday, but you are welcome to view them at any time. During the poster session, authors are asked to stand with their poster.

Live Streaming

Talks will be live-streamed by Palaeocast at palaeocast.com. If you do not want your talk streamed or recorded please inform the committee in advance.

Social Networking

I'm sure you have all been following our Facebook page and Twitter feed, if not it is a great way of keeping up-to-date with what's happening. We encourage tweeting of the conference using #ProgPal17, but we ask you be mindful of other people's data when using social networks, in particular when taking photographs.

T-shirts

We will be selling *ProgPal* 2017 t-shirts (designed by Leicester Geology undergraduate Emily Mason) for £5 throughout the conference. Stocks are limited so get in early to avoid disappointment!

Lunch

We will be providing lunch for delegates in the foyer at 12:40. Please feel free to browse the posters during lunch.

Wi-Fi

Wi-Fi is available throughout the university campus via Eduroam. Automatic connection should be available by delegates from participation universities. Otherwise, temporary access can be arranged by connecting to "_TheCloud" - you'll need to make an account for this, but it is free to use on campus.

Travel Grants

Thanks to last year's auction and the success of this year's crowdfunder we are pleased to annouce that we have been able to award a total of 11 travel grants for delegates, including 5 for international delegates. We would like to thank all who contributed, with special thanks to the following for their generous donations:

Alan Spencer
Paul Smith
Dave Marshall
Tom Hearing
Emily Rayfield
Blair Steel

Annual Dinner

The conference dinner on Friday evening is held at Everest Dine, the award winning Indian and Nepalese restaurant (61 Belgrave Gate, LE1 3HR; see map at back of booklet for guidance). You can make your own way there, or follow the committee shuttle. A member of the committee will leave the University of Leicester Bennett Building foyer (where the main conference is) at 18:30, going via the Railway Station at 18:45 and the city centre clock tower at 18:55 and arriving at Everest Dine just after 19:00.

The conference dinner starts at 19:30, with doors open from 19:00 to give people chance to buy a drink from the restaurant bar beforehand. If you cannot remember what you ordered the committee will have a list to hand so please come and ask one of us.

Wine and soft drinks will be provided on each table at the start of the meal, although you can buy additional drinks from the restaurant bar which is open all evening.

The annual conference auction directly follows the dinner and we have some real star pieces up for grabs this year. From museum-quality 3D prints to palaeo-themed garments, exclusive palaeoart and some chocolate treats, there is something for everyone. Make sure to raid those piggy banks before the auction so you don't miss out!

Workshops

The workshops will run on the afternoon of Thursday 1st June from 14:00 - 17:00 in G72 on the ground floor of the Bennett Building, University of Leicester. Conference volunteers and committee members will be on hand to guide you through the building. Tea, coffee and biscuits will be provided throughout the afternoon. Desks are equipped with electrical sockets if you wish to bring a laptop/tablet to the workshop.

We have two workshops during the afternoon.

An introduction to statistical hypothesis testing in palaeontology: 14:00 - 16:00, with Professor Mark Purnell (University of Leicester) and Dr Duncan Murdock (University of Oxford).

Prior to starting postgraduate research, most palaeontologists receive little if any formal training in statistics, but our discipline is increasingly quantitative as data from all aspects of the fossil record becomes more readily acquired and analysed. This workshop aims to introduce statistical hypothesis testing in a practical and easy to follow way, in an informal setting. We will cover: the basics of how to understand and explore your data; what assumptions you make about your data; how you can identify similarities and differences between samples; how you can quantify relationships and find trends in data; and common pitfalls to look out for. This workshop is aimed at anyone with little or no experience of statistics. It will very much be an introduction, and does not require knowledge or access to any particular software. The Q&A session will provide an opportunity for you to discuss any problems you might be having in your own work.

How to survive and thrive the peer-review process: 16:15 - 17:00

This workshop will serve as an interactive seminar on the processes and importance of peer-review in scientific publishing, and some things that editors and reviewers look out for. This workshop is led by Dr Sally Thomas, Publications Officer for the Palaeontological Association, and Professor Sarah Gabbott from the University of Leicester and editor of Palaeontology. You are advised to come armed with questions.

TIMETABLE

Thursday 1st June

13:00 - 17:00	Registration at the Univeristy of Leicester, Bennett Building foyer
13:00	Tea and Coffee for early arrivals
14:00	Statistics workshop with Mark Purnell and Duncan Murdock
16:00	Tea and Coffee Break
16:15 - 17:00	"How to Survive the Peer Review Process" with Sally Thomas & Sarah Gabbott
18:00 - 20:00	Icebreaker at the New Walk Museum, Dinosaur Gallery

Friday 2nd June

Session 1

08:20 - 08:45	Arrival and put up posters
08:50	Welcome by the committee
09:00	Omar Rafael Regalado Fernandez New phylogeny of Basal Sauropodomorphs using the super-matrix approach
09:15	Klara Nordén Were herbivorous dinosaurs in decline before the K-Pg extinction?
09:30	Thomas Clements Is a 'one size fits all' taphonomic model appropriate for the Mazon Creek?
09:45	Susana Gutarra Diaz Using computational fluid dynamics to study the hydrodynamic performance of fossil marine reptiles
10:00	Virginia L. Harvey Investigating Species Identity and Chronological Frameworks Using Mass Spectrometry on Ancient Collagen
10:15	Richard Howard LTA total evidence approach to understand scorpion evolution
10:20	Christopher Stocker LTThe Silurian and Devonian proetid trilobites of Japan: a biogeographically or ecologically isolated fauna?
10:25	Bence Szabó LTVariability and predictibility of tooth microwear patterns along the dentil of ungulates
10:30	Richard Dearden LTThe earliest known three-dimensionally preserved chondrichthyan branchial skeleton in the Early Devonian acanthodian *Ptomacanthus anglicus*
10:35	Tea and Coffee Break

Session 2

11:05 Catherine G. Klein
A long fuse: molecular evidence for a delayed emergence of modern squamates

11:20 Emma Dunne
Terrestrial Tetrapod Diversity and Biogeography Across the Carboniferous/Permian Boundary

11:35 Christina Shears-Ozeki
Terrestrial bioeroders from the Early to Late Cretaceous in Morocco and the Isle of Wight.

11:50 Alfio Alessandro Chiarenza
Virtual taphonomy and ecological niche modelling to estimate dinosaur diversity in the latest Cretaceous of North America

12:05 Elspeth Wallace
Palaeoecology and Taphonomy of Microvertebrates from the Hell Creek Formation, northwest South Dakota, USA

12:20 David Marshall
[LT]The palaeoecology of the eurypterid genus *Acutiramus*

12:25 Emma Landon
[LT]The first discovery of crinoids and cephalopod hooklets in the British Rhaetian

12:30 Rebecca Bennion
[LT]Tooth morphology and niche partitioning of the Lower Jurassic ichthyosaur fauna of Dorset and Somerset.

12:35 Tiffany Slater
[LT]Examining intrarelationships of bullhead sharks (Chondrichthyes: Heterodontiformes) using cladistics and molecular analyses

12:40 Lunch and posters

Session 3

13:25 Valentina Rossi
Morphology and trace element chemistry of melanosomes as tools for interpreting fossil vertebrate soft tissue

13:40 Aodhan O Gogain
Ontogeny in *Ophiderpeton brownriggi* (Lepospondyli: Aïstopoda) revealed through CT-scanning and 3D modelling; implications for aïstopod evolution and ecology.

13:55 Andrew Jones
Continuous cladistics: a three-pronged attack on phytosaur phylogeny

14:10 Ryan Marek
Grabbing evolution by the throat: functional regionalisation of the avian cervical column

14:25	Rowan Dejardin A micropalaeontological and geochemical palaeoceanographic record of the deglacial and Holocene from the sub-Antarctic island of South Georgia.
14:40	Eva Herbst LTFunctional Morphology of *Crassigyrinus scoticus*: Gaining Insight into Locomotor Evolution in Early Tetrapods
14:45	Adam Woodhouse LTDeath in the oceans: extinction risk in the marine realm
14:50	Hebert Bruno Nascimento Campos LTDrilling pterosaur bone: An invertebrate burrow from the early Late Cretaceous Santana Formation, NE Brazil
14:55	Pedro Godoy LTHeterochrony in hypercarnivorous baurusuchids (Crocodyliformes, Notosuchia) revealed by cranial shape variation
15:00	Poster Session with Tea and Coffee

Session 4

15:45	Christopher Dean No missing molluscs?: Investigating spatial aragonite bias in epicontinental seas
16:00	Daniel Cashmore Completeness of the global non-avian theropod fossil record
16:15	Alexander Askew Irregular depositional dynamics in Northern Spain during the Middle Devonian: evidence from a detailed palynological analysis
16:30	Robert Brocklehurst Osteological correlates of lung structure and breathing mechanics in archosaurs
16:45	Stephen Pates A quantitative analysis of the frequency and location of repaired injuries on Cambrian (Stage 4 and Drumian) trilobites from three sites in the Iberian Chains, Spain
17:00	Steven Zhang LTReappraising the Evolution of the Elephantidae
17:05	Kilian Eichenseer LTFickle oceans – the influence of temperature and Mg/Ca ratio on marine calcifiers
17:10	Christopher Nedza LTReconstructing the distribution of pigmented tissues in river lamprey (*Lampetra fluviatilis*) using three-dimensional serial histological sections
17:15	Thank you and closing statements
17:20	David Marshall The Virtual Natural History Museum
17:25	Next year's host
19:00 - 23:00	Dinner Reception and Auction

Saturday 3rd June

08:00 - 18:00 "Silurian Saunter" field trip – with Professor Mark Williams

TALK ABSTRACTS

Talk abstracts are presented here.[LT] indicates lightning talk. * indicates presenting author. For author contact details please see the delegate list.

Session 1

New phylogeny of Basal Sauropodomorphs using the super-matrix approach

Omar Rafael Regalado Fernandez[1*], Paul Upchurch[1], Paul M. Barrett[2], Philip Mannion[3], Susannah Maidment[4], Anjali Goswami[1]

[1]University College London; [2]Natural History Museum, London; [3]Imperial College London; [4]University of Brighton

Sauropodomorph dinosaurs represent the first radiation of herbivorous dinosaurs and comprise the Sauropoda and taxa traditionally referred to Prosauropoda. After 15 years of studies, some degree of prosauropod paraphyly has become widely accepted. A near-comprehensive phylogeny is presented here after the compilation and revision of all previously published phylogenetic data matrices and characters of basal sauropodomorphs (following standardisation of character statements and their consistent application to all taxa). Specimens from Germany, China, and England have been assessed first-hand. The revised data matrix, comprising 783 characters and 77 taxa, was analysed in TNT. After demonstrating that there is a difference between the topologies based solely on discrete characters and on discretized continuous characters, we assessed the impact on the topology of using continuous data. This new phylogeny provides a better framework for understanding the anatomical modifications towards quadrupedality. Anchisauria shows a trend towards quadrupedalism, and a core 'Prosauropoda' comprising Massospondylidae+Plateosauridae, indicates that bipedality was well-established in this part of the tree. Riojasauridae, previously placed within the obligate quadrupedal clade Melanorosauridae, is retrieved here as either the sister taxon of or at the base of, Anchisauria. The development of an anterolateral process of the ulna was convergent with that in melanorosaurids, and the reduced fourth trochanter and the transversely broad ilium is convergent with features present in quadrupedal ornithischians. Quadrupedality originated at least twice within Sauropodomorpha and most of the taxa traditionally referred to as 'prosauropods' were bipeds.

Were herbivorous dinosaurs in decline before the K-Pg extinction?

Klara Nordén[1*], Thomas L. Stubbs[1], Albert Prieto-Márquez[2] and Michael J. Benton[1]

[1]University of Bristol; [2]Field Museum of Natural History

Despite decades of research, the question of whether dinosaurs were in decline before the K-Pg extinction is still a contentious issue. Analyses of disparity change have so far lagged behind diversity studies, yet these can offer a more ecologically relevant perspective. Here we measured disparity of herbivorous dinosaur jaws and teeth throughout the entirety of the Cretaceous using discrete characters. By including 194 species of sauropods and ornithischians, using three disparity metrics and fine time divisions, this study is the most detailed to date of herbivorous dinosaur disparity trends throughout the Cretaceous. Our results suggest that the disparity of herbivorous dinosaurs was not declining towards the end of the Cretaceous. However, in contrast to the Santonian (86.3-83.6Ma), which shows an expansion in morphospace volume, the Campanian and Maastrichtian (83.6-66Ma) display high levels of morphospace packing. This indicates that successful groups such as hadrosaurids and neoceratopsians were diversifying in species numbers faster than in tooth and jaw morphology. Although disparity was not declining in the Maastrichtian, neither was it unusually high compared with the rest of the Cretaceous. The Aptian-Albian (125-100.5Ma) reached similar levels of disparity, despite a lower diversity. This study adds nuance and fresh insights to a topic that is often discussed in dichotomous terms, and shows that, regarding ecological diversity, herbivorous dinosaurs were neither declining nor at their peak before their

final extinction 66 Ma. Rather, the Cretaceous disparity trends reflect patterns tied to the emergence and radiation of new clades – initial morphospace expansion followed by morphospace packing.

Is a 'one size fits all' taphonomic model appropriate for the Mazon Creek?

Thomas Clements[1*], Mark Purnell[1] and Sarah Gabbott[1]

[1]University of Leicester

The Late Carboniferous Mazon Creek Lagerstätte (Illinois, USA) is a world-renowned fossil deposit containing a huge diversity of preserved flora and fauna. It is widely considered to represent the most complete Late Carboniferous river delta ecosystem preserving organisms from numerous habitats including coastal swamps, brackish lagoons and oceanic environments. These fossils demonstrate exquisite soft tissue preservation yielding far more information that the 'normal' skeletal fossil record, while some unique soft bodied animals are only known from this locality. However, constraining a 'one-size fits all' taphonomic model for the Mazon Creek is challenging because of our poor understanding of sideritic concretionary formation or preservation (i.e. the copious presence of unfossiliferous concretions), the vast geographical area, the influences of salinity during burial and the subsequent complicated diagenetic processes. To determine the preservational pathways of Mazon Creek fossils, the mode of preservation of 'major' morphological characters for key groups of fossil organisms found in this Lagerstätte was compiled, then used to test for variance in preservational mode between taxa and between specific tissue types. More detailed investigations into 'complete' character sets across specific taxa with large n (ie. polychestes), geochemical investigations on geographically disparate concretions and decay experiments have been utilised to elucidate the taphonomic biases operating on this Lagerstätten. Our analysis indicates that there are variations in preservation potential of specific characters shared by taxa; modes of preservation, generally, are consistent across taxa. For the first time, this will allow a detailed taphonomic model to be created for Mazon Creek Lagerstätte.

Using computational fluid dynamics to study the hydrodynamic performance of fossil marine reptiles

Susana Gutarra Diaz[1*], Benjamin C. Moon[1], Imran A. Rahman[1,2], Stephan Lautenschlager[1,3], Alison J. Brimacombe[1] and Michael J. Benton[1]

[1]School of Earth Sciences, University of Bristol; [2]Oxford University Museum of Natural History; [3]School of Geography, Earth and Environmental Sciences, University of Birmingham

Ichthyosaurs, sauropterygians and mosasaurs, were iconic marine reptiles that thrived in the Mesozoic seas, where they became apex predators. The selective pressures imposed by the physical constraints of water lead to adaptation of their bauplans to optimise locomotion. Understanding the principles that governed the evolutionary success of these fossil animals is a challenging endeavor that has been hindered by the lack of an objective, physics-based method for testing functional morphology hypotheses. Computational fluid dynamics (CFD) is a state-of-the art engineering technology that applies the principles of fluid dynamics to the simulation and prediction of the behavior of fluid flows, their interaction with solid bodies and the resulting forces. Here I present a case study in which the hydrodynamic properties of various species of ichthyosaurs are analysed by means of CFD. Using 3D modelling techniques, full-body digital reconstructions are created to use in the fluid simulation experiments, where drag and lift forces are obtained. The results demonstrate that changes in the body plan of ichthyosaurs did not contribute to drag reduction, contrary to what classically had been suggested. However, there is an evolutionary decrease in the lift coefficient, which is plausibly related to the control of buoyancy. This case illustrates the great potential of CFD for addressing questions about form and function in a rigorous and reproducible way. Building upon this experimental strategy, we aim to evaluate the degree of functional convergence in hydrodynamic performance in the most derived species of Mesozoic marine reptiles, and also between these and aquatic mammals.

