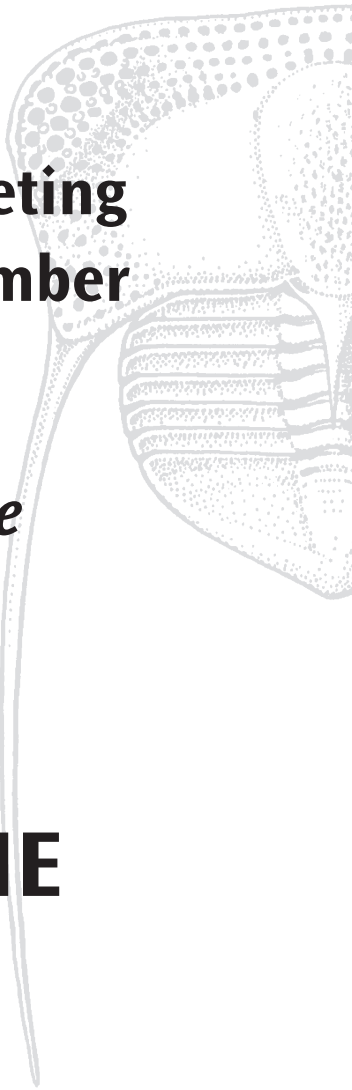
The Palaeontological Association

56th Annual Meeting

16th–18th December 2012

University College Dublin



PROGRAMME and ABSTRACTS

The Palaeontological Association

56th Annual Meeting

16th–18th December 2012

UCD School of Geological Sciences, University College Dublin

The programme and abstracts for the 56th Annual Meeting of the Palaeontological Association are provided after the following summary of the meeting.

Venue

The meeting will take place on the Belfield campus of University College Dublin, which is approximately 4km south of the city centre. Directions to the University and a campus map can be found at <**http://www.ucd.ie/visitors/**>. Two pdf versions of the campus map, one annotated with information relevant to the Annual Meeting, can be downloaded from the homepage of the Palaeontological Association website (**www.palass.org**).

Accommodation

Delegates should book their own accommodation unless advised otherwise. The recommended accommodation is based in the Smithfield area of Dublin city centre, as this is where our evening social activities, including the Annual Dinner, will be held; a map of this area can be downloaded from the homepage of the Palaeontological Association website (**www.palass.org**).

If you would prefer to stay in the vicinity of the UCD campus there are a number of guesthouses and two (moderately expensive) hotels nearby:

(a) Radisson Blu St Helen's Hotel, Dublin Stillorgan Road, Blackrock, Dublin 4 (003531 218 6000)

(b) Stillorgan Park Hotel, Stillorgan Rd, Mount Merrion, Stillorgan, Dublin 18 (003531 200 1800)

We have reserved a limited number of rooms at preferential rates at the following two hotels and one hostel; these are available on a first-come-first-served basis. Please note carefully the booking procedure to ensure you avail yourself of the discounted rates. The Generator Hostel and the Maldron Hotel are less than two minutes walk from each other and the venue for the Annual Dinner. The Jury's Inn, Christchurch is about ten minutes' walk from the others.

(a) Maldron Hotel, Smithfield, Dublin 7:

<**http://www.maldronhotelsmithfield.com/**>

• €65.00 B&B per room per night for a single

• €75.00 B&B for a twin/double

To obtain the discounted rates book directly rather than online, via the following:

Telephone: + 353 (0)1 485 0900
Fax: + 353 (0)1 485 0910
E-mail: <**res.smithfield@maldronhotels.com**>

Ensure that you direct your booking 'For the attention of Mr Philip Downes Reservations Supervisor.' and quote 'PALASS2012'.

(b) Generator Hostel Dublin, Smithfield Square, Dublin 7.

<**http://www.generatorhostels.com/en/dublin/**>

We have reserved a limited number of each of the following in this recently refurbished and very well appointed 'hotel-style hostel':

• twin-bedded rooms ensuite @ €40.00 per room per night

• six-bedded rooms ensuite @ €10.00 per bed per night

• four-bedded rooms ensuite @ €11.00 per bed per night

To obtain these rates ensure that you contact the hostel directly (*i.e.* do not book online) and ensure you use the code: "Palass & BSRG":

E-mail: <**louise.lawlor@generatorhostels.com**> or <**Jodie.hanratty@generatorhostels.com**>
Telephone: +353 1901 0222.

(c) Jury's Inn, Christchurch

<**http://www.jurysinns.com/**>

Saturday 15th December:
• €89.00 (bed & breakfast, single)
• €99.00 (bed & breakfast, twin / double)

Sunday 16th – Tuesday 18th December:
• €65.00 (bed & breakfast, single)
• €75.00 (bed & breakfast, twin / double)

Breakfast is available in the Innfusion Restaurant from 07.00 till 10.00. The rates are per room, per night and include VAT at 9% (which is subject to change without notice).

To make a booking download and complete the booking form available on the conference website at <**www.palass.org**>. The form should be faxed (0044 161 774 0291) or e-mailed (<**ireland@jurysinns.com**>) to Jury's Inn Central Reservations Department. Ensure you quote the reference **PALA161212**. A credit card number is required at the time of booking as a guarantee for the room. The final cut-off date for this booking is **29th November 2012**. Cancellation of any booking will incur charges, details of which can be found on the booking form.

Travel

Dublin is served by Dublin International Airport, which is located north of Dublin City Centre. There are direct air links into Dublin from a large number of airports globally, and, in particular, from Britain, continental Europe and North America. Irish airlines serving the airport are Aer Lingus (<**www.aerlingus.com**>), Aer Arann (<**www.aerarann.com**>) and Ryanair (<**www.ryanair.com**>), with regular flights from most other international carriers. See <**http://www.dublinairport.com/gns/flight-information/destinations-airlines.aspx**> or <**http://www.meetinireland.com/**> for further details.

For those who wish to avoid flying, Dublin can be reached by combining rail or bus links to a number of ferry terminals in Scotland, England and Wales. Some routes also cross to southern Ireland from Brittany and Roscoff in France. However the weather may be rough in December and ferries delayed or cancelled. See <**http://www.aferry.co.uk/ferry-to-ireland-irish-ferries-uk.htm**> for more details on prices and routes.

Transferring from the airport

There are frequent connecting buses from the airport to the city centre, including a shuttle service, Airlink (747), which brings passengers to Busáras (Central Bus Station, Dublin) and terminates at Heuston railway station. Further details are available at <**http://www.dublinbus.ie/**>. Aircoach operates a service from Dublin Airport to Leopardstown / Sandyford / Stillorgan which passes the main entrance to the UCD Belfield campus. Further details are available at <**http://www.aircoach.ie/**>. Taxis from the airport should cost no more than €40 to the city centre and €50 to UCD.

Train

Dublin is served by two main railway stations: Connolly Station and Heuston Station. It is a short walk from Connolly Station to O'Connell Street, where the Dublin Bus numbers 11 and 46A can be boarded for UCD. The route 145 provides a direct route from Heuston Station to Belfield via the city centre. For further information please visit Iarnróad Eireann (Irish Rail) (<**http://www.irishrail.ie/**>).

Bus – Dublin Bus

Dublin Bus numbers 11, 39A, 46A and 145 all provide services to the Belfield campus. The 39A terminates within the Belfield campus, and can be boarded at the Quays adjacent to Smithfield. Numbers 11 and 46A can be boarded at O'Connell Street. Several additional Xpresso services operate directly to campus during morning and evening peak times; these include the 25X, 66X and 67X that can be boarded in the vicinity of Smithfield at peak times in the morning. For services that do not terminate on the campus itself (ask your driver) ask for the 'UCD/Montrose Hotel' stop or, if on the 11 service, the 'AIB Clonskeagh' stop. These are opposite the main N11 entrance, and beside the Clonskeagh entrance, to campus respectively. An annotated map of the relevant bus services and location of the stops around the Smithfield area can be downloaded from <**www.palass.org**>. For timetable information please visit the Dublin Bus website (<**http://www.dublinbus.ie/**>) and search for "University College Dublin".