Investigating Species Identity and Chronological Frameworks Using Mass Spectrometry on Ancient Collagen

Virginia L. Harvey[1*], Victoria M. Egerton[2], Andrew T. Chamberlain[1], Phillip L. Manning[1,2] and Michael Buckley[1]

[1]School of Earth and Environmental Sciences, The University of Manchester; [2]Department of Geology and Environmental Geosciences, College of Charleston, South Carolina, USA

Collagen is the dominant organic component of bone, a ubiquitous biomaterial that dominates the fossil and archaeological vertebrate record. The triple-helical structure of the collagen molecule enables it to intimately lock itself within the mineral phase of bone, making it the most likely protein to be found in fossilised tissues. The interrogation of collagen via molecular methods such as soft-ionisation mass spectrometry provides an invaluable means of obtaining species identification in ancient bone, which unlocks whole proportions of vertebrate bone assemblages otherwise rendered useless in the absence of morphological characteristics or ancient DNA. This research showcases the collagen fingerprinting technique, Zooarchaeology by Mass Spectrometry (ZooMS), as a tool used to assess ancient bone assemblages for species presence or absence, across a chronological framework. Firstly, ZooMS is successfully utilised as a screening mechanism for identifying bones that are suitable for radiocarbon (^{14}C) dating, due to its ability to provide information on the presence and quality of collagen. ZooMS is thereafter applied to hundreds of ancient bone samples from cave systems on Cayman Brac (Cayman Islands) to determine faunal composition, and to report on its application in the establishment of a biodiversity 'catalogue' to expose species presence and abundance throughout the zooarchaeological record. The results here uncover evidence of ecological changes through time on Cayman Brac, including extinction and extirpation events. Such evidence carries the capacity to assist in the direct protection of ecosystems and habitats that are fundamental to the maintenance of biodiversity on the Cayman Islands and beyond.

LTA total evidence approach to understand scorpion evolution

Richard Howard[1*], Jesus Lozano-Fernandez[1], David Legg[2], Gregory Edgecombe[3] and Davide Pisani[1]

[1]University of Bristol; [2]University Museum of Natural History, Oxford; [3]The Natural History Museum

Living scorpions are exclusively terrestrial and probably originated in the Mesozoic. However, several extinct Palaeozoic stem lineages have been described, many of which are of contentious marine (or at least semi-aquatic) habit, and have long caused confusion regarding the nature of arachnid terrestrialization and ancestral diversification more broadly. To clarify these processes, there is a need to marry fossil and extant scorpions in a common macroevolutionary framework, utilizing state of the art advances in phylogenetics. Total evidence dating – wherein both molecules and morphology (from both extant and fossil lineages) are incorporated into a single analysis has emerged as a way of circumventing methodological issues in reconstructing the evolutionary history of clades. Under this framework is possible to simultaneously generate phylogenetic hypotheses and estimate divergence times between clades without constraining the phylogenetic position of fossils. Utilizing this approach, we seek to clarify the evolutionary history of scorpions, with particular focus on understanding the macroevolutionary transition to a terrestrial mode of life of arachnids.

LTThe Silurian and Devonian proetid trilobites of Japan: a biogeographically or ecologically isolated fauna?

Christopher Stocker[1*], Philip Lane[2], Derek Siveter[3], Simon Wallis[4], Tatsuo Oji[5], Thijs Vandenbroucke[6], David Siveter[1], Gengo Tanaka[7], Toshifumi Komatsu[8], Jan Zalasiewicz[1] and Mark Williams[1]

[1]University of Leicester; [2]Keele University; [3]Oxford University Museum of Natural History; [4]Nagoya University; [5]Nagoya University Museum; [6]Ghent University; [7]Kanazawa University; [8]Kumamoto University

The trilobite Order Proetida is widely represented in the Silurian and Devonian strata of Japan, with taxa described from the South Kitakami, Hida Gaien and Kurosegawa lower Palaeozoic terranes. Revision of other Japanese trilobite groups, most notably Illaenida, Scutelluidae and Phacopidae, has extended the biogeographical ranges of several Japanese trilobite taxa but has not provided conclusive

evidence of a consistent biogeographical signature. In part this may relate to the temporally and spatially fragmented Palaeozoic record in Japan, and perhaps also to the different ecological ranges of the trilobites. We present a taxonomic revision of all previously described proetid trilobites from Japan, which comprises some 22 species within 9 genera and 6 sub-genera. These trilobites suggest an endemic signal at species level, not just between Japan and the other East Asian terranes, but also at the level of the individual Japanese terranes: only one species, the Devonian Dechenella minima, occurs across all three terranes. However, this dominance of endemicity may be explicable in terms of the facies range and ecology of the proetids, rather than being only a function of biogeographical isolation.

LT Variability and predictibility of tooth microwear patterns along the dentil of ungulates

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Dental microwear analysis has become one of the most important methods in assessing the diet of extinct animals. The method is widely utilised for diverse groups such as conodonts, dinosaurs, mammals, and so on.Despite this wide usage, of some methodological issues still remained. One of these problems is the fact that tooth microwear analysis was developed for the upper and lower second molars of mammals, however these teeth represent only a small part of the chewing apparatus, and in many cases they are scarce in the fossil assamblages. So a question arises: is it possible to use the microwear pattern observed on the other molars and premolars of mammals to asses their diet?To test this the complete dentil of eight specimens from three extant ungulate species from the Mammalia Collection of the Hungarian Natural History Museum (*Capra caucasica, Caperolus capreolus, Cervus elaphus*) were sampled. For the sampling high, resolution epoxy casts were made from the cleaned surface of the teeth. The number of scratches and pits were calculated on 0.4×0.4 mm areas on each cast on two different positions if it was possible. The acquired microwear data was analyzed with mixed models where specimens were chosen as random factors and the position of the tooth was chosen as a fix factor. The results suggest that the microwear pattern observable on the surface of premolars and molars (other than M2, m2) are comparable to that on the surface of the second lower and upper molars.

LT The earliest known three-dimensionally preserved chondrichthyan branchial skeleton in the Early Devonian acanthodian *Ptomacanthus anglicus*

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Branchial arches - the series of skeletal struts that support the gills - are a potentially rich source of comparative morphological characters with which to understand the early evolution of gnathostomes (jawed vertebrates) during the Paleozoic. However, taphonomic processes rarely leave the delicate branchial arches with their spatial relationships intact, and sampling is restricted largely to the two internal gnathostome crown-groups - cartilaginous (chondrichthyan) and bony (osteichthyan) fishes. Recent efforts to broaden this with the Palaeozoic chondrichthyan *Ozarcus* have led to an osteichthyan-like interpretation of the plesiomorphic gnathostome gill skeleton. However, this data conflicts with reconstructions of the stem-chondrichthyan *Acanthodes* – itself subject to several conflicting interpretations. This combined with phylogenetic uncertainty surrounding *Ozarcus* leaves our sampling of the chondrichthyan stem-group indecisive. Here we use computed tomography scanning to image the pharyngeal skeleton of the Early Devonian stem-chondrichthyan *Ptomacanthus anglicus*, revealing the earliest articulated three-dimensionally preserved branchial skeleton known in a crown-gnathostome. *Ptomacanthus* possesses a basihyal articulating directly with the ceratohyals and the first branchial arch, consistent with some reconstructions of *Acanthodes* and numerous other gnathostomes. In contrast to the stem-gnathostome *Paraplesiobatis* and some osteichthyans wherein they contact one another, the posteriormost two branchial arches are separated ventrally. This unambiguous branchial architecture in a stem-chondrichthyan suggests that gnathostomes plesiomorphically had a single basihyal and no separate hypohyals, and that ventrally separate posterior branchial arches may constitute a chondrichthyan synapomorphy.

Session 2

A long fuse: molecular evidence for a delayed emergence of modern squamates

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Squamates (the reptilian group including snakes, lizards, and amphisbaenians) are thought to have diverged from their closest relatives near the Permo-Triassic boundary (roughly 251 million years ago). However, their fossil record is depauperate until the Cretaceous–over 100 million years later–producing extensive ghost ranges on phylogenies. Consequently, little is known about the early evolutionary history of squamates. The oldest definitive fossils of crown squamates are Jurassic in age. Previous molecular clock estimates suggest that crown squamates originated near the Triassic-Jurassic boundary (~200 million years ago). Here, we used Bayesian inference methods to assemble phylogenies with a wide selection of squamate taxa, and performed relaxed molecular clock analyses. Our results reveal that crown squamates may have originated later than previously estimated. 10 outgroup taxa and up to 44 calibration points were used in our molecular clock analyses, as multiple outgroup taxa and numerous calibration points have been shown to be important for well-informed divergence time analyses. Uncorrelated and autocorrelated molecular clock models were compared, but all analyses suggest that the deepest divergences within squamates may have occurred in the Middle to Late Jurassic. This result is consistent with an emerging pattern of mid-to-late Jurassic vertebrate radiations, which have thus far been illustrated in mammals, dinosaurs, and pterosaurs. This congruence supports the idea that the Jurassic was an important period of diversification and evolutionary innovation.

Terrestrial Tetrapod Diversity and Biogeography Across the Carboniferous/ Permian Boundary

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During the Carboniferous and Permian (359-252 million years ago) the first terrestrial tetrapod ecosystems were established against a backdrop of major environmental change. Disagreement continues to surround the major patterns of tetrapod diversification across this interval, stemming from the ongoing debate on the importance of spatial and temporal sampling biases in the fossil record. Previous estimates of tetrapod diversity across the Carboniferous/Permian boundary suggest that tetrapod communities were significantly affected by the late Carboniferous Rainforest Collapse (CRC). However, these studies failed to account for temporal and spatial variations in sampling. A new global species-level dataset (465 species from 380 unique localities) has been created within the Paleobiology Database. Our analysis of species richness and alpha diversity reveal a fluctuating pattern distinct from previous estimates showing a continuous rise in taxonomic diversity across this interval. Subsequent analyses that attempt to correct for sampling indicate that sampling biases strongly affect our ability to decipher genuine patterns of diversity change during this interval, particularly in the Carboniferous. To further examine the effect of the CRC on tetrapod communities, we used a newly-devised biogeographical network method which uses phylogenetic data to quantify biogeographic connectivity between distinct geographic regions. Our results do not support the previous hypothesis that habitat fragmentation drove endemism following the CRC; instead cosmopolitanism increased markedly across the Carboniferous/ Permian boundary. Our analyses highlight the caveats associated with estimating Paleozoic terrestrial tetrapod diversity and serves as a cautionary tale on the impact of sampling for future analyses during this era.

Terrestrial bioeroders from the Early and Late Cretaceous of Morocco and the Isle of Wight, England

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Post mortem processes subject bones to various deleterious effects, all of which can be responsible for significant information loss during fossilisation. Some of these processes are biological in origin and the result of infestation by both macro and micro-organisms. We examined various bones, mainly of dinosaurs, exhibiting borings and surface scratches recovered from the non-marine Early Cretaceous Wessex Formation, Isle of Wight (Barremian) and the Early-Late Cretaceous Kem-Kem beds (?Albian-L. Cenomanian) in south east Morocco. Our aim was to evaluate the role of bioeroders in the taphonomy of ancient fluvial systems. Evidence of bioerosion although obvious in some examples, does not appear to be common. In the Kem Kem beds we identified borings most likely attributable to coleopteran and isopteran insects, bite marks from macro predators/scavengers and surface scratches of uncertain origin. Vertebrate bite marks were also found in the Wessex Formation, but boring by insects seem rare. Branched, anastomosing microbial borings perhaps attributable to fungi (e.g. *Mycelites* sp.) appear common in the Wessex bones but are unrecorded in the Kem Kem beds. Our approach - comparing the record of surface borings and scratches in different assemblages - could help to identify palaeoclimatic conditions prevelant in a variety of palaeo river settings.

Virtual taphonomy and ecological niche modelling to estimate dinosaur diversity in the latest Cretaceous of North America

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The latest Cretaceous (Campanian and Maastrichtian) is a pivotal time interval capturing the lead-up to the K-Pg mass extinction, 66 Ma ago, which killed off the non-avian dinosaurs. Palaeodiversity trends during this time of dramatic environmental change are important for understanding this mass extinction, but these are masked by geological and anthropogenic sampling biases. Digital elevation models and palaeo-climatic envelopes were used for evaluating the impact of environmental agents on the spatial distribution of the fossil record. A HadCM3 coupled global climatic model was run in order to provide model outputs of several physical parameters (e.g. temperature and precipitation) during these Cretaceous stages. These palaeo-geographic and palaeo-climatic data were used to model basin drainage analysis, producing predictive maps of lithofacies suitable for fossilisation and compared them with published interpretations of dinosaur bearing formations. Using this virtual habitat approach, we calculated total genus richness of each taphofacies to estimate palaeodiversity loss in unsuitable areas. Dinosaur occurrences (>4100) for Hadrosauridae, Ceratopsidae and Tyrannosauridae have been over imposed to past climatic and geographic envelopes and elaborated with the Maximum Entropy algorithm. We produced a series of ecological niche models for these Late Cretaceous dinosaur taxa with a projection in the Danian. The results show a niche contraction for all the three clades of Dinosauria after the K-Pg event. Habitat modelling and plotting estimated variation in niche ranges and contraction could be an alternative proxy of biodiversity variation through time instead of other traditional methods (raw time bin analyses, subsampling diversity curves, etc.).

Palaeoecology and Taphonomy of Microvertebrates from the Hell Creek Formation, northwest South Dakota, USA

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Microvertebrate fossils are essential in the understanding and reconstruction of past ecosystems. It is necessary to adopt a broad approach to microvertebrate accumulations to determine the palaeoecology of the complex ecosystems they represent. Newly discovered microvertebrate localities in the Hell Creek Formation of northwest South Dakota have been analysed through a multiple-taxa approach. 287 fossils have been identified, described and assigned a taphonomic grade in order to discover the composition, structure and diversity of the assemblage. Mammals, reptiles and birds comprised the studied taxa. The relationships between taphonomic grade and skeletal elements preserved, taphonomic grade and species, and species and skeletal elements preserved have been analysed through correspondence analysis. Analysis of the preserved ecosystem has then been undertaken. Stratigraphic data suggests the assemblage has been preserved within channel lag and flood deposits. Amphibia, squamata and mammalia are taphonomically best preserved. Of the preserved taxa, amphibia are most abundant. Amphibia and squamata are commonly preserved as vertebrae, mammalia as teeth and aves as bone fragments. The preserved ecosystem has therefore been interpreted as parautochthonous, having undergone limited transport and time-averaging before final burial. The microfauna inhabited a variety of trophic levels, however the trophic structure of the preserved ecosystem is skewed. This is due to a lack of preserved primary consumers and an overabundance of secondary consumers. Comparison of these results to related palaeoecological data has revealed these sites are among the most taxonomically rich ever studied, thus demonstrating their palaeoecological significance.

[LT]The palaeoecology of the eurypterid genus *Acutiramus*

David Marshall[1*]

[1]University of Bristol

The pterygotid eurypterid *Acutiramus* has been the subject of two recent palaeoecological reconstructions, both of which cast doubt over the traditional consideration of this genus as hyper-predatory. In the first instance, the chelicerae of *Acutiramus* were subjected to a biomechanical analysis. Having been attributed with the material strength of the carapace of the horseshoe crab *Limulus*, its claws were modelled using simple engineering equations. The resulting calculations suggested that the chelicerae would not have possessed the mechanical strength to pierce similarly-armoured prey. It was therefore concluded that *Acutiramus* was likely a predator of soft-bodied organisms, a scavenger or even consumed plant material. A subsequent study presented a similar palaeoecological interpretation based on a study of its visual systems. In it, a method for estimating the acuity of flattened apposition compound eyes, through an innovative application of trigonometry, was presented. Having established this, palaeoecological inferences were then drawn through comparison with living arthropods. *Acutiramus,* was demonstrated to possess relatively poor resolution eyes, a trait inconsistent with other highly-visual predatory arthropods, and was suggested to have an ecology comparable to that of *Limulus*. Here, the emerging consensus of *Acutiramus* as a poor predator is challenged. In both instances, it can be demonstrated that the methods used were limited in their application and relied on comparisons with poor anatomical or ecological analogies. Investigations into the visual ecology of apposition compound eyes and chelicerate cuticular structures reveal many overlooked factors consistent with a hyper-predatory lifestyle.

[LT]The first discovery of crinoids and cephalopod hooklets in the British Rhaetian

Emma Landon[1*], Christopher Duffin[2], Claudia Hildebrandt[1], Thomas Davies[1], Michael Simms[3] and Michael Benton[1]

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The Late Triassic Rhaetian stage is perhaps best known in south-west Britain for the bone beds of the Westbury Formation, but there are other fossil-rich horizons within this and the underlying Blue Anchor Formation. Samples from a borehole drilled at the Filton West Chord, and collected from exposures near

Bristol Parkway railway station, have yielded significant fossil material from both formations, including an unusual occurence of a 'Rhaetian-type bone bed' within the Blue Anchor Formation. The borehole samples have produced the first recorded evidence of crinoids in the British Triassic, and the first evidence of coleoid cephalopods from the Rhaetian and from the British Triassic, in the form of grasping hooklets.

LT Tooth morphology and niche partitioning of the Lower Jurassic ichthyosaur fauna of Dorset and Somerset.

Rebecca Bennion[1*], Aubrey Roberts[1], Jessica Lawrence Wujek[1]

[1]University of Southampton

Great abundance and diversity of marine reptiles are known from the Mesozoic, especially from Lower Jurassic localities in Southern England. However, little work has been done on the division of niches and trophic levels between these diverse groups. This study aimed to investigate and quantify the niche differentiation between ichthyosaur taxa from localities in Southern England, particularly Lyme Regis and Street. Measurements of tooth and jaw characters were recorded from photographs as well as from museum specimens. Specimens were classified according to a new guild system combining those of previous studies. PAST software was used to run bivariate and PCoA analyses to highlight differences between feeding ecologies and to determine if the proposed guilds are statistically valid. Results show significant overlap between species of *Ichthyosaurus* suggesting niche partitioning occurred on other scales besides tooth morphology. There is evidence for a potential ontogenetic niche shift in this genus as well as in the species *Temnodontosaurus platyodon*. The functional significance of the overbite teeth in *Excalibosaurus* and relatives is considered, with the conclusion that no living or extinct marine vertebrate with a similar morphology is a perfect ecological analogue. Overall it was concluded that the guild system does have some merit for showing patterns in tooth morphology, however a tooth guild is not the same thing as a niche, and guilds should be assigned to teeth not whole animals.

LT Examining intrarelationships of bullhead sharks (Chondrichthyes: Heterodontiformes) using cladistics and molecular analyses

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[1]University of Worcester; [2]University of Vienna

The evolution of modern sharks, skates, and rays (Neoselachii) is largely enigmatic due to the small window of opportunity for fossilisation of their cartilaginous skeleton, resulting in a preservational bias towards isolated teeth. Sharks underwent rapid diversification in the Jurassic and by the end-Jurassic all modern clades were established. Bullhead sharks (Heterodontiformes) occupy a basal position within Neoselachii, their remains amongst the oldest in the neoselachian fossil record. Heterodontiformes contain three genera: †*Proheterodontus* and †*Paracestracion* disappear from the fossil record before the Cretaceous while *Heterodontus* underwent further radiation. This study investigates the intrarelationships of Heterodontiformes. Elucidation of their phylogenetic relations helps inform key questions regarding the extinction of †*Paracestracion* and the success of *Heterodontus*. 113 morphological characters were used to investigate intrarelationships within the genera †*Paracestracion* and *Heterodontus* using parsimonious methods (TL=61; CI=0.9016; RI=0.9062). A time-dated maximum likelihood phylogeny was then produced using molecular data to examine intrarelationships of extant *Heterodontus*. Our results suggest that †*Paracestracion* and *Heterodontus* were slightly different in their ecomorphotype. Thus, *Heterodontus* was potentially more successful in food acquisition during oceanic regressions and a minor extinction of invertebrates in the end-Tithonian. Additionally, crown heterodontids diverged in the middle Eocene likely due to a reduced equator-to-pole temperature disparity in the Atlantic Ocean. This study highlights the fragility of sharks in pelagic waters as ocean acidification and increased temperatures continue to influence coastal ecosystems.

Session 3

Morphology and trace element chemistry of melanosomes as tools for interpreting fossil vertebrate soft tissue

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Melanosomes are important components of integumentary tissues in modern vertebrates and have been reported from various vertebrate and invertebrate fossils ranging in age from the upper Palaeozoic to the Cenozoic. Much previous work on fossil melanin has focussed on reconstructions of integumentary colour in fossils. Modern vertebrates, however, also possess melanin in internal tissues; the impact of these internal melanosomes on preservation and interpretation of fossil soft tissues has not been assessed. Here we present the first systematic analysis of the anatomical distribution and abundance of melanosomes in different vertebrate taxa. The abundance of melanin in tissues of extant amphibians, reptiles, birds and mammals was assessed using histological sections stained with the Warthin-Starry technique. Pure samples of melanosomes from different tissues were obtained using enzymatic extraction. The melanin extracts were analysed using scanning electron microscopy (SEM), transmission electron microscopy (TEM) and synchrotron X-ray fluorescence (XRF). Our results reveal that the relative abundance of melanosomes varies among internal tissues of the same taxon and among taxa, in some case they differ in morphology, and always differ in trace element chemistry. These findings can be applied to fossils to allow integumentary and non-integumentary melanosomes to be discriminated, offering new tools for the investigation of the preservation potential of soft tissues in the fossil record and more accurate interpretation of the internal anatomy of extinct animals.

Ontogeny in *Ophiderpeton brownriggi* (Lepospondyli: Aïstopoda) revealed through CT-scanning and 3D modelling; implications for aïstopod evolution and ecology.

Aodhan O Gogain[1*] and Patrick Wyse Jackson[1]

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The Pennsylvanian (Langsettian) Jarrow Seam in south-east Ireland preserves a high diversity of semi-aquatic tetrapods, the second most abundant of which are the aïstopods. A large range of preserved body sizes in this assemblage allow for ontogenetic variation within the aïstopods to be investigated, however the poor appearance of many of the specimens has hindered this so far. A combination of µCT-scanning and 3D rendering has been used on three specimens, ranging from the smallest specimen to the largest specimen, in order to investigate ontogeny stages. Additionally cranial lengths were measured from complete specimens to calculate the size distributions of the whole sample. The cranium of smaller aïstopods is poorly preserved possibly indicative of un-ossified elements. Despite this the head region and the ventral side of the post-cranium are covered in dermal osteoderms and gastralia respectively, which are characteristic of adult forms. Size distribution of specimens shows an even distribution. Additional mature characteristics within the smallest specimen supports the hypothesis that aïstopods were direct developers and did not go through a larval stage as seen in lissamphibians and certain temnospondyls. An even distribution of preserved body sizes suggests that the depositional environment of the Jarrow assemblage did not act as a nursery. There is still no current consensus on whether aïstopods were stem-lissamphibians or stem-amniotes. The lack of a larval stage in aïstopods, which is seen in temnospondyls and modern lissamphibians, suggests less of an affinity between aïstopods and the lissamphibians.

Continuous cladistics: a three-pronged attack on phytosaur phylogeny

Andrew Jones[1*] and Richard Butler[1]

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The in-group phylogeny of Phytosauria has historically consisted of multiple 'wastebasket taxa', with improvement sluggish due to a limited set of characters and poor transatlantic sampling. Recently, new methods in parsimony analysis have permitted incorporation of alternative data types with the potential to help elucidate phytosaur phylogeny. Here we investigate the in-group relationships of Phytosauria and the impacts of discrete, continuous and morphometric character data on tree

topology using differentially coded variants of a single dataset. Extensive first-hand study of both European and American specimens, alongside intensive investigations to identify novel characters and unite the character lists of previous analyses have generated the most taxonomically comprehensive cladistic dataset of phytosaurs with an almost two-fold increase in the phylogenetic information scored for each taxon. In conjunction with traditional phylogenetic methods, continuous and morphometric characters are analysed without discretisation using the software TNT, bypassing issues of arbitrary or subjective character scoring. Four phylogenies are presented to compare the effects of data type on tree topology: 1) discrete characters only, 2) discrete + continuous, 3) discrete + morphometric, 4) discrete + continuous + morphometric. Results from the different data types show generally consistent, well resolved tree topologies, which differ in the placement of some taxa and clades previously identified as unstable. The discrete + continuous data types resulted in best tree resolution. Morphometric characters are limited due to being cumbersome to implement and requiring complete and undistorted morphology – reducing the number of specimens for which such characters could be scored.

Grabbing evolution by the throat: functional regionalisation of the avian cervical column

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Birds have evolved powerful forelimbs that are used in flight. This has rendered these appendages less useful for environmental manipulation than in many of their dinosaurian antecedents. Reliance on the head/neck for feeding and environmental interaction places high selective pressure on cervical form-function potentially explaining the diversity in avian neck morphology. To-date there has no been no systematic study of morphological diversity in the avian neck and it's correlation with feeding habits. We use a combination of three-dimensional geometric morphometrics (GMM) and qualitative character coding to assess regionalisation within the cervical column of a variety of extant birds. These species represent a diverse array of feeding and functional ecology, cervical count (12-17) and body size. Results provide strong support for 5 cervical subregions (axis, anterior, middle, midposterior, posterior) in all species. The atlas subregion appears to show the strongest signal, with the axis being clearly separate in all studied birds, possibly owing to its function into head stabilisation. Other subregions with a stable cervical count (anterior and posterior) also display a clear functional role. The remaining 2 regions (middle, midposterior) show much variability in cervical count between species (middle 2-6 cervicals, midposterior 1-4 cervicals). These results suggest that whilst the underlying *Hox* genetics may restrict avians to 5 cervical subregions, expansive variability in the middle and midposterior regions allow the cervical columns of birds to adapt to many different functional ecologies, and may be responsible for the large variety of neck morphologies observed in extant Aves.

A micropalaeontological and geochemical palaeoceanographic record of the deglacial and Holocene from the sub-Antarctic island of South Georgia.

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[1]University of Nottingham

In order to assess the Southern Ocean's sensitivity to climate change and place recent environmental changes within a historical context, it is important to develop our understanding of how water mass properties and circulation patterns have varied through the Holocene, particularly in the Subantarctic Zone. Understanding oceanographic variation in this region is important because the Southern Ocean has been proposed as an important carbon sink and source during transitions between glacial and interglacial periods. South Georgia is of particular interest because it sits in the path of the Antarctic Circumpolar Current, and the interaction of the current with the island supports intense phytoplankton blooms. These blooms form one of the largest seasonal sinks of atmospheric CO2 south of the Antarctic Polar Front, in addition to supporting one of the most diverse ecosystems in the Southern Ocean. Here we present micropalaeontological and geochemical data from a sediment core on the continental shelf east of South Georgia, spanning the last 15 kyrs. Benthic foraminiferal assemblages and organic carbon accumulation indicate a highly productive late deglacial and early Holocene, with phytodetritivore dominating benthic foraminiferal assemblages. Subsequent environmental changes, possibly affecting carbonate preservation potential, during the mid and late Holocene lead to assemblages dominated by *Miliammina arenacea*. We consider that the changing oceanographic conditions on the South Georgia shelf, revealed by a suite of palaeoceanographic proxies, may inform us about sub-Antarctic ocean-climate evolution since the last deglacial.

[LT]Functional Morphology of *Crassigyrinus scoticus*: Gaining Insight into Locomotor Evolution in Early Tetrapods

Eva Herbst[1*], Timothy Smithson[2], Jennifer Clack[2], John Hutchinson[1]

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Advances in our understanding of early tetrapods continue to raise questions about the evolution of novel locomotor modes in these animals. Many characters that were once regarded as adaptations to life on land appear in the fossil record before evidence of terrestriality. Recent studies have shed light on the locomotion of animals such as *Ichthyostega*, but to gain a more comprehensive understanding of tetrapod evolution, a range of animals must be analysed. The Carboniferous tetrapod *Crassigyrinus scoticus* from Scotland is of interest because of its unusual morphology. *Crassigyrinus* has extremely reduced forelimbs and was likely to have been completely aquatic. We used micro-CT scans to investigate skeletal morphology because scales, matrix and other bones obscure the in situ fossils. This digital segmentation has led to the discovery of several new elements and has given us a better understanding of the morphology of *Crassigyrinus*. There is possible evidence of pleurocentra, indicating *Crassigyrinus* may have had diplospondylous vertebrae, rather than only possessing intercentra. The scans also revealed caudal supraneural spines and what is probably an ossified pubis. Further analysis of these bones will increase our knowledge of the evolution of these elements and help infer the ancestral condition for early tetrapods. Future work will also place these anatomical discoveries in a functional context. We will conduct range of motion studies of the limbs and backbone to estimate the potential locomotion of *Crassigyrinus scoticus*. Comparative studies of the skeletal morphology will help infer the evolution and diversity of locomotion in early tetrapods.

[LT]Death in the oceans: extinction risk in the marine realm

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Extinction rates are currently at their highest for 66 million years and are rising at an unprecedented rate. Oceanic ecosystems are particularly vulnerable to rapid environmental change, which is compounded by our lack of knowledge regarding the evolutionary history of many marine groups. Planktonic foraminifera are marine, free-living, amoeboid protozoa widely distributed throughout the modern oceans which exhibit an extensive fossil record dating back to the Late Triassic. Modern planktonic foraminifera exhibit vertical stratification throughout the upper portion of the water column, wherein distinct morphological and ecological adaptations permit their occupation within distinct latitudes, trophic conditions and oceanic layers. Due to the completeness of their fossil record, high abundance and global distribution, the planktonic foraminifera offer the best means of assessing Cenozoic extinction events, as the only group with a complete enough species-level fossil record to investigate extinction risk. This project harnesses a multidisciplinary approach, including geochemical, morphometric and biogeographical modelling, to analyse the planktonic foraminiferal fossil record of the Neogene and Quaternary periods (23 million years ago to the present day). The analysis will highlight any precursor effects to extinction, such as alterations in ecology, morphology, abundance or geographic range within the terminal 1.5 Ma of extinct lineages, as a possible means to predict present-day and future extinction. The project aims to provide the most detailed and comprehensive analysis of extinction risk in a marine group to date, and subsequently provide a means to determine which present-day species and marine ecosystem are under the highest risk of extinction through anthropogenic climate change.