Please Note: Exact monies are required: bus drivers do not provide change.

Taxi

There are usually abundant taxis in operation in the city centre at any given time. It is possible to hail a taxi from the street, but convenient taxi ranks in the city centre are located on O'Connell Street, Middle Abbey Street, Dame Street and St Stephen's Green. Please note that vehicular access

to, and through, the campus is limited at certain times of the day and evening. Vehicles may not travel through the campus between 07.00 and 10.30, and 16.30 and 19.30. The 'Greenfield' entrance to campus is the closest to the conference venue but is for pedestrians only. It is about a two minute walk from this entrance to the Health Sciences Building and the route will be signposted. This entrance is accessed from Greenfield Park; advise your taxi driver that the turning is off the Stillorgan Road opposite RTE. If you require vehicular access to Health Sciences itself then use the 'Clonskeagh' entrance.

Coach service between Smithfield and Belfield

For those who selected this option at the time of booking, a coach service will transfer you directly between UCD and the Smithfield area in the city centre. We will provide further details on speciifc pick-up points in the delegates' packs and on notices displayed in the Malvern Hotel and Generator Hostel. The coaches will depart at the following times:

(a) Sunday 16th December, from UCD, after the 'Welcome Reception' circa 22.30.

(b) Monday 17th December to UCD at 07.40 **promptly**.

(c) Monday 17th December to Smithfield at 18.15 **promptly**.

(d) Tuesday 18th December to UCD at 08.00 **promptly**.

(e) If booked separately Tuesday 18th December to Smithfield after 'PalAss/BSRG Reception' *ca.* 21.30.

Delegates should make their own way to the Belfield campus on Sunday 16th December.

Car parking is available on the UCD campus; this is currently a mix of free parking and pay-and-display. Please ensure which you are in; parking regulations are enforced strictly. Car parks fill up very quickly in the morning; you are unlikely to find a place afer 09.00.

Registration at the conference

Registration will take place in the foyer of the UCD Student Centre from 12.30 to 20.00 on Sunday 16th December, and in the foyer of the UCD Health Sciences building from 08.00 to 17.00 on Monday 17th December.

Symposium

The opening symposium on 'Taphonomy and the fidelity of the fossil record' will take place in the Astra Hall of the UCD Student Centre beginning at 13.45 on Sunday 16th December.

Sunday evening meal

For those who have booked it, a light evening meal will be available in the UCD Student Centre between the Symposium and the Annual Address.

Annual Address

The Annual Address – sponsored by the Palaeontological Association and University College Dublin – will be given at 19.15 on Sunday 16th December by Professor Chris Stringer FRS, of the Natural History Museum, London on 'New views on the origin of our own species'. This will be held in the Astra Hall of the UCD Student Centre.

Welcome Reception hosted by Fáilte Ireland

This will commence at 20.30 and will take place in the foyer of the UCD Student Centre. A coach service to Smithfield afterwards is available for those who have booked it.

Oral and poster sessions

These will take place on Monday 17th and Tuesday 18th December in the UCD College of Health Sciences building. Single sessions will be held in Lecture Theatre B004, and the parallel sessions in two adjacent lecture theatres (C004 and C005). All are on the ground floor of the building, which is wheelchair accessible. Posters and exhibitors' stands will be in, and tea and coffees served in, the foyers adjacent to these three theatres.

There will be a dedicated poster session from 08.45 – 10.00 on Monday 19th December. Each poster will be assigned a single poster board approximately 2m tall and 1m wide. Volunteers will be present to assist contributors in putting up their posters; access to the poster boards will be from Monday morning onwards. Please only affix your poster to the board in the allocated space and using the fixing materials provided. Do not use Blu-Tak, pins, tacks or any other fixing material you have brought yourself.

Those who do not wish to travel with their poster (*e.g.*, because of luggage restrictions) may post it to the organisers in advance, and collect it upon arrival.

Drinks Reception & Annual Dinner

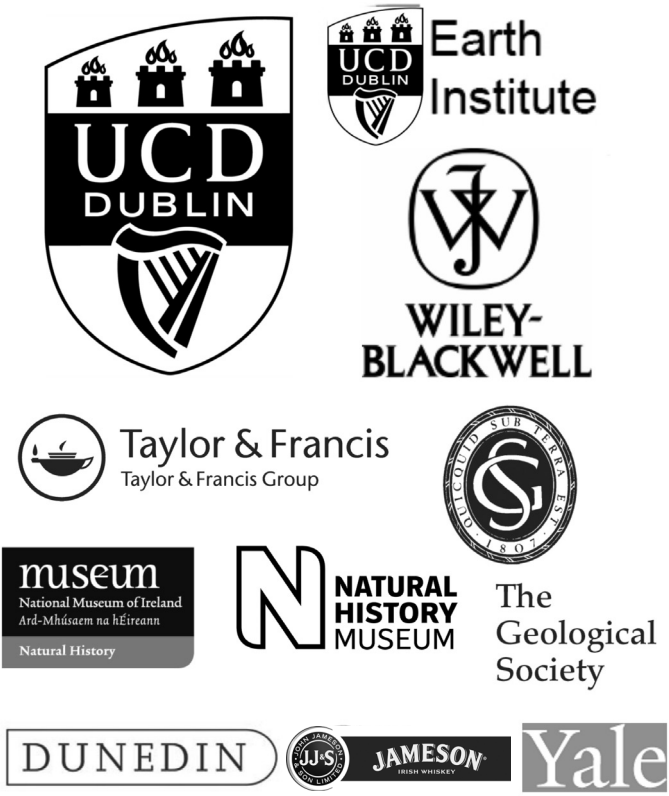
There will be a drinks reception, hosted by Wiley-Blackwell, followed by the Annual Dinner in the Old Jameson Distillery, Smithfield (beside the Generator Hostel and Maldron Hotel). The drinks reception will commence at 19.15, followed by a short tour of the distillery, a complimentary whiskey cocktail, with the dinner itself commencing around 20.00.

UCD Earth Institute Lecture

The UCD Earth Institute lecture in association with the Geological Survey of Ireland and the Geological Survey of Northern Ireland will be given at 18.15 on Tuesday 18th December by Professor Andy Knoll, of Harvard University on 'Systems Paleobiology: Physiology as the link between biological and environmental history'. This will be held in Lecture Theatre B004 in the Health Sciences Building.

Acknowledgements

We would like to express our appreciation to our sponsors and exhibitors for their invaluable support of this meeting (highlighted on the following two pages).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Schedule of events and timetable for presentations

Sunday 16th December 2012

Thematic Symposium: "Taphonomy and the Fidelity of the Fossil Record"

Astra Hall, UCD Student Centre.

Chair: Prof. Jane E. Francis

13.50 **Welcome and Introductory Remarks**
Prof. Stephen Daly (Head of School, UCD School of Geological Sciences)

14.00 **The limits of the fossil record: how far can the exceptions extend?**
Derek Briggs

14:30 **Wetland bias and T^0 conditions: ecological and ecophysiological filtering dominate the fossil record of hot spring floras**
Alan Channing

15.00 **A taphonomic foundation for Conservation Palaeobiology: Using death assemblages to evaluate modern ecosystems**
Susan Kidwell

15.30 Coffee break

16.00 **Experimental taphonomy of colour in fossil insects and feathers**
Maria McNamara

16.30 **Taphonomy distorts phylogeny**
Rob Sansom

17.00 **Tissue chemical records of animal behaviour – new possibilities or pipe dreams still?**
Clive Trueman

17.45–19.00 A light meal is available to delegates

Annual Address

19.15 **New views on the origin of our species**
Chris Stringer (Department of Earth Sciences, Natural History Museum, London)

Reception

20.30 Icebreaker reception hosted by Fáilte Ireland

Monday 17th December

Oral Presentations

* Candidates for the President's Award are marked with an asterisk.
+ denotes speaker other than first author.

8.50 **Welcome** by Dr Hugh Brady, President, University College Dublin.

Session 1: B004

9.00 **Early complexity of brain and eye structure in Cambrian arthropods**
Gregory Edgecombe, Xioaya Ma, M. S. Y. Lee, and N. J.Strausfeld

9.15 **A re-examination of *Anomalocaris* from the Burgess Shale and the functional morphology of anomalocaridids**
* Allison C. Daley and Gregory D. Edgecombe

9.30 **Head-butt for *Sidneya***
* Martin Stein

9.45 **A new view on *Nematothallus*: non-mineralizing coralline red algae from the Silurian of Gotland**
* Martin R. Smith and Nicholas J. Butterfield

10.00 **Early Cambrian microfauna from Northern Montagne Noire (Southern France): Biostratigraphic and paleogeographic significance**
* Lea Devaere, Sebastien Clausen and Michael Steiner

10.15 **Non-shelly "small shellies": demineralized paraconodonts, palaeoscolecids, and ?*Anatolepis* from the Deadwood Formation (Middle to Late Cambrian) of subsurface Saskatchewan, Canada**
* Thomas H. P. Harvey, Martin R. Smith, Javier Ortega-Hernández, G. S. Nowlan, and Nicholas J. Butterfield

10.30–11.00 Coffee

Session 2A: C004

11.00 **Microfossil adventures in the Iron Age**
Mark Williams, Jeremy Taylor, Ian Wilkinson, Ian Whitbread, Ian Boomer, Rebecca Stamp and Emma Yates

11.15 **Palynological analysis of the 2004 tsunami deposits of Khao Lak coast Thailand: comparison with Jurassic paleo-tsunami sediments from Sweden**
Vivi Vajda

11.30 **Classification of grass pollen using pattern analysis of texture**
* Luke Mander, Mao Li, Washington Mio and Surangi W. Punyasena

11.45 **Improving reconstructions of plant biodiversity from fossil pollen assemblages: super-resolution microscopy, machine learning, and bioimage informatics**
* Surangi W. Punyasena, Luke Mander, Washington Mio and David K. Tcheng

12.00 **Understanding amber deposits through modern resin studies**
* Leyla J. Seyfullah, Christina Beimforde, Vincent Perrichot, Jouko Rikkinen and Alexander R. Schmidt

12.15 **Revision of *Acrotreta socialis*, clarifying 150 years of confusion**
* Timothy P. Topper and David A. T. Harper

12.30 **Early Silurian (Aeronian) faunas of north-eastern Iran: a new insight on post-extinction recovery patterns in temperate-latitude Gondwana**
* Mansoureh Ghobadi Pour, Leonid E. Popov, Hadi Jahangir, Caroline Buttler, David Evans, David and Anna Suyarkova

12.45–13.45 Lunch

Session 2B: C005

11.00 **Exceptionally preserved red algal fossil Leveilleites hartnageli from Kalana quarry, Estonia**
* Viirika Mastik and Oive Tinn

11.15 **The Jurassic beetroot stone: a pink and white puzzle revisited**
* Holly E. Barden, Melanie J. Leng, Nicholas P. Edwards, Sam W. Webb, Uwe Bergmann, Phil L. Manning, Roy A. Wogelius and Bart E. van Dongen

11.30 **To see and be seen: sight and stripes in early vertebrates**
Sarah E. Gabbott, Mark A. Purnell and Robert S. Sansom

11.45 **Experimental decay of velvet worms (onychophorans) and taphonomic bias in the lobopodian fossil record**
Mark A. Purnell, Duncan J. E. Murdock and Sarah E. Gabbott

12.00 **Burgess Shale-type Preservation**
Robert R. Gaines

12.15 **Soft-part preservation in heteromorph ammonites from the Cenomanian–Turonian Boundary Event (OAE 2) in the Teutoburger Wald (Germany)**
Christian Klug, Wolfgang Riegraf and Jens Lehmann

12.30 **Virtual Palaeontology and the largest collection of 3D digital fossils? – The GB/3D fossil types online portal**
Mike P. A. Howe

12.45–13.45 Lunch

Session 3A: C004

13.45 **Correlation between the Palaeozoic diversification of alluvial sedimentary facies and the terrestrialization of plants and animals**
Neil S. Davies and Martin R. Gibling

14.00 **Time series analysis in distal shelf sediments, Middle Ordovician, Baltica**
Jan A. Rasmussen

14.15 **The Early Miocene Cape Melville Formation fossil assemblage from King George Island, Antarctica**
Rowan J. Whittle, Alistair J. Crame, Katrin Linse, Huw J. Griffiths and Fernanda Quaglio

14.30 **Mid Ordovician biodiversity in the Amadeus Basin, central Australia: What can we learn from local faunal indications in this shallow water clastic setting?**
* Kristian G. Jakobsen, Arne T. Nielsen, David A. T. Harper, and Glenn A. Brock

14.45 **Conservation of substrate affinity within marine invertebrate genera during the Phanerozoic**
* Melanie J. Hopkins, Wolfgang Kiessling and Carl Simpson

15.00 **Marine benthic community dynamics through the Early Toarcian (Early Jurassic) global warming event**
* Silvia Danise, Richard J. Twitchett, Crispin T. S. Little and Marie Clemence

15.15–15.45 Coffee

Session 3B: C005

13.45 **Applications of a new method to model the skeletal taphonomy of fossil vertebrates**
* Sue Beardmore, Patrick J. Orr and Heinz Furrer

14.00 **Asymmetry in conulariid cnidarians and some other invertebrates**
Consuelo Sendino, Kamil Zagorsek and Paul D. Taylor

14.15 **Leaf physiognomic variations as a proxy for elevated atmospheric SO_2 across the Triassic–Jurassic boundary**
* Karen L. Bacon, Claire M. Belcher, Matthew Haworth and Jennifer C. McElwain

14.30 **Reconstructing the genome size of early angiosperms**
Barry H. Lomax, Ian R. A. Smillie, C. A. Knight and Garland R. Upchurch

14.45 **Is the world's oldest bryozoan actually the world's oldest pennatulacean?**
Paul D. Taylor, Bjorn Berning and Mark A.Wilson

15.00 **The earliest rugose coral fossil – discovered using Synchrotron technology**
Christian Baars, Mansoureh Ghobadi Pour and Robert Atwood

15.15–15.45 Coffee

Session 4: B004

15.45 **Using penetrative tracks to reconstruct dinosaur limb kinematics**
* Peter L. Falkingham and Stephen M. Gatesy

16.00 **Pelagic trilobite eyes: ancient ocean temperatures revealed?**
* Carys E. Bennett, Thijs R. A. Vandenbroucke, Mark Williams, Melanie J. Leng, Richard A. Fortey, Alan W. Owen, Clare Torney, Alex A. Page, Axel Munnecke, Matthias López Correa and John R. Laurie

16.15 **Sexual selection in prehistoric animals: misidentifications and false positives**
Kevin Padian and Jack R. Horner

16.30 **Golden goose or bad egg? Juvenile eurypterids from Cottonwood Canyon, Wyoming, and the influence of ontogeny on phylogeny**
* James C. Lamsdell

16.45 **A new non-minimal algorithm for dating phylogenies of fossil taxa**
* Graeme T. Lloyd, Matt Friedman and Mark A. Bell

17.00 **Testing the phylogenetic position of Cambrian 'Orsten' pancrustacean larval stages using semaphoront coding**
* Joanna M. Wolfe and Thomas A. Hegna

17.15 **The first stem-harvestman**
Russell J. Garwood, Jason A. Dunlop, Parshant P. Sharma, and Gonzalo Giribet

17.30 **Launch of *Virtual Palaeontology* Issue 1**
Soren Hemmingsen and Michael J. Benton

17.40 **Annual General Meeting**

18.15 Coaches to Smithfield

19.15 **Pre-dinner drinks reception** at the Old Jameson Distillery, hosted by Wiley-Blackwell

20.00 **Annual Dinner at the Old Jameson Distillery**

Tuesday 18th December

Oral Presentations

* Candidates for the President's Award are marked with an asterisk.
+ denotes speaker other than first author.