[LT]Drilling pterosaur bone: An invertebrate burrow from the early Late Cretaceous Santana Formation, NE Brazil

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The Santana Formation (Albian-?Cenomanian) the crops out along the slopes of the Chapada do Araripe, NE Brazil, is one of the most important *Fossillagerstätten* of Brazil because of the enormous fossil diversity that includes mainly fishes, which ranks among the highest in the world for the early Late Cretaceous. A burrow is seen on the left femur of a new azhdarchoid pterosaur skeleton from Santana Formation. The linear structure is visible on the surface of the fractured bone and is horizontal, slightly curved, unbranched, massive with continuous transversal undulations on the

wall. The burrow is filled with sediment and attributed to invertebrate. Ventrally occur a fracture, characterized by incomplete longitudinal break with semi-parallel grooves. According to Genise (2017; p. 477), "feeding traces referred to insect osteophagy are hollow or comminuted bone-filled borings with circular cross-sections, shallow, hemispherical and star-shaped pits". Insect feeding trace fossils in bones are biogenic structures that cut or destroy hard bone tissue in dead animals (Neumann, 1996; Pirrone et al., 2011). Pathologies referred probably to living pterosaurs, were also observed in other specimens from Santana Formations. Kellner and Tomida (2000) also reported a series of pathologies in *Anhanguera piscator* associated to injuries and infections; Bennett (2003) has reported signals of necrosis, hyperplasia and healed fracture in *"Santanadactylus" araripensis*. And, Martill and Witton (2008) described catastrophically fractured rostrum of *Tupuxuara*. The burrow reported here is the first register of this invertebrate interaction observed in a vertebrate fossil from Santana Formation.

Heterochrony in hypercarnivorous baurusuchids (Crocodyliformes, Notosuchia) revealed by cranial shape variation

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Notosuchians, the most diverse clade of Gondwanan crocodyliforms during the Mesozoic, reached their apex during the Late Cretaceous. Their remarkable morphological disparity indicates that this group filled a wide range of ecological roles usually occupied by other vertebrates. Among notosuchians, the distinctive cranial morphology of Baurusuchidae, as well as their large body size, suggests a role as top predators in ecosystems in which the otherwise dominant predatory theropod dinosaurs were scarce. Other large-bodied crocodyliforms, modern or extinct, achieve their size by extending the growing phase, hinting that peramorphic heterochronic processes, such as time hypermorphosis, might have driven the evolution of baurusuchids. However, despite the considerable number of species and specimens described, ontogenetic studies on baurusuchids are scarce, mostly because juvenile specimens are rare and fragmentary. In this context, the recent discovery of a new juvenile specimen of the baurusuchid *Pissarrachampsa sera,* provides the opportunity to investigate the role of heterochrony in the evolution of these hypercarnivorous crocodyliforms. Here we use a geometric morphometrics approach to provide quantitative evidence of peramorphic processes leading to the cranial specializations related to hypercarnivory in baurusuchids. Using a novel set of procedures, we find a strong link between cranial peramorphic modifications and size increase, suggesting that the peramorphosis in the evolution of the baurusuchid skull occurred synchronized with the shift to a hypercarnivorous habit. Our results illustrate the role of heterochrony as a macroevolutionary driver, and demonstrate the ability of geometric morphometric techniques to identify heterochronic processes behind evolutionary trends.

Session 4

No missing molluscs?: Investigating spatial aragonite bias in epicontinental seas

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Ancient shelly marine faunas are susceptible to misrepresentation due to preferential dissolution of the biogenic carbonate polymorph aragonite. Epicontinental seas, predisposed to water column stratification and seasonally dysoxic conditions, may be more prone to preferential aragonite loss than modern oceans; ramp like basin floor topographies combined with temporal variation of oxycline position in the water column might result in spatially extensive zones with conditions predisposed for aragonite dissolution. Here we present a multifaceted spatial investigation of aragonite dissolution within the Western Interior Seaway. Occurrence data of lower Campanian and Cenomanian/Turonian boundary molluscs were gathered from the literature, USGS collections and publically available databases, and plotted on new high resolution paleogeographic/paleobathymetric reconstructions of these time slices to assess aragonite distribution across the seaway. The distribution of raw occurrences for calcitic and aragonitic molluscs were compared to areas likely to experience enhanced dissolution, defined by paleobathymetry and stratification data generated from GCM climate and Fluidity-ICOM tidal models. Occurrences, diversity and SQS subsampled diversity were also compared with increasing depth across the seaway. Chi-squared

tests showed no statistically significant difference between calcitic and aragonitic distribution for enhanced dissolution zones or basinwards profiles, suggesting this bias has a limited regional influence. Whilst aragonite dissolution likely affects the distribution of fauna on local scales, time averaging effects and instantaneous preservation events allow for potentially lost biodiversity to be captured. As such, our results suggest paleoepicontinental seas provide as accurate a snapshot of deep time biodiversity as ancient oceans.

Completeness of the global non-avian theropod fossil record

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Our understanding of ancient species' diversity, ecology, biogeography and macroevolution can be biased by changes in the quality of the fossil record through time, space and phylogeny. Calculating the proportion of a complete skeleton that is preserved within an individual fossil specimen (Skeletal Completeness Metric [SCM]) provides one approach to quantifying the quality of the tetrapod (four limbed vertebrate) fossil record. Here, we use the SCM to specifically analyse the global non-avian theropod dinosaur fossil record in relation to other tetrapod groups and to understand potential natural (e.g. biological and geological) and human (e.g. sampling techniques) biases acting upon it. Specimen-level SCM scores were collected from the literature for all non-avian theropod taxa previously included in phylogenetic analyses, and an existing sauropodomorph completeness dataset was updated. Theropod completeness was statistically compared to taxic diversity through geological time, sampling proxies (e.g. counts of dinosaur-bearing formations), sauropodomorph SCM, other tetrapod groups, body sizes and geographical localities. Theropod completeness does not correlate with global diversity or sampling changes, but its similarity to the sauropodomorph dinosaur fossil record suggests there may be a specific dinosaurian signal. This necessitates analysis of the ornithischian dinosaur record to confirm. Asia and North America have the most complete theropod records but the overall completeness of theropod skeletons surprisingly does not correlate with body size. The theropod and sauropodomorph dinosaur fossil records require further examination to unpick their relationship to sedimentary settings, palaeoenvironments, taphonomic regimes and modern day climate zones.

Irregular depositional dynamics in Northern Spain during the Middle Devonian: evidence from a detailed palynological analysis

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The Middle Devonian was an important time of change for life on Earth, as the earliest terrestrial forests appeared and a series of extinction events occurred, heavily affecting marine communities. Unfortunately little is known regarding these extinction events' effect on terrestrial life. To address this a major palynological analysis has been conducted on the Huergas, Naranco and Gustalapiedra formations of Asturias, Castilla y León and Palencia provinces in Northern Spain. These laterally equivalent formations, of Eifelian and Givetian age, represent a transect from shallow nearshore marine through to deep offshore shelf deposits on Peri-Gondwana. They consist of large sandstone bodies, interspersed with black shales, sandwiched between thick limestones of the overlying and underlying formations, marking a major depositional anomaly. Palynological analysis of samples from 30 sites, including 4 logged sections, have revealed an unexpected depositional dynamic. The unfossiliferous lower half of the formation appears to have been deposited very much more slowly than the heavily interbedded upper half. While the base of the formation is Lower Eifelian the upper half was deposited entirely within a short interval of the Lower Givetian, potentially only 400,000 years, as revealed by biostratigraphical analysis of fossil spores, acritarchs and chitinozoans, in conjunction with conodonts from the overlying and underlying limestones. This step change in the rate and character of deposition occurs after the Kačák Event, an important global extinction event in the marine realm. It seems likely that the Kačák Event is connected to this major disruption in Northern Spain during the Middle Devonian.

Osteological correlates of lung structure and breathing mechanics in archosaurs

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Studies on the evolution of the respiratory system in dinosaurs have mainly focused on the presence/absence of post-cranial pneumaticity as evidence of bird-like air sacs. However, this provides little information about the structure of the lungs themselves. In living birds and reptiles, the bony morphology of the costovertebral joint- where the rib heads meet the vertebral column- directly affects the gross morphology of the lung and can be used as an osteological correlate for lung structure in fossils. To test whether dinosaurs had lungs more similar to modern birds or crocodilians, vertebral shape (as a proxy for lung structure) was quantified using geometric morphometrics and linear measurements, with an emphasis on the position and orientation of the costovertebral joint. In birds, the costovertebral joint is oriented vertically, creating a furrowed thoracic ceiling where the rigid lungs are incised by the rib heads. In crocodilians, the costovertebral joint is oriented horizontally, creating a smooth thoracic ceiling, associated with compliant lungs ventilated by the "hepatic piston" visceral pump. Principal components analyses and Procrustes ANOVAs show dinosaurs occupy distinct regions of vertebral morphospace, but are closer to birds than crocodilians. Additionally, almost all dinosaurs examined had a vertically oriented costovertebral joint. This suggests that dinosaurs likely had rigid bird-like lungs, and there is no evidence to suggest a crocodilian-like "hepatic piston" mode of ventilation in any of the dinosaur taxa analysed. These results clarify respiratory evolution in bird-line archosaurs, with implications for the evolution of endothemy and elevated aerobic capacity in this lineage.

A quantitative analysis of the frequency and location of repaired injuries on Cambrian (Stage 4 and Drumian) trilobites from three sites in the Iberian Chains, Spain

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Repaired skeletons provide the opportunity to study predator-prey interactions in the fossil record. Numerous descriptive studies document repaired injuries on trilobites since the Cambrian, and a previous study suggested that these injuries occur dominantly on the right-hand side of Cambrian trilobites. To understand the importance of predation in driving the evolution of putative anti-predatory traits and behaviours in trilobites (e.g. additional or lengthened spines, burrowing, enrolment, occupation of refuges), a more quantitative approach taking into account geographic variation and allowing comparison between different trilobite groups is needed. This is the first study to gather both frequency and location data on repaired injuries on trilobites. Specimens were collected from three Cambrian sites during fieldwork in September 2016: redlichiids from Minas Tierga (Stage 4) and *Eccaparadoxides pradoanus* from Purujosa and Mesones (Drumian). We assessed the presence and location of repaired injuries on hundreds of trilobite exoskeletons. The frequency of injury at each site was calculated, a Bayesian inference method was used to estimate uncertainties, and binomial tests evaluated right-handed and anteroposterior selectivity in repair scar location. Only trilobites from Purujosa displayed repaired injuries, demonstrating variation in repair frequencies from geographically close sites of the same environment, on the same species of trilobite at the same geological time (Drumian). We found no evidence for right-handed location of repair scars in *Eccaparaodixies pradoanus*. However there is evidence for anteroposterior selectivity, for the rear three thoracic segments, in this species: suggesting sophisticated predatory-prey interactions early in animal history.

[LT]Reappraising the Evolution of the Elephantidae

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The understanding of macroevolution requires the presence of robust phylogenies. The Elephantidae has been the poster child for rapid evolutionary rate and phyletic morphological transitions in the fossil record. However, rampant parallelisms and intraspecific variability of craniodental morphology throughout their evolutionary history has made them resistant to a comprehensive phylogenetic treatment. Recent preliminary molecular results which suggest the phylogenetic closeness of *Palaeoloxodon* and *Loxodonta*, which presents a stark contrast to the established morphology-

based paradigm, emphasise the pressing need to reappraise the current morphological paradigm of elephantid systematics, which is still largely based on pre-cladistic literature. Hereby, I present preliminary outputs from extensive first-hand examinations of Old World elephantid materials curated in several European museums, including both fossil and extant species. Understanding the craniodental homology and homoplasy issues of elephantids is leading to the refinement of the largest morphological character set to date, for constructing a detailed species-level phylogeny of elephantids.

[LT]Fickle oceans – the influence of temperature and Mg/Ca ratio on marine calcifiers

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Throughout the Phanerozoic, secular changes in the Mg/Ca ratio of seawater have caused "aragonite seas" and "calcite seas" to alternate. Although several studies linked ecological success with skeletal mineralogy at the 'correct' aragonite-calcite sea conditions, a Phanerozoic scale study using fossil occurrences recorded in the Paleobiology Database (PBDB) found that mass extinctions, not Mg/Ca ratio, shaped the skeletal composition of marine biotas. Following recent insights that aragonite-calcite sea conditions are strongly temperature-dependent, we combine models of inorganic CaCO3 polymorph precipitation with Phanerozoic $\delta^{18}O$ records to produce a temperature-corrected model of inorganic aragonite and calcite precipitation in tropical latitudes. We use this updated model to re-evaluate links between the fossil record of marine calcifiers and aragonite-calcite sea conditions using Summed Common genus Occurrence Rates (SCOR) as a measure of ecological success. Preliminary results indicate a lagged response in the ecological dominance of calcitic algae, sponges and corals to shifts in the calcite – aragonite sea state during the Palaeozoic.

[LT]Reconstructing the distribution of pigmented tissues in river lamprey (*Lampetra fluviatilis*) using three-dimensional serial histological sections

Christopher Nedza[1*], Jakob Vinther[2], Mark Purnell[1] and Sarah Gabbott[1]

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Pigment bearing organelles – melanosomes – are found in a variety of tissues across a broad range of taxa. Melanin, the pigment found within these organelles, plays an important role in determining colouration patterns in the skin and hair, and can provide inferences into their ecology. However, little is known of the distribution of melanin throughout a single taxon and how it is affected by decay. Here I present the first preliminary three-dimensional reconstruction of the distribution of melanin within tissues of the extant river lamprey, *Lampetra fluviatilis*. Exploratory data reveals that melanin distribution is more complex than previously thought, and can be affected by the decay process. This has significant implications for interpreting the pigmented anatomy of extinct organisms, and provides evidence that melanin distribution could help untangle debates surrounding controversial interpretations of pigmented anatomy.

Poster abstracts are presented here.* indicates presenting author. For author contact details please see the delegate list.

Biomechanical insights into multituberculate extinction and competitive exclusion

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Multituberculates were one of the most successful mammalian orders to have ever lived, persisting for at least 125 million years from the Middle Jurassic through the K-Pg mass extinction to the late Eocene. The cause of multituberculate extinction remains unresolved and has received minimal research attention for several decades. One widely accepted view is that the Paleogene radiation of placental rodents, which developed convergently similar craniodental anatomy, led to multituberculate decline through competitive exclusion. However, rigorous quantitative and functional tests of this hypothesis have hitherto been lacking. Here, we present initial results of a study using a range of biomechanical techniques to assess the supposed superiority of rodents over multituberculates for the first time. CT scans of multituberculate and rodent skulls have enabled the construction of 3D digital models, which are the subjects of the current biomechanical study. Finite element analysis (FEA), mechanical advantage (MA), and second moment of area calculations are being used in tandem to investigate jaw stress and strain, jaw efficiency, and resistance to bending and torsional forces, respectively. This approach will test the hypothesis that it was the more efficient and resistant jaws of rodents that gave them a competitive advantage over multituberculates. Not only does this work have the potential to begin to address the role of competitive exclusion in driving macroevolutionary processes, but it will also provide fresh evidence on a disputed issue in mammalian evolution.

Was body size linked to extinction selectivity in archosauromorphs during the Triassic-Jurassic mass extinction?

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Many previous studies have considered whether the possession of certain traits can be linked to reduced (or heightened) extinction risk during mass extinctions, however few have done so whilst taking phylogeny into account. As such, this study hopes to examine whether one of the more commonly retrieved traits from earlier work, namely body size, can be seen to have had an effect on the extinction of archosauromorph species across the Triassic-Jurassic mass extinction. This will be carried out by analysing species size characteristics within the framework of an informal supertree, with the use of phylogenetic comparative methods.

Quantifying the completeness of the bat (Mammalia: Chiroptera) fossil record between the Eocene and Miocene

Emily Brown[1*], Daniel Cashmore[1] and Richard Butler[1]

[1]University of Birmingham

Assessing the changes in completeness of the fossil record through time is important for identifying the various taphonomic and sampling biases that make inferring biological signals directly from the fossil record problematic. Chiropterans (bats) are known to have evolved just after the Cretaceous-Palaeogene mass extinction, but are not found in the fossil record until ~14Ma later, and are generally thought to have a poor fossil record. Here we quantify the specimen preservation quality of 200 valid species from the Eocene to Miocene based on the previously defined Skeletal Completeness Metric (SCM).