Session 5 poster session (Main Hall)

08.45–10.00 Tea, coffee and pastries will be available from 08.45

Delegates are requested to stand by their poster(s).

Session 6: B004

10.00 **Paleoniches: using collection data to study species' distribution through time**
* Una C. Farrell and Bruce S. Lieberman

10.15 **The biomechanics of herbivory – a case study on therizinosaur dinosaurs**
* Stephan Lautenschlager, Emily J. Rayfield, Perle Altangerel and Lawrence M. Witmer

10.30 **Tempo and mode of biting performance evolution in sabre-toothed cats**
* Manabu Sakamoto and Marcello Ruta

10.45 **Dietary change and diversity in Palaeotheriidae (Mammalia, Perissodactyla) across the Eocene–Oligocene transition**
* Sarah C. Joomun, Jerry Hooker and Margaret E. Collinson

11.00 **Did early jawed vertebrates share a meal?**
* Laurent P. G. Darras, Mark A. Purnell and Philip C. Donoghue

11.15–11.45 Coffee

Session 7: B004

11.45 **A new primitive ornithischian dinosaur from the La Quinta Formation of Venezuela**
Richard J. Butler, Paul M. Barrett, Randall B. Irmis, Torsten M. Scheyer, Ronald Mundil and Marcelo R. Sánchez-Villagra

12.00 **A new azhdarchid pterosaur from the Late Cretaceous of the Transylvanian Basin, Romania: Implications for azhdarchid diversity and distribution**
Mátyás Vremir, Alexander Kellner, Darren Naish and +Gareth J. Dyke

12.15 **Palaeobiogeographic implications of the middle Cretaceous sauropods from the Winton Formation of Queensland, Australia**
* Stephen Poropat

12.30 **The importance of deep time data when reconstructing body size: insights from the Canidae (Mammalia, Carnivora)**
* John A. Finarelli and Anjali Goswami

12.45 **Role reversal in the Mesozoic: When teleost fish played second fiddle to their sister group**
* John T. Clarke and Matt Friedman

13.00 **"Sharks" from the Ordovician–Silurian: tracing the root of the chondrichthyan evolutionary tree**
* Plamen S. Andreev and Ivan J. Sansom

13.15–14.15 Lunch

Session 8A: C004

14.15 **Traces of early land plants from the Silurian of Sweden**
* Kristina Mehlqvist and Vivi Vajda

14.30 **The late Palaeozoic amalgamation of Pangaea: the view from the tropical riverbanks**
* Sarah C. King, Chris J. Cleal and Jason Hilton

14.45 **Cretaceous forest composition and productivity inferred from a global fossil wood database**
* Emiliano Peralta-Medina and Howard J. Falcon-Lang

15.00 **Did fire play a role in the formation of vertebrate deposits at Dinosaur Provincial Park, Alberta, Canada?**
* Sarah A. E. Brown, Margaret E. Collinson and Andrew C. Scott

15.15 **Early to Middle Miocene vegetation and climate at the Wilkes Land margin, East Antarctica**
Ulrich Salzmann, Francesca Sangiorgi, Sandra Passchier, Stefan Schouten, Joerg Pross, Peter Bijl, Lisa Tauxe, James Bendle, Carlota Escutia, Henk Brinkhuis and the IODP Expedition 318 Scientists

15.30 **Arthropod and fungal interactions with gymnosperm roots in a Triassic permineralized peat from Hopen, Svalbard Archipelago**
Stephen McLoughlin, Christine Strullu-Derrien, Paul Kenrick, Marc Philippe, Alte Mørk and Jean-Philippe Rioult

15.45 Coffee and Posters

Session 8B: C005

14.15 **The nature of fake predation traces in the Cambrian – implications for the early record of macrophagy**
Michael Streng

14.30 **Inside the Cambrian Explosion: the diversity of midgut morphologies in Cambrian arthropods**
R. Lerosey-Aubril, J. Vannier, T. A. Hegna, C. Kier and E. Bonino

14.45 **Early evolution of biomineralization in brachiopods**
Uwe Balthasar, Martin D. Brazeau, Glenn A. Brock, David A. T. Harper, Lars E. Holmer, Alistair J. McGowan, Christian B. Skovsted, Michael Streng and Zhifei Zhang

15.00 **Tannuolinids from Morocco and scleritome reconstructions of stem group brachiopods**
* Christian Skovsted, Sebastian Clausen, J. J. Alvaro and D. Ponlevé

15.15 **Spectacular preservation of an Ediacaran rangeomorph community: The MUN Surface, Bonavista Peninsula, Newfoundland**
* Alexander G. Liu and Jack J. Matthews

15.30 **Palaeocommunity analysis of the Burgess Shale Tulip Beds locality**
* Lorna J. O'Brien, Jean-Bernard Caron

15.45 Coffee and Posters

Session 9: B004

16.15 **The blue snail problem: the distorting effect of successful predation on the fossil record of gastropod**s
Graham E. Budd and *+R. P. Mann

16.30 **Mass Extinction of Lizards and Snakes at the Cretaceous–Palaeogene Boundary**
* Nicholas R. Longrich, Bhart-Anjan S. Bhullar and Jacques A. Gauthier

16.45 **Advances in understanding trilobite vision**
Brigitte Schoenemann and Euan N. K. Clarkson

17.00 **Incumbency effects control the recovery of benthic molluscs after the end-Cretaceous mass extinction in Patagonia**
Martin Aberhan

17.15 **The Fossil Record of Bioirrigation**
Liam G. Herringshaw

17.30 **Solving Darwin's dilemma: new Mesozoic barnacles fill in phylogenetic gaps**
Andy Gale

17.45 Announcement of prize winners and close of meeting.

18.15 UCD Earth Institute Lecture, in association with the Geological Survey of Ireland and the Geological Survey of Northern Ireland, by Prof. Andy Knoll, Harvard University:
'Systems Paleobiology: Physiology as the link between biological and environmental history'.
Introduced by Prof. Chris Bean, Director, UCD Earth Institute
Followed by Palaeontological Association/British Sedimentological Research Group Icebreaker Reception.

Abstract of Annual Address

New views on the origin of our species

Chris Stringer
Department of Earth Sciences, Natural History Museum, London SW7 5BD, UK

Views on modern human origins have undergone many fluctuations in the last 50 years as the fossil record and techniques of investigation have developed. Multiregional continuity (*i.e.* several centres of origin, on different continents) was arguably the dominant model when I began my doctoral research in 1970, but by 2000 the impact of more accurate chronologies and fast-growing genetic data had swung the pendulum towards a purely African origin for *Homo sapiens*, with any non-African input regarded as of negligible importance. However the most recent genomic-scale studies of recent humans and fossil samples have revealed a small but significant signal of introgression from archaic humans into early modern humans in both Africa and Eurasia. These inputs appear to have derived from separate episodes of interbreeding with (in Eurasia) Neanderthals and a newly recognised ancient Asian population known as Denisovans, and (in Africa) a currently unidentified archaic source. The impact of these new complexities on evolutionary and species models is still being absorbed by old and new generations of researchers.

REFERENCES

STRINGER, C. B. 2012. *The Origin of Our Species*. Penguin, London.

STRINGER, C. B. 2012. What makes a modern human. *Nature* **485**: 33–35.

STEWART, J. R. and STRINGER, C. B. 2012. Human evolution Out of Africa: the role of refugia and climate change. *Science* **335**: 1317–1321.

Launch of *Virtual Palaeontology* Issue 1: Origins of Biodiversity

Michael J. Benton
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Palaeontologists have always had something to say about the origins of biodiversity. However, until recently most of what they had to say was somewhat speculative. Following the inspirational suggestions by Simpson in the 1940s, the American 'paleobiological revolution' of the 1970s encouraged palaeontologists to think numerically and in terms of hypothesis-testing. What was lacking from that revolution was phylogeny, and this provides the basis of informative analyses that truly link deep-time fossil data with molecular trees and extant taxa.

UCD Earth Institute Lecture
Systems Paleobiology: Physiology as the link between biological and environmental history

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Increasingly, paleontologists have come to appreciate that our rapidly expanding knowledge of Earth's dynamic physical history provides a necessary context for interpreting the history of life. Physiology constitutes the proximal interface between organisms and environment. Systems Paleobiology, then, seeks to interpret the history of life within the framework of Earth's environmental history, using physiology as the conceptual bridge between paleontological and geochemical datasets. In some cases, physiological performance can be estimated directly from fossils – this is commonly the case for vascular plant remains. In other instances, statistical inferences about physiology can be made on the basis of phylogenetic relationships. Examples from research in paleobotany, marine micropaleontology and invertebrate paleontology illustrate how physiological observations, experiments and models can link biological radiations and extinctions to both long term environmental trajectories and transient perturbations to the Earth system. The systems approach also provides a template for evaluating the habitability of other planets, not least the ancient surface of Mars. Expanding physiological research motivated by concerns about our environmental future provides an increasing diversity of tools for understanding the relationship between Earth and life through time. The geologic record, in turn, provides critical input to research on contemporary global change.

Abstracts of symposium presentations: Taphonomy and the Fidelity of the Fossil Record

The limits of the fossil record: how far can the exceptions extend?

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The vitality of palaeontology, like any other science, depends on the generation and testing of new hypotheses, but equally on new discoveries. This year's list of remarkable extensions of the fossil record – evidence of >3.4 billion-year-old microbes, the brain of a Cambrian arthropod, an armoured Silurian aplacophoran, a Carboniferous lobopodian, iridescent plumage on *Microraptor*, a high-coverage human genome sequence >30,000 years old – will no doubt be succeeded by ever more extraordinary preservations next year. The limits of the shelly fossil record are clear and intuitive but our understanding of 'soft' tissue preservation is much less complete. The earliest stages of diagenesis are the most critical to the survival of molecular components and the preservation of soft tissues. Investigations at the interface between taphonomy and phylogenetic analyses show how decay can distort the appearance of an organism and compromise interpretations of affinity; incompletely preserved fossils tend to slip toward the base of a clade. Yet new discoveries of ancient biomolecules and fossilized soft tissues continue to push the boundaries. How much can the fossil record reveal of the history of life – of molecules and morphology, ecology, and the distribution of organisms in time and space?

Wetland bias and T^0 conditions: ecological and ecophysiological filtering dominate the fossil record of hot spring floras

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We review the fossil record of hot spring floras from the Cenozoic to Lower Devonian Rhynie chert. Angiosperms (*e.g.* Cyperaceae, Restionaceae) dominate Cenozoic floras, *Equisetum* and aquatic gleicheniaceous ferns Mesozoic examples and sphenophytes and herbaceous lycophytes Palaeozoic examples that post-date the Rhynie flora.

Siliceous hot springs form above low-sulphidation epithermal mineralisation and erupt saline, alkaline, heavy metal-rich, silica-supersaturated water. Cooling-driven Opal-A precipitation creates sinter aprons and geothermally influenced wetlands, the latter provide habitat for abundant plants. Here, *in situ* encrustation- and permineralisation-style plant preservation creates T^0 assemblages that are clearly affected by the fossil record's well-known wetland megabias. Partitioning of wetland (hydrophyte) and dryland (mesophyte) communities, typical of active geothermal areas, is evident around well-preserved fossil sinter deposits where initial geothermal-water flooding of environments causes forest ecosystem decline.

Bias extends beyond broad ecology. Cenozoic to Mesozoic geothermal wetlands also contain abundant evidence of *in situ* preservation of silicon-accumulating, salinity-, alkalinity-, heavy metal- and high pH-tolerant plants. Such observations suggest that

around hot springs removal of taphonomic filtering is accompanied by increased ecological and ecophysiological filtering. By extension we hypothesise that this was also the case around Palaeozoic hot springs and extends to the early land plants of the Rhynie Chert.

A taphonomic foundation for Conservation Paleobiology: Using death assemblages to evaluate modern ecosystems

Susan M. Kidwell

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Ecosystems today are under growing pressure, with human domination at many scales from individual species to key habitats and entire biomes. But it is difficult to gauge what has changed or been lost – and why – in the absence of data from periods before human activities. In many areas, marine ecosystems had probably already degraded significantly by the time that biological surveys and research began. Actualistic taphonomic studies, originally motivated to understand preservational controls on deep-time fossil records, are now providing insights into modern death assemblages as historical archives of present-day ecosystems, turning taphonomy on its head.

Here I review what we have learned in the last twenty years about the ability of time-averaged skeletal assemblages to capture ecological information. I then describe two promising directions for "applied taphonomy" at regional scales, where conservation and environmental remediation efforts are most tractable: (1) using live-dead mismatch – that is, observed discordance in the diversity, species composition, and distribution of living animals and co-occurring skeletal remains – to recognize recent anthropogenic change, and (2) using death assemblages to estimate diversity and variability in un-impacted areas, as a supplement or substitute for live-collected data.

Experimental taphonomy of colour in fossil insects and feathers

Maria McNamara

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Coloration is an important multifunctional attribute of modern animals but its evolution is poorly understood. This stems, partly, from our limited understanding of how colour alters during fossilisation. Investigation of structural colour in fossil insects has identified key taphonomic patterns, but their origins are not well understood; reconstructions of original plumage coloration in theropods are based upon several assumptions (*e.g.*, the fidelity of preservation of melanosomes) that remain untested. We resolve these issues by using elevated pressures (up to 500 bar) and temperatures (up to 270°C) to simulate the effects of burial on structurally colored cuticles of modern beetles and on modern feathers coloured via diverse mechanisms. Our experiments identify burial temperature as the primary control on the preservation of structural colour in insects, and demonstrate that diagenetic alteration of structural colours results from morphological and chemical alteration. Our feather experiments show that melanosomes alter geometrically due to the effects of pressure and temperature. Reconstructions of original plumage coloration in fossils based largely on preserved features of melanosomes should thus be treated with caution. Taphonomic experiments are crucial to interpreting the fossil record of colour and will constrain interpretations of original coloration and its functions in fossil insects and theropods.

talks

Taphonomy distorts phylogeny

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Fossils are not perfect. The information they provide is filtered and biased by intrinsic taphonomic processes; how do these processes affect our ability to interpret fossils, construct phylogenies, and test evolutionary hypotheses? Simulations and actualistic experiments shed new light on this problem. Partition tests investigating phylogenetic signal in extant datasets find significant differences between "hard", fossilizable characters and "soft", less fossilizable characters. These differences are concentrated in "problematic" clades (*e.g.* acanthopterygian fishes, bivalve molluscs), indicating that poor phylogenetic fidelity is an inherent property of some clades. Furthermore, experimental investigation of patterns of soft-tissue character loss during decay in chordates reveals preferential loss of informative, synapomorphic characters. This causes fossils to appear more primitive than they were in life. These processes of stem-ward slippage, and hard-soft differences, undermine our ability to reconstruct the phylogenetic relationships of extinct organisms. Understanding these biases enables us to take account of missing data, and revise evolutionary inferences accordingly. To that end, we have mapped an "Atlas of Vertebrate Decay" as a visual and taphonomic guide to the interpretation of non-biomineralized characters in chordate fossils and illustrate, with examples, how it allows us to revise phylogenetic placements.