SCM scores were statistically compared to raw taxic diversity through geological time, between different body sizes and family groups. SCM scores were also compared to a simpler quantitative metric (Beardmore's Skeletal Completeness Metric). Completeness does not significantly correlate with taxic diversity but was found to be strongly affected by the temporal and spatial distribution of fossil Lagerstätten. Isolated teeth are the predominant elements occurring in the bat fossil record, but are diagnostic enough for taxonomists to identify significant diversity even at times of low completeness. Chiropteran fossils are consistently incomplete regardless of body size, but show a bias towards the preservation of cave-dwelling species. With such low levels of completeness it is unsurprising that transitional fossil material has not been found for the evolution of flight or echolocation in bats. Analyses also suggest the importance of using more in-depth metrics on groups where completeness is known to be poor as they avoid lower resolution inaccuracies.

Quantifying the cranial adaptations to bipedalism in hominid species.

Matilda Elgood Field[1*], Emily Rayfield[1] and Ben Garrod[1]

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Becoming upright is considered a fundamental reason for *Homo* success, and the anatomical adaptations conferred have been carefully studied, particularly relating to the postcranium. Recent discoveries of new hominid species have highlighted the need to consider mode of locomotion when studying skeletal adaptations. Whilst we have a good understanding of how postcranial changes impacted modes of locomotion over hominid evolution, cranial information is lacking. Various cranial adaptations (e.g. reduced prognathism, rounding of the cranium and movement in foramen magnum) are cited as being associated with the transition to bipedalism but there is little quantifiable evidence to support this. This project uses photogrammetry and 2D geometric morphometric analysis to provide evidence for trends in cranial morphology over hominid evolution, and relate this to changes in locomotary mode. Skulls/casts have been used from museums and university collections across the country, and photographs have been used when specimens are not available. This will also show whether photographs are suitable for use in research, which is critically important as the hominid fossil record is notoriously poor and research-quality specimens are hard to access.

A bizzare 'blop' from Sirius Passet

Grace Fordham[1*]

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Although the Sirius Passet is one of the most famous lagerstätte it also one of the most poorly described and least understood. There have been many discoveries of exceptionally preserved fossil specimens including stem arthropods, lobopods, sponges and annelids; however recently collected slabs reveal previously unnoticed highly reflective 'blops'. The specimens in question can grow to become several centimetres in size with an effaced margin, a quasi-oval outline and a prominent central ridge with significant relief. Assessment of the specimens reveal it to be a biological, multicellular organism. This project uses geometrical morphometrics and statistical analyses as well as electron microscopical and EDS analyses. These techniques facilitate a detailed description of this organism characterising its ontogeny and fine structure enabling the exploration of likely affinities and ultimately a firm placement into a group within the known phyla.

Mass estimation in pterosaurs: convex hull volumetric analysis with bats as an analogue

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Calculating the body mass of extinct organisms, such as pterosaurs, is crucial to understanding their physiology and biomechanics. Previous attempts to derive mass in pterosaurs have used a variety of linear and geometric techniques, which has led to numerous inconsistent mass estimates within the species studied. This makes it difficult to reliably study pterosaur biomechanics, particularly in regards to flight mechanics. This project aims to find a reliable and consistent method of mass estimation in pterosaurs via a hybrid method known as convex hull volumetric analysis. Unlike other geometric-based methods, convex hulling does not require any assumption of soft tissue volume, instead creating a mesh around skeletal material only. This provides a fixed minimum mass estimate which, when compared to living

specimens, is proven to consistently underestimate body mass by a measurable proportion. This method has previously been used to give consistent mass estimations in specific animal groups, including volant birds and large mammals. To confirm this method can work with the pterosaur body plan, convex hulling will first be applied to modern bats, which share a similar skeletal morphology to pterosaurs. The convex hull masses for each specimen will be compared to species average masses, taking bat phylogeny into account. Assuming the method proves reliable for bats, convex hulling will be applied to two pterosaur species, and the bats' proportional differences will be used to estimate the mass of each pterosaur. If successful, convex hulling will be proven to give consistent mass estimations for pterosaurs in the future.

Megaloolithid dinosaur eggs: scrambled parataxonomy and nesting strategies

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The detailed study of fossil dinosaur eggshells from Upper Cretaceous continental deposits from the Haţeg Basin (Romania), the Arc Basin and Argentina and from the Thanetian of the Rians Basin (France) was made in order to test the robustness of fossil eggs' parataxonomy and to reveal novel data on dinosaur palæobiology. µXRF, XRD and cathodoluminescence analyses attest a limited diagenesis on these fossils, which allow interpreting observed traits from a palæobiological point of view. According to their microstructure, analysed eggs mainly belong to the titanosaur-related Megaloolithidae oofamily. Measured histological variables analysed through PCA – clustering unveil a weak megaloolithid parataxonomy scheme which needs to include whole shell units morphology forming the eggshell in addition to descriptions. XRD analyses point to an almost pure calcite eggshell composition (LMC) as well as a preferential orientation of this calcite along the shell unit growth axis, the latter involving biomechanical properties of the egg. Water vapour conductance (GH2O) estimation of some fossil eggshells together with the corresponding porosity – modelled mass pairs suggest that Haţeg and Arc Basins titanosaurs burrowed their nest in humid conditions. The vegetation-mount hypothesis is rejected whereas a hydrothermal environment is proposed for the Argentinian sample.

PalaeoENM: Ecological Controls on Triassic/Jurassic Coral Reefs

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Although inhabiting less than 0.1% of the world's oceans, coral reefs house one of the most biologically diverse and economically valuable ecosystems on Earth. However, climate change, with a projected global warming of 2 - 4.8 °C, is likely to leave coral reefs at substantial risk. Elucidating the ecological controls on the distribution of coral reefs is vital for future conservation efforts. However, the study of contemporary coral reefs limits our understanding of responses over longer time periods, reducing our ability to consider how corals might adapt to changing environments or survive in refugia. Fortunately, an extensive record of coral reef response to climate change is available from the sedimentary and fossil record. Recent developments in ecological niche modelling (ENM) and global environmental datasets have enabled opportunities to assess ecological controls in the modern day. This project proposes a novel approach to assessing the ecological controls on coral reefs using their deep time record. In particular, this work focuses on coral reefs across the Triassic/Jurassic boundary, approximately 200 Ma. Initial work has involved validating the model through predicting the distribution of modern coral reefs. ENM was performed using the machine-learning algorithm Maxent, a presence/background method. Predictive variables employed include sea surface temperature, salinity, current speed, and irradiance. Annual means were used for all environmental variables at a 3.75° x 2.5° resolution to produce coral reef probability maps to compare with known occurrences. This will allow insights into temporal variation of ecological tolerances and provide a foundation for further studies.

New Pycnodontiformes from the Middle Jurassic of the Isle of Skye (Scotland) and the distribution of pycnodonts during the break-up of Pangaea

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Ray-finned fish (Actinopterygii) make up approximately half of all extant vertebrates. They exhibit an

overwhelming morphological diversity and are well-adapted to an array of ecological niches. The Jurassic was a key time in the evolution of actinopterygians with the Late Jurassic fossil record showing a burst in diversity. In contrast, the Middle Jurassic is somewhat neglected with considerably fewer studies on fish in general from this time. Using a new assemblage of recently recovered Middle Jurassic fossil fish from the Isle of Skye (Scotland) this study aims to shed light on this time. This is the first dedicated study of actinopterygian fish fossils from this region revealing, in particular, new pycnodont (Pycnodontiformes) taxa with distinct dentitions. Whereas pycnodonts are typically known from marine palaeoenvironments, the Skye assemblage represents a brackish lagoonal palaeoenvironment. A new taxon has been identified showing an intriguing vomerine dentition with robust grinding teeth diminishing in size caudally, in contrast to what is observed in most pycnodont dentitions where teeth enlarge posteriorly. A distinctive taxon similar to that of the Cretaceous taxon *Lemanja* is also reported indicating that some distinct pycnodont forms originated considerably earlier than previously thought. Such finds require a reconsideration of the palaeobiogeographic distribution of pycnodonts, and possibly other groups, in the Mesozoic as the supercontinent, Pangaea, became fragmented.

Using the fossil record of Crocodylia to assess current extinction risk

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The 24 living species of crocodylians (crocodiles, alligators, caimans and gharials) are the sole remnants of a once much more diverse group that evolved 250 million years ago (Ma), with crocodylians first appearing in the fossil record 80 Ma. Approximately 50% of living crocodylians are vulnerable to extinction or critically endangered, reflecting the wider global biodiversity crisis. In response, the field of conservation biology has encompassed palaeontological data, giving rise to conservation palaeobiology. Phylogenetic data can be used to account for bias in studies of extinction selectivity and to test for taxonomic patterns of extinction, particularly whether extinction clusters in certain taxa. Although studies show that extinction risk is not randomly distributed across species, these studies are based on living species only. This leads to a bias in assessments of extinction risk: living groups might seem less threatened because the most susceptible species are already extinct. This project will generate a comprehensive new global phylogeny for Crocodylia that will form the baseline for analysing patterns of extinction in this group. Correlates of extinction susceptibility will be tested, in addition to the taxonomic clustering of extinction. The critically endangered Chinese alligator will be used as a case study. Local ecological information collected from southern Anhui Province, China will be combined with historical, archaeological and palaeontological data to reconstruct spatiotemporal distribution patterns and assess future threats to reintroduced alligators. This work will demonstrate the application of the fossil record and evolutionary history of organisms to modern conservation and assessing extinction risk today.

Strategies in times of crisis

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Foraminifera are a vital part of the marine ecosystem, however, with the rapid input of anthropogenic CO2 into the current climate, there is increasing concern over the long-term effects on ocean systems. The precise effects of ocean warming and acidification on biology are poorly understood making it is difficult to determine whether the consequences are irreversible. The Palaeocene-Eocene Thermal Maximum (PETM) is the closest comparison to present climate change in the geological record, with global temperatures rising by 5-8° due to increasing CO2 levels. I will look at microfossils found before, during, and after this climate event to further understand the underlying biological responses. Foraminifera are unique in that these single-celled organisms record their entire developmental history through the sequential addition of chambers onto their test. In benthic species, I look at features such as shell size, the number of chambers, and the size of the proloculus to show how these organisms adapted to environmental change. Shell size is used to tell whether growth was constrained, the number of chambers present acts as a proxy for life span, and the size of the proloculus indicates whether asexual or sexual reproduction was utilised. I use X-ray tomographic microscopy and 3D imaging software to show it is possible to reconstruct and explore the internal structure of these shells and I will, therefore, determine how their development and reproduction changed across a period of intensive climate change.

New data on the Mesozoic radiation of chelonioids

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"Turtles" (Testudines) form a successful group of reptiles with several terrestrial, marine and fresh-water species. Their peculiar and somewhat constrained morphology (i. e. carapace incorporating ribs, curved limbs, anapsid skull exempt of temporal fenestrae) and ecology has often obscured their relationships and, hence, their evolutionary history, notably in marine turtles (chelonioids). Modern chelonioids are divided in two clades (i. e. shoft-shelled turtles and hard-shelled turtles) supported by distinct morphological and embryological characters. Their origin is traced back up to the Cretaceous, along with a series of extinct forms, many of which being collectively known as Protostegidae. Fossil evidence show that at least five clades of marine turtles were roaming the seas at the end of the Cretaceous. In fact, chelonioids appeared during the first stages of the Early Cretaceous and quickly exploded to reach a high level of disparity at the lowermost part of the late Cretaceous. Therefore, the Mesozoic radiation of chelonioids must have happened during the "middle" Cretaceous (especially the Aptian-Albian interval). However this radiation is poorly understood as the phylogenetic relationships of marine turtles are not resolved yet. Bringing new data may help resolve these issues, and it is the exact reason why the genus *Rhinochelys* is being investigated.

The cosmine conundrum - developmental insights from 3D histology of *Megalichthys hibberti*

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Cosmine has traditionally been described as a combination of tissues and structures unique to the sarcopterygian lineage. These studies, based predominantly on two dimensional serial sections, also interpreted cosmine as a discrete phylogeentic character based on presence and absence. New fossil finds have revealed cosmine like tissues, however, in taxa along the Actinopterygian lineage. Using 3D synchroton tomography and digital reconstruction to elucidate the structure of cosmine and its associated pore canals in the Osteolepiform *Megalicthys,* we interpret cosmine as a character complex progressively aquired or concomitantly lost in different lineages of Osteicthyans, reaffirming the hypothesis that rhombic scales are ancestral.

Soft tissues in Strawberry Bank fishes

Holly Young[1*], Sam Giles[2], Mike Benton[1], Benjamin Moon[1], Matt Friedman[2], Matt Williams[3] and Jakob Vinther[1]

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The Toarcian locality of Strawberry Bank in Somerset has yielded a large number of fossils including fish, insects and marine reptiles. Many of these fossils also exhibit exceptionally preserved soft tissue. Among these finds are several specimens of the pachycormid fish *Pachycormus* with both gut structure and content preserved. The exact affinities of *Pachycormus* have long been debated, 3D modelling of the gut structure utilising Avizo could reveal specific features either refuting or confirming the teleost affinities of the animal. In addition, samples taken from the gut of one of the specimens reveal the existence of a variety of objects in the contents of the gut. The exact feeding mode of *Pachycormus* is another subject of debate as it is unknown whether it was a suspension feeder or macrocarnivore. Identification of the gut contents with the SEM could reveal the feeding mode of *Pachycormus* along with its place in the trophic structure of Strawberry Bank.

A systematic review of Devonian Palaeobioregionalisation

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Devonian Palaeobioregionalisation is a poorly constrained field of research. Though useful for the understanding of palaeoreconstructions and area relationships, the field has been stuck in a cycle of reinvention since the seminal work of A.J. Boucot. The framework for Boucot's palaeobioregionalisation

lay in the description of established geological units using environmental, taxic, and geographical characteristics. Discrepancies in taxa, method, and weighting of the geophysical have resulted in over 10 untested revisions and the hypothesis of over 100 other units. Using the International Code of Area Nomenclature (ICAN), we aim to produce a systematic review of all Devonian palaeobioregionalisation to act as a foundation for the Devonian palaeobiogeographic studies of the future. The result of this study is an interim bioregionalisation with a strict and consistent diagnosis for rigorous testing.

The completeness of the early hominin fossil record

Simon J. Maxwell[1,2*], Philip J. Hopley[1,2], Paul Upchurch[2] and Christophe Soligo[3]

[1]Department of Earth and Planetary Sciences, Birkbeck, University of London; [2]Department of Earth Sciences, University College London; [3]Department of Anthropology, University College London

The early hominin fossil record is notoriously poor, particularly during the period molecular clock studies estimate the lineage originated, and there is much scope for a quantitative analysis of the biotic, geological, and anthropogenic factors controlling fossil record completeness. Here we assess the completeness of the early African hominin fossil record using the Skeletal and Character Completeness Metric (Mannion and Upchurch, 2010). The average completeness score (Strait and Grine, 2004; Dembo et al., 2015) is plotted through geological time and compared to taxic diversity, number of hominin-bearing formations (HBF) and localities (HBL), abundance of hominin specimens, and a record of continental scale aridity. Preliminary results for the Character Completeness Metric reveal hominin fossil record completeness varies greatly from less than 19% (mostly 0%) during the late Miocene, increasingly gradually through the Plio-Pleistocene. Pairwise tests reveal no significant control of completeness. However, multiple regression model fitting reveals that completeness is best explained by a combination of taxic diversity, HBF, and, to a lesser extent, HBL. That character completeness is best explained by taxic diversity, HBF, and HBL suggests (1) completeness influences the ability of palaeoanthropologists to recognise species, and (2) early hominin fossil record completeness is controlled largely by sampling. These preliminary findings demonstrate that character completeness may be a poor continental-scale proxy for sampling. They also imply a complex interplay between completeness, genuine evolutionary dynamics, and the influence of sampling. The quantification of the Skeletal Completeness Metric is in progress at the time of writing.

Can Foot Surface Area *in vivo* Predict Skeletal Surface Area?