Tissue chemical records of animal behaviour – new possibilities or pipe dreams still?

Clive E. Trueman
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Biological systems (ecosystems) function due to the interaction of organisms with one another and their environment. Studying ecosystems, ancient or modern, is therefore essentially the study of behavioural interactions between organisms. Behaviour is very poorly preserved in the fossil record, and we are largely reduced to making inferences based on morphology or ecological theory.

Trophic behaviour is particularly important in shaping ecosystem structure – and luckily trophic interactions between organisms, and between organisms and their environment, are expressed in tissue chemistry, particularly in tissue stable isotope composition. Archaeologists and palaeontologists were instrumental in developing isotope proxies for animal behaviour, but the value of these tracers in addressing serious ecological questions has been hampered by taphonomic and sampling constraints. New developments in analytical capabilities offer hope that in some cases these constraints might be lifted, and this would enable palaeoecologists to benefit from recent developments in isotopic ecology.

In this talk I will explore the taphonomic context required for preservation of tissues suitable for stable isotope analysis, detail some of the analytical refinements that offer new scope for palaeontological analyses, and finally outline some recent applications of stable isotope ecology in modern ecosystems that may be particularly applicable to the fossil record.

Abstracts of oral presentations

* Candidates for the President's Prize are marked with an asterisk.
+ denotes speaker other than first author.

Incumbency effects control the recovery of benthic molluscs after the end-Cretaceous mass extinction in Patagonia

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Biological incumbency is the constraining effect that existing organisms impose on the potential survival of invading or evolving species. Mass extinctions are generally thought to reduce or remove the incumbency effect. However, analysis of the recovery dynamics of benthic molluscs after the Cretaceous–Paleogene (K-Pg) mass extinction in Patagonia reveals patterns consistent with incumbency. First, the most diverse and abundant elements of post-extinction assemblages are genera surviving the K-Pg boundary. Immigrating and newly evolving genera played minor roles and did not compensate the diversity loss at the boundary. Second, the survivors that dominated the early Paleogene recovery fauna were rare before the extinction event. This suggests that, although resistant to environmental stress, these survivors were rather mediocre competitors prior to the extinction event. Once released from competition by the disruption of stable Maastrichtian communities via removal of dominants, their relative competitiveness increased. This indicates a particular type of incumbency, where numerically subordinate taxa rose to ecological dominance in the aftermath of a major environmental perturbation. Incumbency appears to have been an important factor controlling the rebuilding of diversity after the mass extinction at the Cretaceous–Paleogene boundary.

"Sharks" from the Ordovician-Silurian: tracing the root of the chondrichthyan evolutionary tree

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The Lower Palaeozoic record of "sharks" is dominated by diverse scale taxa of uncertain interrelationships. A comprehensive revision of eleven Ordovician and Silurian scale genera of putative chondrichthyan affinities has been conducted in order to test the phylogenetic significance of scale-derived characters in stem cartilaginous fish.

The collected data reveal a wide range of morphogenetic and histological variation in the scales of early "chondrichthyans", requiring a reconsideration of the systematic utility of scale characters in basal gnathostomes as a whole. This has resulted in the development of an expanded scale-based character set, and has enabled the identification of those characters which can be viewed as diagnostic for the total-group Chondrichthyes.

The study places polyodontode scales as plesiomorphic for the clade and confirms the taxonomic validity of the Order Mongolepidida, which is recognised to be the earliest major lineage of shark-like taxa with a first appearance in the Late Ordovician. The

mono-odontode condition in chondrichthyans is first represented in Llandovery–Wenlockian taxa, including *Elegestolepis*, *Kannathalepis*, *Frigorilepis* and *Wellingtonella*. Scale diversity therefore reveals a potentially significant and early evolutionary radiation of basal chondrichthyans, some 40 Myr prior to the appearance of chondrichthyan teeth and articulated specimens in the fossil record.

talks

The earliest rugose coral fossil – discovered using Synchrotron technology

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The Rugosa are thought to have evolved from an ancestral anthozoan during the Middle Ordovician, although there is a lack of fossil evidence for their early evolutionary history. Previously documented species of early Rugosa are assigned to the main orders Calostylina, Streptelasmatina, Cystiphyllina and Stauriina, all of which had evolved by the late Sandbian. Fossils of *Lambelasma*? sp., a new rugose coral, were recovered from the Upper Darriwilian part of the Shirgesht Formation of Central Iran. One of the fossils was examined using Synchrotron X-ray tomography at Diamond Light Source, Oxfordshire, which is here demonstrated as a useful tool in taxonomic studies. Conventionally, the fossil would have been sectioned. Instead, the Synchroton technique allowed non-invasive investigation. The partially silicified fossil embedded in a calcitic-dolomitic carbonate rock was imaged three-dimensionally using the monochromatic beam of Beamline I12. The specimens combine features of both the *Streptelasmatina* and *Calostylina*, but are here assigned to the latter on grounds of a very deep, non-everted calice, the size and structure of the septa and a lack of tabulae. The new fossils form part of a mid-latitude fauna and are considerably older than the previously known earliest confirmed records of rugose corals.

Leaf physiognomic variations as a proxy for elevated atmospheric SO_2 across the Triassic–Jurassic boundary

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The Triassic–Jurassic boundary (*c.* 200 Ma) is marked by a doubling of atmospheric CO_2, rising temperatures and ecosystem instability, likely driven by Central Atlantic Magmatic Province volcanism. This volcanism probably delivered huge amounts of SO_2 to the atmosphere; however, relatively little convincing evidence has been presented from the fossil record to suggest SO_2 as a cause of plant extinctions at this time. To address this, we performed a physiognomic leaf analysis of groups of fossil leaves from nine plant beds spanning the T-J boundary at Astartekløft, East Greenland. The physiognomic responses of key taxa were compared to the leaf physiognomic variations observed in nearest living equivalent taxa exposed to simulated palaeoatmospheric conditions in the controlled

environment chambers of the PEAC facility. All modern taxa showed a statistically significant increase in leaf roundness when exposed to elevated SO_2. A similar increase in leaf roundness was observed in the T-J fossil taxa immediately prior to a sudden decrease in relative abundance. These findings suggest that SO_2 can be traced in the fossil record by leaf physiognomic changes and that the role of SO_2 in plant biodiversity declines across geological boundaries coinciding with global-scale volcanism may currently be underestimated.

Early evolution of biomineralization in brachiopods

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The evolution of shell composition in brachiopods is under debate with molecular phylogenies indicating that the last common ancestor had a calcareous shell whereas palaeontological data suggest the existence of a phosphatic-shelled stem group represented by tommotiids. These conflicting hypotheses have been tested by cladistic analysis of Cambrian–Ordovician brachiopods. The result supports the same overall superphylum-level relationships recovered by molecular analysis, including a calcitic-shelled last common ancestor. Tommotiids together with paterinids form a paraphyletic clade that forms the stem group of phoronids and the sister group to brachiopods. Both brachiopods and phoronids emerge from a calcareous-shelled bivalved stem group consisting of a number of short-lived Cambrian taxa including kutorginids, chileids, and naukatids. These results suggest that during the Early Cambrian apatite biomineralization evolved in brachiopods at least twice independently from calcareous ancestors: once in the paterinid–tommotiid clade and a second time in the Linguliformea.