Eleanor Strickson[1*]

[1]Liverpool John Moores University

The surface area of feet in contact with the ground is a key aspect of an animal's locomotion. Dependent upon the size and shape of this area are underfoot pressures (and consequently forces experienced by the foot), and stability of an animal during locomotion. When studying locomotion of extinct taxa, information can be found in both trackways (recorded *in vivo*) and skeletons. However, there is a disconnect in many cases between these sources of information – tracks are produced by the soft tissues surrounding the bones, not the bones themselves. We set out to examine whether the area of a skeletal foot could predict in vivo soft-tissue foot surface area. Computed Tomography (CT) scans of several extant tetrapods (covering mammals, crocodilians, birds and salamanders) were used to produce models of the full extent of both the flesh and the bones of their feet. Models were aligned to the horizontal, approximating life positions, and their outlines projected onto a surface to produce two-dimensional 'footprints'. Areas of these projections were calculated using both convex hulls and alpha shapes, to investigate the best method for consistently calculating area. Convex hulls were highly sensitive to pose (e.g. interdigital angles), while alpha-hulling produced more consistent 'tight-fitting' outlines for area calculation. Under-foot area calculated from osteology alone was generally around 50 to 60% that of the area calculated from a fully-fleshed foot. Primary exceptions to this trend were found in horses (as might be expected) and among crocodilians.

Can the phosphate oxygen palaeothermometer take the temperature of Cambrian oceans?

Thomas Hearing[1,2,*], Thomas Harvey[1], Mark Williams[1], Sarah Gabbott[1], Philip Wilby[2], Melanie Leng[3] and Angela Lamb[3]

[1]Department of Geology, University of Leicester; [2]British Geological Survey, Keyworth; [3]NERC Isotope Geosciences Facilities, British Geological Survey, Keyworth

Stable oxygen isotope ratio (δ18O) data, obtained from carbonate and phosphate biominerals, are routinely used to quantitatively constrain palaeoclimates throughout the Phanerozoic Eon. Whilst a near-continuous global record of δ18O data now exists back to the Early Ordovician, there is a notable absence of data for the climates of the Cambrian Period. This 50 million year data gap exists because phosphatic euconodonts are not known from strata below the uppermost Cambrian, and Cambrian calcareous fossils have so far been found to be diagenetically altered. To address this problem, we investigate phosphatic 'small shelly fossils' (SSFs) as an alternative source of δ18O data. Selected taxa are demonstrably biophosphatic, with known modern analogues and/or well-constrained benthic ecologies and include linguliformean brachiopod shells, tubular *Torellella* and *Hyolithellus* tests, and hallucigeniid spines *Rhombocorniculum*. To determine the potential impact of diagenetic alteration, selected specimens were examined using optical and scanning electron microscopy and X-ray spectroscopy. Both well-preserved and poorly-preserved (late diagenetic) microstructures, ultrastructures and chemical signals could be distinguished in different specimens. Isotope data were collected by bulk and *in situ* sampling methods from both well-preserved and poorly-preserved control specimens. Our preliminary δ18O data consistently discriminate between poorly-preserved late diagenetic and better-preserved isotope values, in line with predictions based on our preservation screening protocol. Importantly, the well-preserved samples yield data that support geological evidence for a Cambrian greenhouse world with a low latitudinal temperature gradient, comparable to Mesozoic hothouse climates. These data provide the first robust quantitative constraints on Cambrian sea surface temperatures.

Inferring the diets of pterosaurs and extant analogues using quantitative 3D textural analysis of tooth microwear

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Pterosaurs (Pterosauria) were a successful group of Mesozoic flying reptiles. For 150 million years they were integral components of terrestrial and coastal ecosystems, yet their feeding ecology remains poorly constrained. Postulated pterosaur diets include insectivory, piscivory and/or carnivory, but many dietary hypotheses are speculative and/or based on little evidence, highlighting the need for alternative approaches to provide robust data. One method involves quantitative analysis of the micron-scale 3D textures of worn pterosaur tooth surfaces – dental microwear texture analysis. Microwear is produced as scratches and chips generated by food items create characteristic tooth surface textures. Microwear analysis has never been applied to pterosaurs, but we might expect microwear textures to differ between pterosaurs with different diets. An important step in investigating pterosaur microwear is to examine microwear from extant organisms with known diets to provide a comparative data set. This has been achieved through analysis of non-occlusal microwear textures in extant bats, crocodilians and monitor lizards, clades within which species exhibit insectivorous, piscivorous and carnivorous diets. The results - the first test of the hypothesis that non-occlusal microwear textures in these extant clades vary with diet - provide the context for the first robust quantitative tests of pterosaur diets.

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James Mckay is a paleoartist specialising in working with researchers to communicate their findings e.g. in papers, textbooks, museum murals and for outreach projects. James is interested in illustrating all forms of prehistoric life, including invertebrates, vertebrates, flora, and palaeoenvironments/landscapes.

James contributed illustrations to the book 'Dinosaurs of the British Isles' by Dean Lomax, and has been published in the Journal of Palaeogeography, Palaeoclimatology, Palaeoecology among others. He has worked with Scarborough Rotunda Museum, Leicester New Walk Museum, Doncaster Museum and the Lapworth Museum. James regularly attends Lyme Regis and Yorkshire Fossil Festival creating live art as a tool for engaging young people in palaeontology.

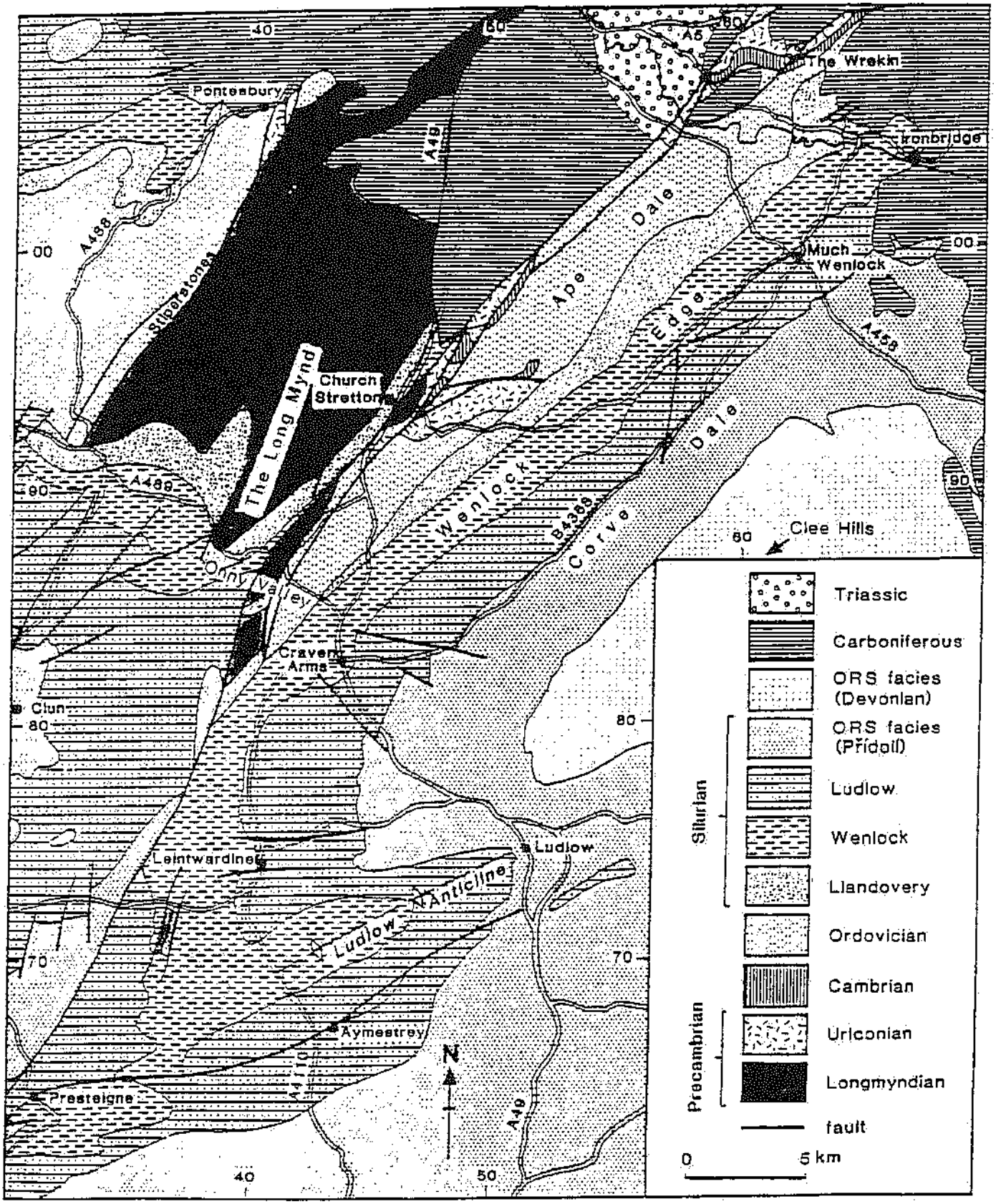
If you are interested in commissioning James to create artwork for your research or outreach projects, contact: jamesmckay76@hotmail.com

ProgPal 2017 Field Trip
'Silurian Saunter'

with

Professor Mark Williams

We will visit some of the important Silurian rock successions in the Ludlow anticline that were formative in establishing the stratigraphy of the Silurian System worldwide. These rocks, deposited on the eastern margin of the Welsh Basin, are highly fossiliferous marine carbonates and mudstones, with a range of shelly fauna, and from deeper marine facies, graptolites: we should be able to collect several different species of the latter. We'll also see the famous 'Ludlow Bone Bed', and the transition into quasi-marine facies at the beginning of the Pridoli Series (the uppermost series of the Silurian) that heralds the onset of 'Old Red Sandstone' facies in southern Britain. And, in the latter rocks, are traces of one of the oldest terrestrial animal communities on planet Earth.



Geologic sketch map of part of Shropshire showing the geology of Wenlock Edge, the Ludlow anticline and immediately adjacent areas

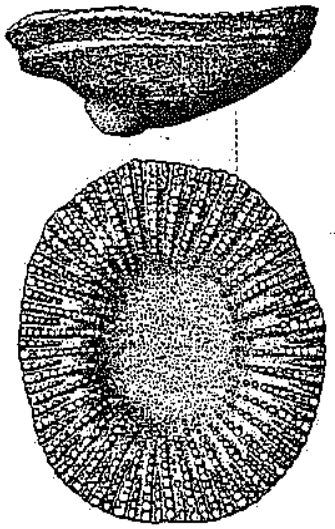
LOCALITIES:

Pitch Coppice SO 4726 7301
Gorsty SO 476 735
Ludlow - 'The Whitcliffe' SO 507 743
Ludlow - Ludford Corner SO 512 741
Trippleton Farm SO 414 737

SYSTEM	SERIES	SUBSTAGES / STAGES	LITHOSTRATIGRAPHY
SILURIAN	PRIDOLI	Stages not yet defined	Ledbury Formation Temeside Shales Formation Downton Castle Sandstone Fm { Sandstone Mbr. / Platyschisma S.Mbr. / Ludlow B.B. Mbr. }
	LUDLOW	Ludfordian	Upper Whitcliffe Formation Lower Whitcliffe Formation Upper Leintwardine Formation Lower Leintwardine Formation
		Gorstian	Upper Bringewood Formation Lower Bringewood Formation Upper Elton Formation Lower Elton Formation
	WENLOCK	Homerian	Much Wenlock Limestone Formation Coalbrookdale Formation { Farley Member / Apedale Member }
		Sheinwoodian	Buildwas Formation
	LLANDOVERY	Telychian	Purple Shales Pentamerus Beds
		Aeronian	Kenley Grit
ORDOVICIAN	CARADOC	Onnian	Onny Shale Formation
		Actonian	Acton Scott Formation
		Marshbrookian	Cheney Longville Formation
		Woolstonian	Alternata Limestone Formation
		Longvillian	Horderley Sandstone Formation
		Soudleyan	Glenburrell Formation
		Harnagian	Smeathen Wood Formation
		Costonian	Coston Formation
	TREMADOC	Migneintian	Shineton Shales
		Cressagian	
CAMBRIAN	MERIONETH	Stages not yet defined	Bentleyford Shales Shoot Rough Road Shales
	ST. DAVID'S		Upper Comley Group
	COMLEY		Lower Comley Limestone Lower Comley Sandstone Wrekin Quartzite
PRE-CAMBRIAN	Series not yet defined		Longmyndian: Wentnor Group: Bridges Formation, Bayston-Oakswood Formation Longmyndian: Stretton Group: Portway Formation, Lightspout Formation, Synalds Formation, Burway Formation, Stretton Shale Formation Uriconian Volcanics

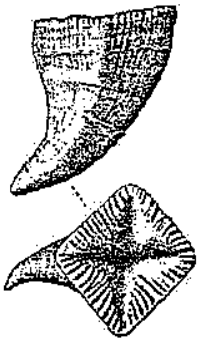
Generalised stratigraphical succession of the Pre-Cambrian and Lower Palaeozoic of Shropshire (eastern part).

Silurian Corals

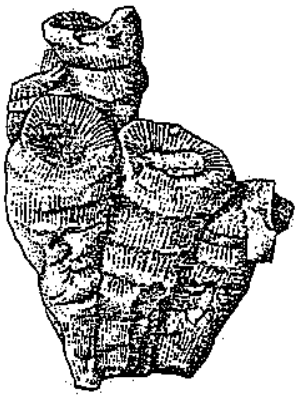


Rhabdocyclus fletcheri

Ketophyllum subturbinatum



Goniophyllum pyramidale

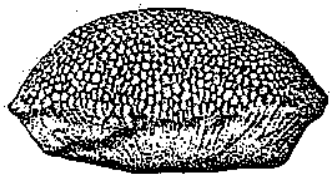


Kodonophyllum truncatum

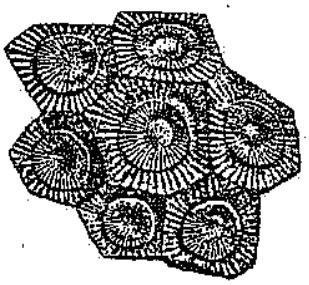
Heliolites interstinctus

Tryplasma loveni

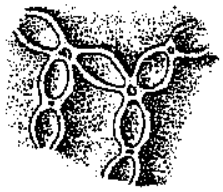
Thamnopora cristata



Favosites gothlandicus



Acervularia ananas



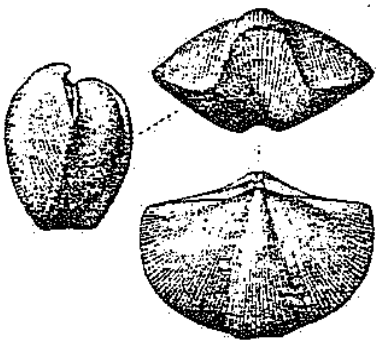
Halysites catenularius

Arachnophyllum murchisoni

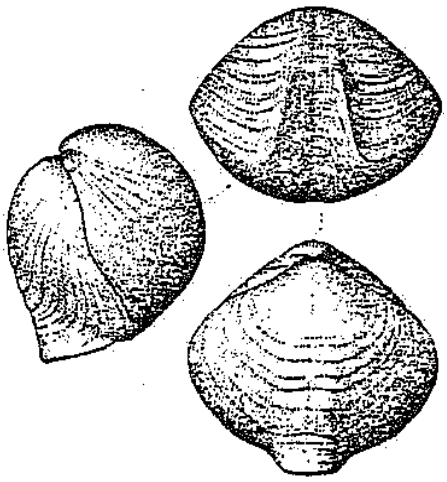
Silurian Brachiopods

13.

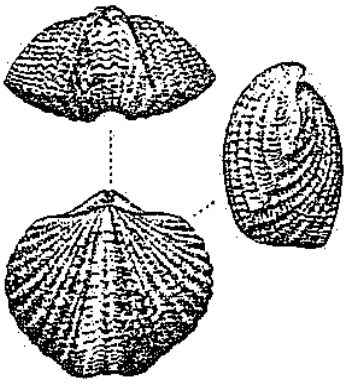
Atrypa reticularis



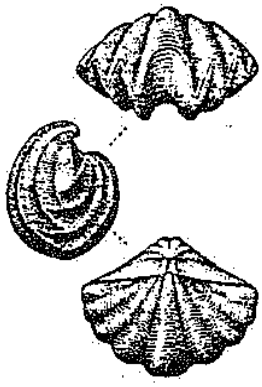
Eospirifer radiatus



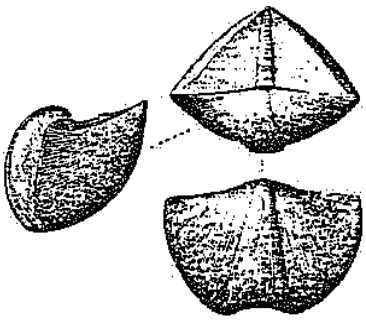
Meristina obtusa



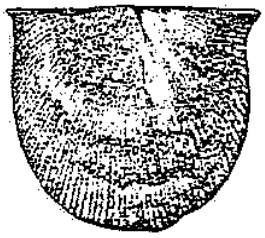
Plectatrypa imbricata



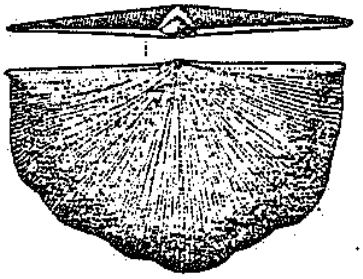
Howellella elegans



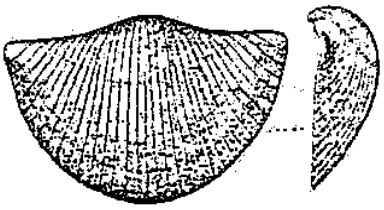
Cyrtia exporrecta



Strophonella euglypha



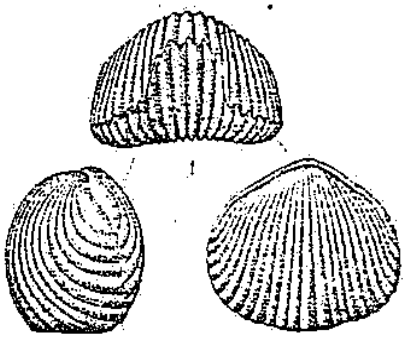
Strophonella funiculata



Plectodonta transversalis

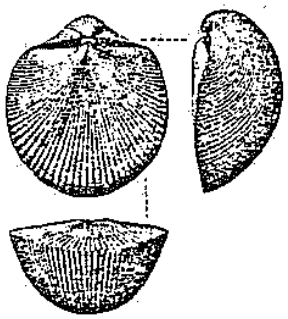
Dolerorthis rustica

Leptaena rhomboidalis

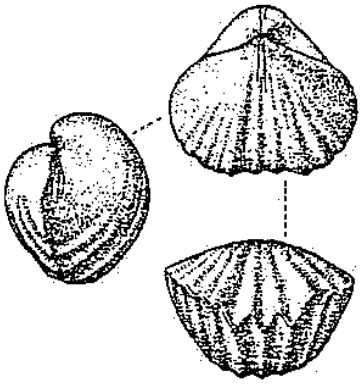


Trigonirhynchia stricklandi

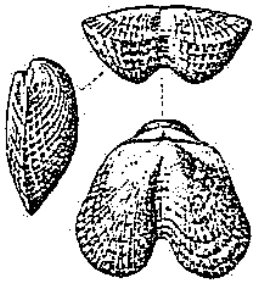
Silurian Brachiopods



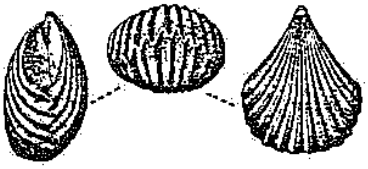
Resserella elegantula



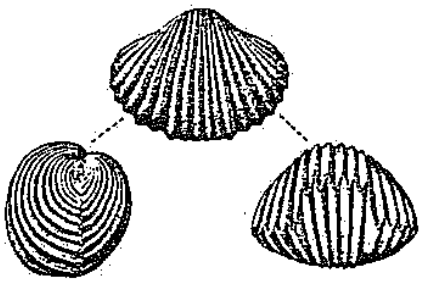
Gypidula dudleyensis



Dicoelosia biloba

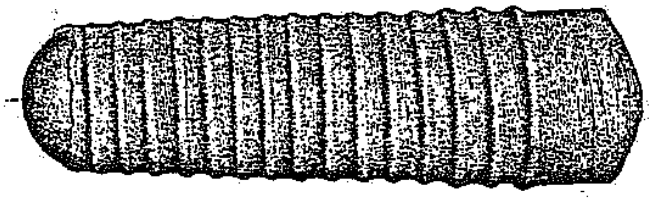


Rhynchotreta cuneata

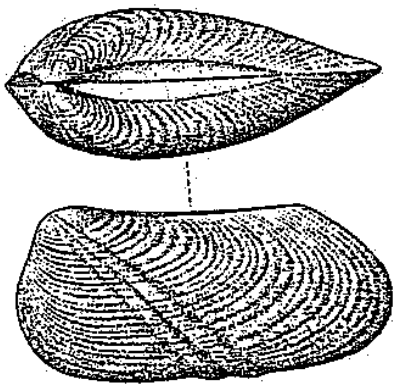


Anastrophia deflexa

Silurian Molluscs

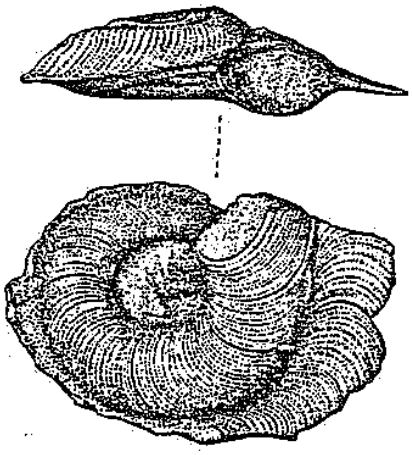


Dawsonoceras annulatum



Grammysia cingulata

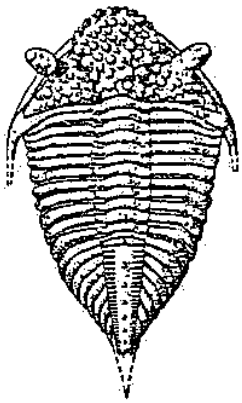
Platyceras haliotis



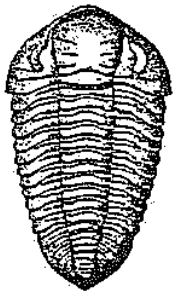
Euomphalopterus alatus

Pteronitella retroflexa

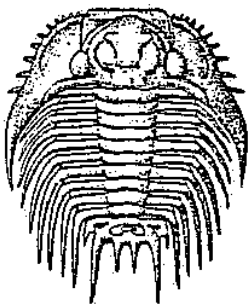
Silurian Trilobites



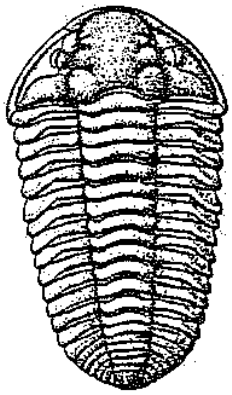
Encrinurus punctatus



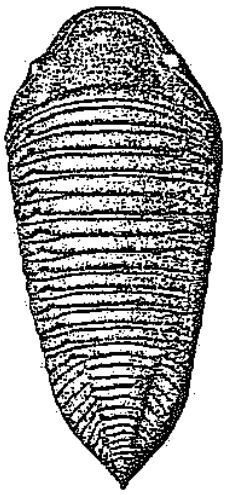
Acaste downingiae



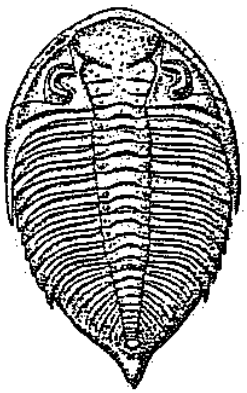
Acidaspis deflexa



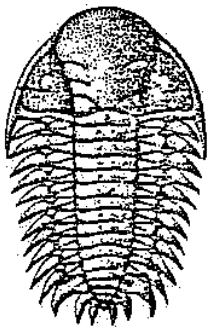
Calymene blumenbachi



Trimerus delphinocephalus

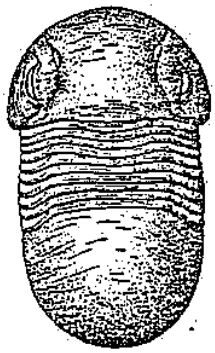


Dalmanites myops

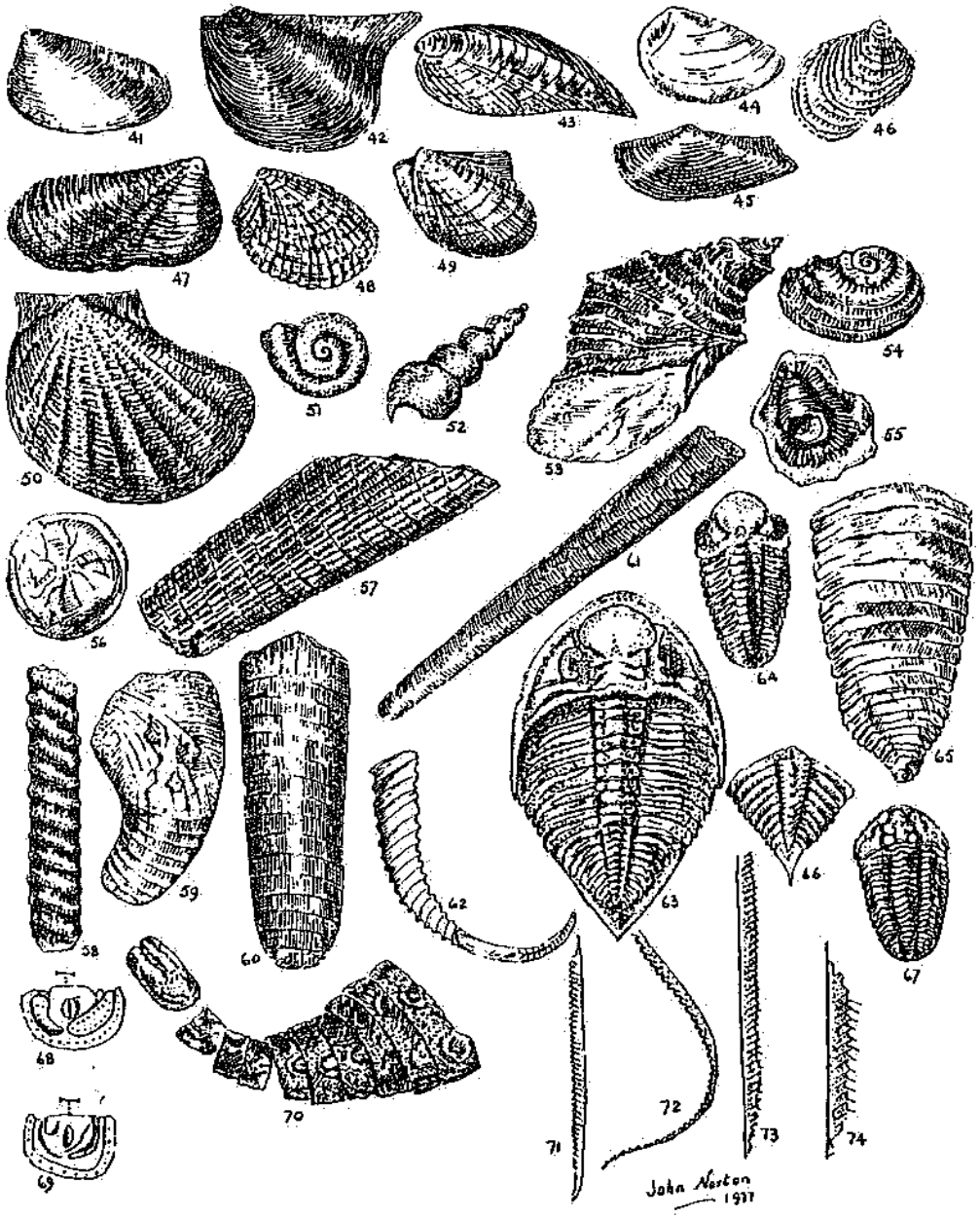


Cheirurus bimucronatus

Phacops stokesi



Bumastus barriensis



Ludlow fossil drawings 41—74

KEY TO LUDLOW FOSSIL DRAWINGS

Superceded, but often more familiar names, have been placed in square brackets.

41 to 50 are bivalves

41. *Fuchsella* [*Orthonota*] *amygdalina*
42. *Pteronitella* [*Pterinea*] *retroflexa*
43. *Goniophora cymbaeformis*
44. *Nuculites* [*Cucullella*] *antiquus*
45. *Praectenodonta* [*Tancrediopsis*] *ludensis*
46. *Cypricardinia* cf. *subplanulata*
47. *Grammysia* cf. *cingulata*
48. *Cardiola* [*Slava*] *interrupta*
49. *Ptychopteria* [*Pterinea*] *tenuistriata*
50. *Palaeopecten danbyi*

51 to 55 are gastropods

51. *"Platyschisma" helicites*
52. *Lokonema* [*Holopella*] *obsoletum*
53. *Bembexia* [*Murchisonia*] *lloydii*
54. *Poleumita* [*Horiostoma*] sp.
55. *Cyclonema* [*Turbo*] *corallii* (overgrown by bryozoa)

56 to 62 are cephalopods

56. *Laurocycloceras whitcliffensis*
57. *Kionoceras angulatum*
58. *"Orthoceras" ibex*
59. *"Cyrtoceras" intermedium*
60. *Michelinoceras* [*Orthoceras*] *bullatum*
61. *"Orthoceras"* sp. [*"Orthoceras" subundulatum* of authors]
62. *"Lituites" ibex*

63 to 66 are trilobites

63. *Dalmanites myops* [= *Dalmanites vulgaris* of authors]
64. *Phacops* sp.
65. *Homalonotus knightii* (body and tail)
66. *Encrinurus* sp. (tail)
67. *Calymene* sp.