The Jurassic beetroot stone: a pink and white puzzle revisited

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Solenopora jurassica, the beetroot stone, was first described in 1877 and has been somewhat of an enigma ever since. Striking for its characteristic pink and white banding

it has been variously classified as a chaetid sponge or calcareous algae. Relatively little is known about this unusual fossil, and until very recently nothing at all was known about its colour, now thought to be a unique boron-containing pigment. In an attempt to resolve the confusion about its affinities, to determine why it is banded and understand more of its geochemistry with regard to organic remains and colour in particular, we have employed a variety of analyses including organic and inorganic geochemical techniques as well as carbon and oxygen isotope analysis. X-ray fluorescence and isotopic analysis indicate that the banding is most likely a seasonal effect. Carbon isotopes suggest that productivity is higher in the thicker pink bands than in the thinner white bands allowing for the hypotheses that the white bands were either deposited during winter months, or that they are the result of bleaching due to increased temperatures and or UV exposure.

Applications of a new method to model the skeletal taphonomy of fossil vertebrates

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Existing methodologies to assess the fidelity of preservation of vertebrate skeletons are either overly-simplistic (relying on a purely qualitative "flashcard" approach) or based on exceptionally detailed analysis of skeletons (whether individual bones are present/absent). A new method was devised that allows rapid, semi-quantitative analysis of large datasets and defines the fidelity of preservation of the skeleton as a whole and of its different anatomical units. The method, or a modified version thereof, can be applied to most vertebrate body plans.

The method's potential is confirmed by analysis of the taphonomy of vertebrates from the Middle Triassic succession at Monte San Giorgio, Switzerland. The near identical marine pachypleurosaurids *Serpianosaurus* and *Neusticosaurus* occur in the Besano, and succeeding Meride, formations, respectively, that both comprise black shales punctuated by numerous carbonate event beds. Variation in skeletal fidelity between the taxa reflects subtle differences in environmental conditions when each formation was deposited. The new method can also be used to infer the palaeoecology of fossil vertebrates. Patterns of skeletal completeness and articulation in the "giraffe-necked" protorosaur *Tanystropheus* (the ecology of which is controversial) are near-identical to those of the terrestrial taxon *Macrocnemus*, but distinct from those of the marine taxon *Serpianosaurus*.

Pelagic trilobite eyes: ancient ocean temperatures revealed?

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Current fossil-derived proxies for seawater temperature in the Ordovician are oxygen isotopes and clumped isotopes derived from conodont apatite and brachiopod calcite respectively. Diagenetic alteration and the analytical techniques used are respectively problematic or still under development, and neither proxy can give a robust indication of surface-water temperature. This study assesses the potential for oxygen isotopes from the calcitic lenses of epipelagic trilobites eyes as a palaeotemperature proxy. We have analysed Floian age specimens of the widespread *Carolinites* from Spitsbergen. Well-preserved eyes can be distinguished from diagenetically altered eyes using microstructure preservation and geochemistry. Well-preserved eyes have low $\delta^{18}O$ values of -8‰ to -7‰VPDB that may signal warm ocean temperatures. Data from Mid Ordovician Australian specimens provide a second case study. Both telephinid (epipelagic) and asaphid (benthic) species occur in the same samples. The morphology and optical properties of the trilobite eyes reflect their respective palaeobathymetries, and we test this against the oxygen isotope results.

Did fire play a role in the formation of vertebrate deposits at Dinosaur Provincial Park, Alberta, Canada?

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The Late Cretaceous Dinosaur Park Formation outcropping in Dinosaur Provincial Park, Alberta, Canada contains multiple dinosaur deposits occurring as bone beds, articulated skeletons, microvertebrate deposits and isolated bones. Despite prior palaeontological and geological research being carried out into this formation, the presence of charcoal has never previously been recorded. Therefore, the impact of wildfires on the landscape, the ancient dinosaur-rich communities or their fossil record has not been considered. Charcoal has now been documented and quantified in four sampled vertebrate deposits (two bone beds and two articulated skeleton quarries), 22 sedimentary units containing isolated dinosaur bones, and 32 sedimentary units containing no bones. Charcoal is more abundant in the vertebrate deposits than in sediments containing isolated bones or no bones, including those in identical lithofacies. The levels of charcoal in the studied sites indicate that flooding events enhanced by post-fire erosion are a possible mechanism for the formation of some

vertebrate deposits, and that fire was a common and important component of the terrestrial ecosystem in this area. These results demonstrate the importance of documenting charcoal occurrence in order to consider the role of post-fire erosion in the formation of vertebrate deposits.

The blue snail problem: the distorting effect of successful predation on the fossil record of gastropods

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Studying predation rates through time has been critical in constraining evolutionary models such as the 'arms race' of Vermeij. Estimation of predation rates has focused on counting numbers of healed injuries in shelled taxa such as gastropods. However, accurate estimation of the predation rate is hindered by the loss from the fossil record of the victims of successful predation (the 'blue snails'). Do low numbers of scars reflect generally low predation rates, or the survival of a few lucky individuals in a regime of successful predation?

Using a Markov model to generate gastropod distributions under known rates of attack and success, we infer the initial parameters used through application of a bootstrap-like procedure. The attack and success rates can be recovered from the generated populations with rapidly-increasing accuracy as the sample size of fossils increases. Our results surprisingly suggest that accurate inference of predation and success rates is possible given a few assumptions, and that inference error is predictably related to other factors such as population profile. In principle these results can be applied to real assemblages, but unfortunately it turns out that few, if any of the correct data for solving the problem have yet been collected.

A new primitive ornithischian dinosaur from the La Quinta Formation of Venezuela

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Ornithischian dinosaurs were major components of large-bodied terrestrial herbivore assemblages from the Late Jurassic onwards, but their early evolution during the Late Triassic–Early Jurassic is poorly understood, as a result of a sparse fossil record. A significant assemblage of early ornithischian material has been collected from the La Quinta Formation of the Venezuelan Andes, of uncertain Late Triassic to Middle Jurassic age. Here, we describe new bone-bed material from the La Quinta Formation that is dominated by the remains of small, primitive ornithischian dinosaurs. Multiple examples of several postcranial skeletal elements are present and display little variation, suggesting

that only one ornithischian taxon is present. On this basis, this site represents the earliest-known monospecific ornithischian bone-bed. The unique morphology of the dentition and several other skeletal elements allows us to diagnose the La Quinta ornithischian as a new species that represents one of the most basal ornithischian dinosaurs yet discovered. The La Quinta Formation provides a rare example of a low-latitude dinosaur fauna, and is one of the only dinosaur assemblages to be documented to date from the northern part of South America, providing key information on early dinosaur biogeography.

Role reversal in the Mesozoic: When teleost fish played second fiddle to their sister group

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Teleosts are the dominant living group of aquatic vertebrates; they comprise approximately 29,000 species, assume a bewildering array of morphologies, and have come to occupy nearly every environment imaginable. In extreme contrast, their holostean sister group comprises a mere eight living species, all of which are restricted to the freshwaters of eastern North America. It is this pattern of extreme contrast, gleaned from living taxa alone, which has provided the basis for assertions of teleost superiority and fuelled a series of evolutionary scenarios. However, the fossil record indicates that these groups likely arose in the Permian, and so more than 250 million years of diversification has largely been excluded from the debate. By reconstructing the historical diversity trajectories for these groups, we can establish the pattern by which teleosts came to dominate. We quantified taxonomic and morphological diversity for holosteans and teleosts through the Triassic and Jurassic. Contrary to the pattern observed in extant taxa, our datasets suggest that holosteans were both taxonomically and morphologically dominant over teleosts for the entire duration of the Triassic. Holosteans continue to dominate in the Lower Jurassic, yet sustained teleost diversification from this point onwards led them to overtake holosteans during the Middle–Late Jurassic.