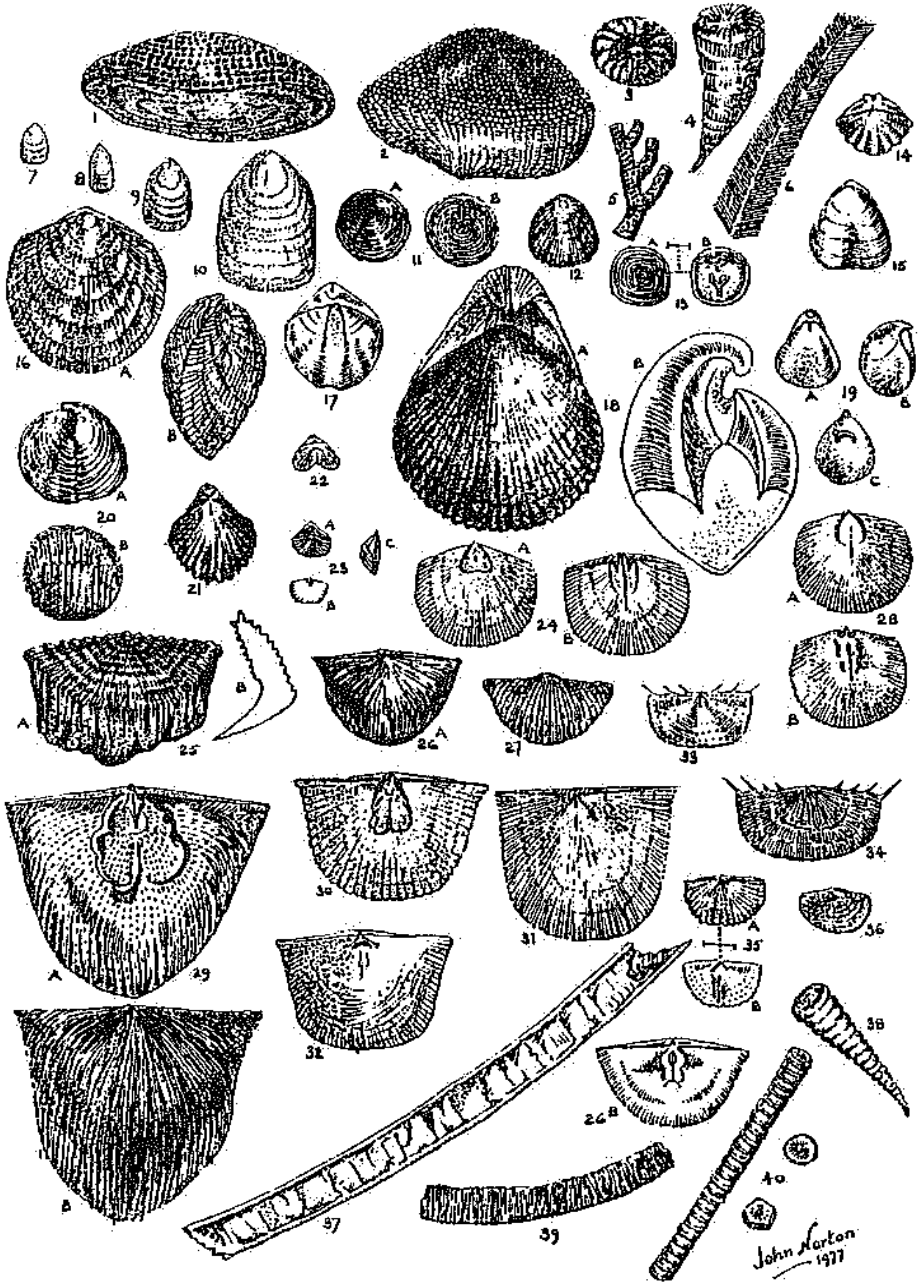
68 and 69 are ostracods; 70 a eurypterid

68. *Neobeyrichia torosa*
69. *Neobeyrichia lauensis*
70. *Pterygotus* sp.

71 to 74 are graptolites

71. *Pristiograptus* [*Monograptus*] *tumescens*
72. *Neodiversograptus* [*Monograptus*] *nilssoni*
73. *Saetograptus* [*Monograptus*] *colonus*
74. *Saetograptus* [*Monograptus*] *leintwardinensis*

N.B. The sketches are approximately natural size, except where enlargement is indicated.



Ludlow fossil drawings 1—40

KEY TO LUDLOW FOSSIL DRAWINGS

Superceded, but often more familiar names, have been placed in square brackets.

1 to 4 are corals

1. *Heliolites interstinctus* } colonial corals
2. *Favosites gothlandicus* }
3. *Rhabdocyclus porpitoides* ('button coral')
4. solitary rugose 'horn coral'

5 and 6 are bryozoans

5. stick bryozoan
6. *Ptilodictya lanceolata*

7 to 36 are all brachiopods

7. *Lingula lata*
8. *Lingula minima*
9. *Lingula cornea*
10. *Lingula lewisii*
11. *Orbiculoidea rugata* (A, dorsal & B, ventral valve)
12. *Schizocrania* [*Orbiculoidea*] *striata* (dorsal valve)
13. *Craniops* [*Pholidops*] *implicata* (A, dorsal & B, ventral valve, internal enlarged)
14. *Howellella* [*Delthyris*] *elegans*
15. *Hyattella* [*Whitfieldella*] *canalis* [= *Meristella didyma* of authors]
16. *Atrypa reticularis* (A, dorsal view & B, side view)
17. *Gypidula lata*
18. *Kirkidium* [*Conchidium*] *knightii*
19. *Dayia navicula* (A, dorsal view, B, side view & C, ventral internal)
20. *Sphaerirhynchia* [*Wilsonia*] *wilsoni* (A, side view & B, anterior view)
21. *Microsphaeridiorhynchus* [*Camarotoechia*] *nucula*
22. *Dicoelosia* [*Bilobites*] *biloba*
23. *Skenidioides* [*Skenidium*] *lewisii* (A, dorsal view, B, dorsal internal & C, side view)
24. *Salopina* [*Dalmanella*] *lunata* (A, ventral internal & B, dorsal internal)
25. *Leptaena depressa* [= *Leptaena rhomboidalis* of authors] (A, ventral view & B, cross section)
26. *Amphistrophia* [*Strophonella*] *funiculata* (A, dorsal view & B, ventral internal)
27. *Eoplectodonta* cf. *duvalii* [= *Plectodonta transversalis* of authors]
28. *Isorthis* [*Dalmanella*] *orbicularis* (A, ventral internal & B, dorsal internal)
29. *Strophonella euglypha* (A, ventral internal & B, dorsal valve)
30. *Shaleria* [*Brachyprion*] *ornatella* (ventral internal)
31. *Leptostrophia filosa* (ventral internal)
32. *Coolinia* [*Fardenia*] *pecten* (ventral internal)
33. *Shagamella ludloviensis* [= *Chonetes lepisma* of authors] (ventral internal)
34. *Protochonetes ludloviensis* [= *Chonetes striatellus* of authors]
35. *Aegiria* [*Chonetoidea*] *grayi* (A, dorsal view & B, ventral internal)
36. *Mesopholidostrophia* cf. *lepisma* [= Brachyprion sp. nov. of authors, but not *Chonetes lepisma*]

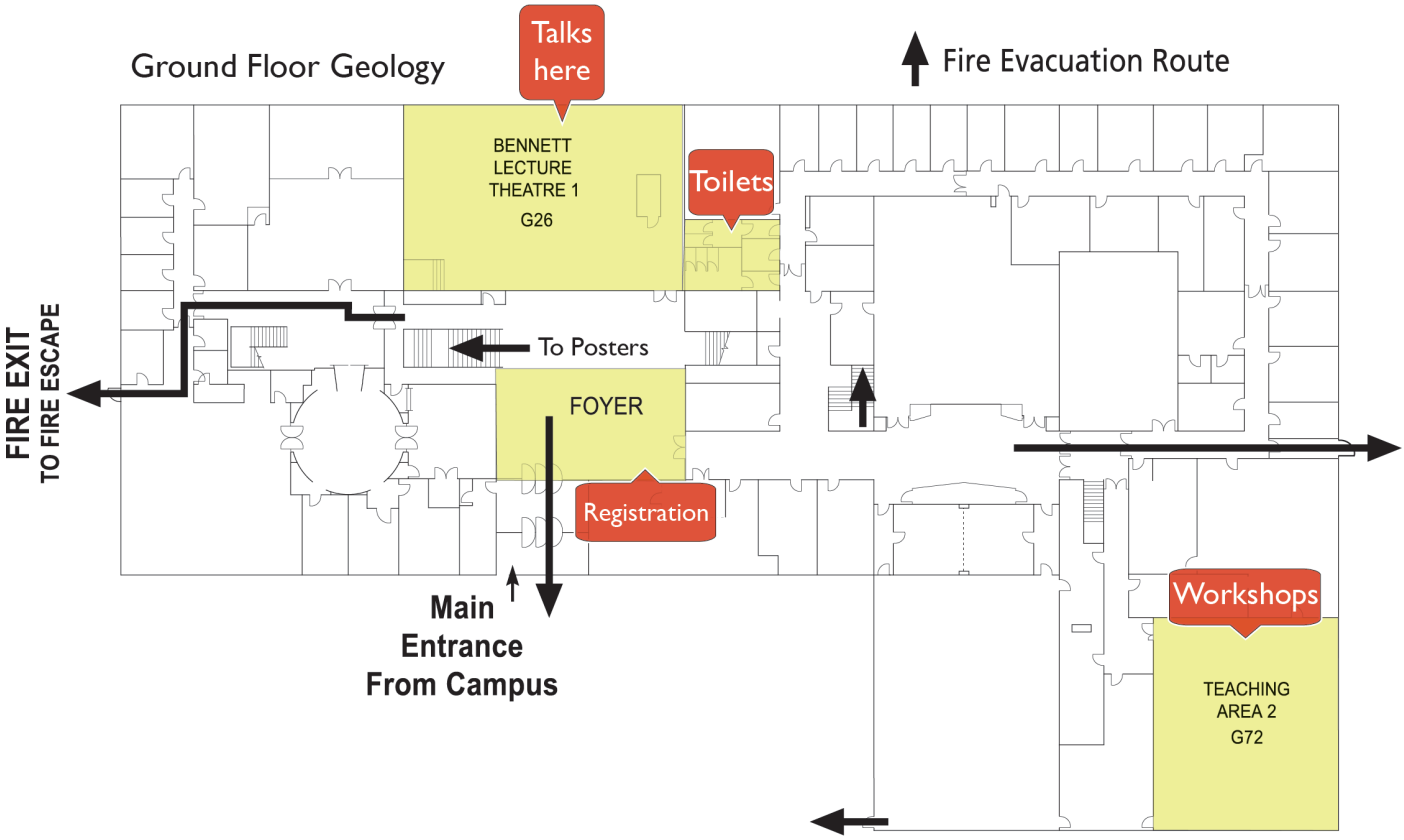
37 to 39 are fossil remains of worms

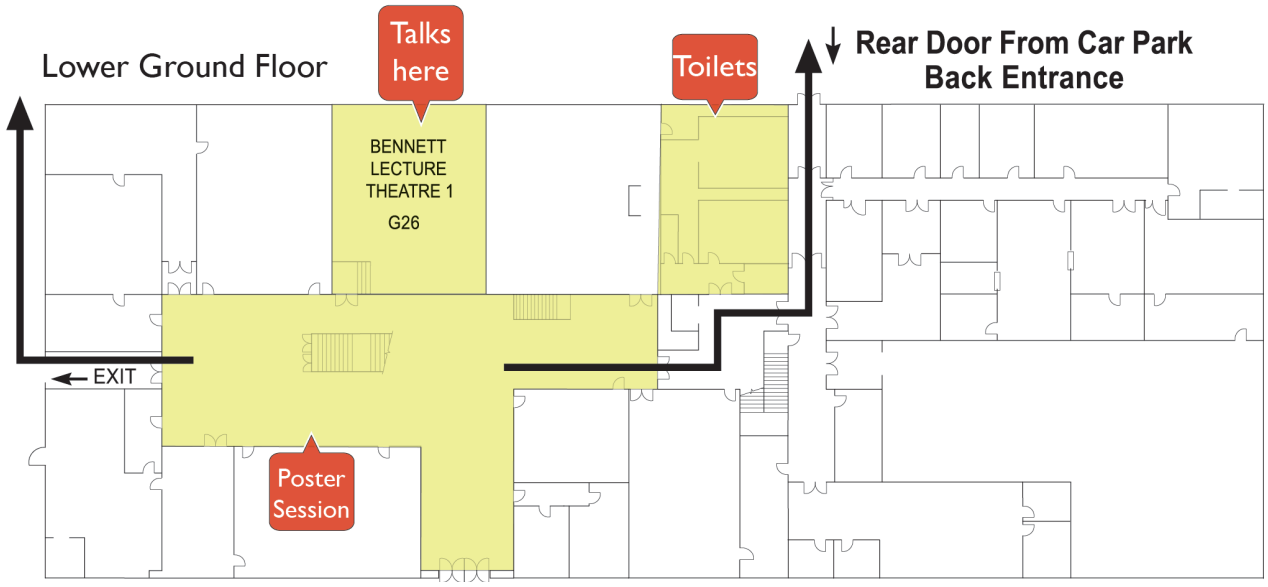
37. *Serpuloides* [*Serpulites*] *longissimus*
38. *Cornulites serpularius*
39. *Kailorites squamosus*

40. crinoid stem (part of), and columnals.

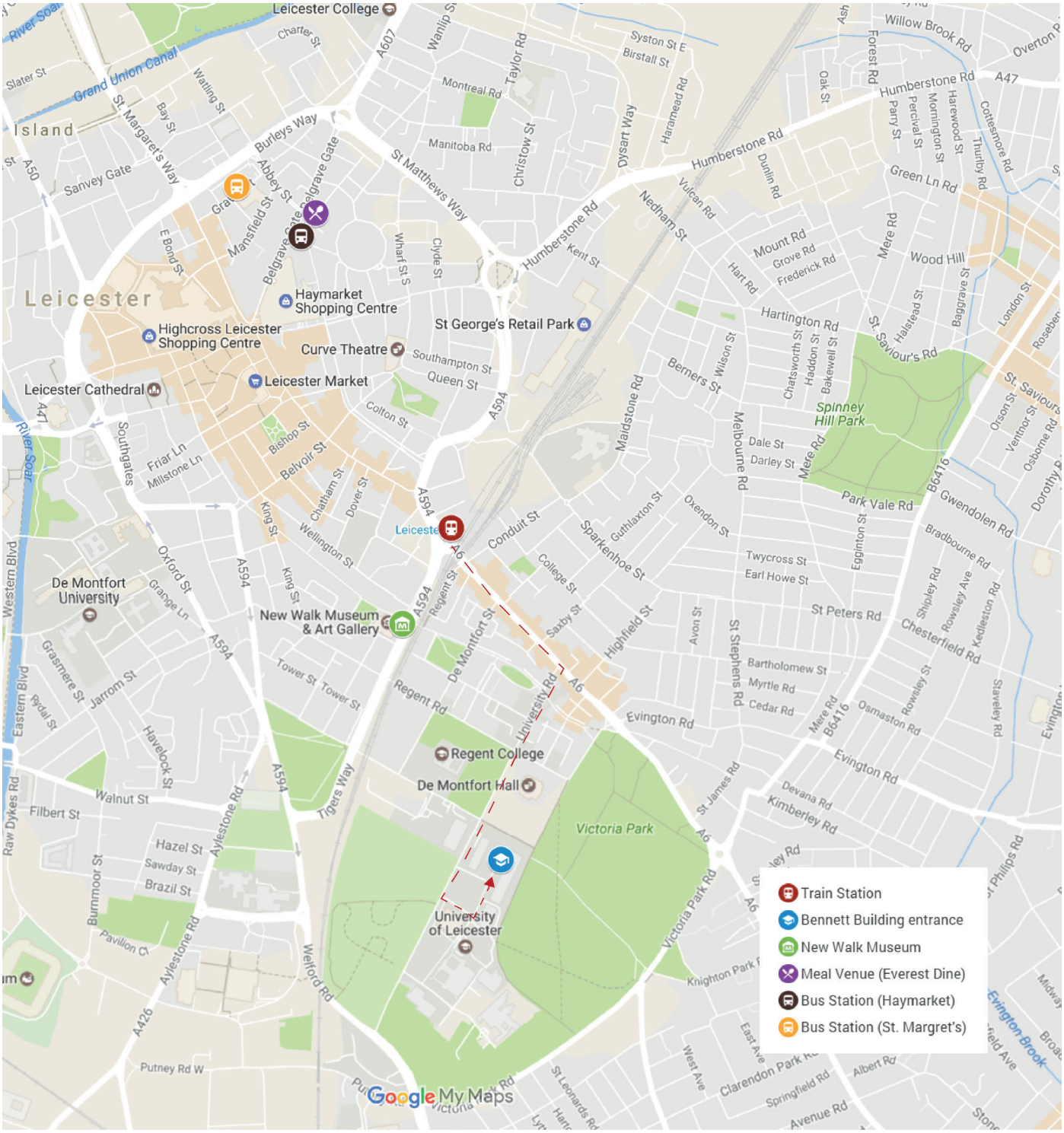
N.B. The sketches are approximately natural size, except where enlargement is indicated.

Bennett Building Floorplan





Leicester map with key locations highlighted. Suggested walking route from the train station to the University of Leicester Bennett building (location of ProgPal 2017) is indicated.



University of Leicester Campus Map

www.le.ac.uk/maps