A re-examination of *Anomalocaris* from the Burgess Shale and the functional morphology of anomalocaridids

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Despite being one of the most renowned taxa from the Burgess Shale-type (BST) biotas and the largest Cambrian predator, the morphology of *Anomalocaris* is relatively poorly known. Recent research revealed the high taxonomic and morphological diversity of the globally-distributed group of anomalocaridid taxa, and isolated features such as the eyes, oral cone and body flaps (lateral lobes) are described in detail. All known specimens of *Anomalocaris canadensis* from the Burgess Shale have been re-examined in the context of providing a cohesive morphological description of this stem lineage arthropod. The dorsal surface of the head is covered by a small, oval carapace in close association with paired stalked eyes, and the ventral surface has only the triradial oral cone, with no evidence of a hypostome or anterior sclerite. The posterior body region reveals a complex suite of digestive, respiratory and locomotory characters that includes a segmented foregut and hindgut, a midgut with

paired glands, gill-like setal blades, and evidence of muscle bundles and support struts that presumably supported the swimming movement of the body flaps. Many of these structures are not visible in other taxa, making *Anomalocaris* critical for understanding the functional morphology of anomalocaridids and confirming their arthropod affinities.

Marine benthic community dynamics through the Early Toarcian (Early Jurassic) global warming event

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The Pliensbachian–Toarcian interval (Early Jurassic) is an archive of natural experimental data of the benthic community's response to past global warming and anoxia. Contemporary temperature increase was of similar magnitude to that expected for the near future. Organic-rich black shales were deposited in many epicontinental basins, and a biotic crisis occurred in the marine realm. Quantitative abundance data of benthic invertebrates were collected from coastal sections of the Cleveland Basin (North Yorkshire, UK). Twelve biofacies were identified, which correspond to four stages of community maturity (III-climax, II-transitional, I-pioneer, 0-highly disturbed), as observed in modern habitats affected by anoxia. Two faunal turnover events occurred: (i) at the onset of anoxia, with the extinction of most benthic species and the survival of a few adapted to dysoxic conditions (Stages I to 0), and (ii) in the recovery, when newly evolved species colonized the oxygenated soft bottom (Stages I to II). Ordination of samples coupled with sequence stratigraphy and palaeotemperature proxies allowed us to correlate faunal variations with relative long- and short-term sea-level and temperature changes, showing that the onset of anoxia and the extinction horizon coincided with a rise in both palaeotemperature and sea-level.

Did early jawed vertebrates share a meal?

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There is a growing interest in understanding the links between fossil anatomy, the functional information that can be derived from it, and how it relates to palaeoecology. As computerised models of evolutionary processes increasingly integrate intraspecific variability, it is important that palaeontologists provide robust information regarding the amount of ecological variability in fossil organisms. Recent developments regarding patterns of morphological diversity within early gnathostomes associated with newly-developed techniques for inferences of palaeoecology offer an opportunity to contrast ecological and morphological information; for example: how wide an area of "ecospace" is linked to a single point in a "morphospace"? The range of potential ecologies inferred from mechanical models in related organisms may overlap but a test of the realised ecologies provides both the actual ecological information and an estimate of the competition between predators for resource use. Dental microtexture analysis has proven its efficiency as a tool for inferences and comparisons of diets in fossil and extant fishes. Here we present the results of dental microtextural analysis of a range of early vertebrates and assess the degree to which the breadth of their dietary niche and trophic ecology is reflected by functional and morphospace analyses.

Correlation between the Palaeozoic diversification of alluvial sedimentary facies and the terrestrialization of plants and animals

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Data from an extensive literature review and fieldwork demonstrate that many sedimentary landforms present in modern rivers appear in the Palaeozoic record only after terrestrial vegetation had adopted certain evolutionary advances: *e.g.*, point bars are associated with the development of rooting and avulsive fluvial systems with arborescent vegetation. This talk presents data showing that these changes also closely correlate with the ichnological and body fossil record of the colonization of continental habitats by animals. Factors such as atmospheric composition, climatic events, global tectonic organisation, sea-level changes, extinction events, weathering rates and nutrient supply are all known to have played a role in promoting the terrestrialization process. However, a further fundamental prerequisite for achieving terrestrial biodiversity was likely the variety and segregation of physical habitats available for newly evolved organisms, especially within riparian systems. The evolution of the anabranching alluvial habit created an abundance of new physical landforms for colonization and would have promoted increasingly complex hyporheic flow regimes, while the concomitant increasing supply of large woody debris permitted new microhabitats. We argue that the expanding extent, diversity and partitioning of physical alluvial niches during the Palaeozoic is an underappreciated driver of the terrestrialization of early continental life.

Early Cambrian microfauna from Northern Montagne Noire (Southern France): Biostratigraphic and paleogeographic significance

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The 'Cambrian Stage Subdivision Working Group' has recently emphasized the high-potential of the Cambrian skeletal microfossils (so-called small shelly fossils, SSFs) for the biostratigraphic subdivision of the Terreneuvian, pre-trilobitic Cambrian. FAD of *Watsonella crosbyi* and *Aldanella attleborensis* appeared as best candidates for the definition of the base of the Cambrian Stage 2. Nevertheless, since the work of Cobbold in the 1930s, *Watsonella crosbyi* is also known from Montagne Noire in so-called '*Heraultia* Limestones'. The Montagne Noire is divided into three main structural domains: (i) the axial, metamorphic zone; (ii) the southern flank, constituted of well-studied, fossiliferous rocks; and (iii) a poorly understood, complex, Northern flank arranged into imbricated tectonic units, in which the Cambrian strata are poorly fossiliferous. '*Heraultia* Limestones', from the Northern flank, were dated as Cambrian stage 3 to 4 based on questionable lithological comparisons with Southern Nappes. The reassessed fossil assemblage of the '*Heraultia* Limestones' argues for a correlation with Cambrian stage 2 (Tommotian) beds of Siberia and China. The '*Heraultia* Limestones' would thus represent one of the earliest but isolated Tommotian carbonate-platforms on the Western Gondwana margin. Tectonic and palaeogeographic models have to be emended, and other factors that would favour such isolated platforms should be reassessed.

talks

Early complexity of brain and eye structure in Cambrian arthropods

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The nervous system provides fundamental data for inferring arthropod relationships. Neural tissue rarely preserves in fossils and thus stem- and early crown-group taxa have hardly figured in reconstructing nervous system evolution in Arthropoda. Exceptional preservation of the brain and optic lobes of the stem-group arthropod *Fuxianhuia protensa* from the Chengjiang Lagerstätte reveals detailed neuroanatomy. The brain of *Fuxianhuia* has three neuromeres connected to segmental structures: the protocerebrum is supplied by optic lobes with traces of neuropil areas, the deutocerebum is defined by antennal nerves, and a contiguous tritocerebrum is indicated by a pair of more caudal nerves. A tripartite prestomodeal brain and nested optic neuropils are shared with Malacostraca and Insecta. An early origin of sophisticated brains is coincident with versatile visual behaviours, as witnessed by compound eyes known from the Early Cambrian of Australia comparable in size and resolution to those of modern taxa. The evolutionary rates required to acquire these morphologies by the Early Cambrian are quantified by probabilistic phylogenetic methods that apply "morphological clock" techniques to an anatomical and 62-gene dataset for extant arthropods. Conservatively, phenotypic evolution was around four times faster, and molecular evolution around 5.5 times faster, during the Cambrian Explosion than in subsequent Phanerozoic intervals.

Using penetrative tracks to reconstruct dinosaur limb kinematics

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The fossil tracks described by Edward Hitchcock and housed at the Beneski Museum of Natural History, USA, include a variety of track morphologies. Among them are tracks which show considerable variation over multiple surfaces. These successive impressions are subsequent exposures of penetrative tracks, where the trackmaker's foot has directly interacted with, and passed through, each layer. Most surfaces within a volume show an exit trace, formed as the foot is withdrawn. This exit trace occurs in a spatially consistent location throughout the track volume, indicating a vertical foot withdrawal, rather than a forwards removal of the foot as in other deep dinosaur tracks (*e.g.* from Greenland).

The substantial deformation and considerable depth that some track volumes display implies that the substrate was so soft as to behave in a semi-fluid manner. In order to reconstruct the limb kinematics, including where, when and how the substrate provided resistance and supported the foot during the step cycle, we used computer simulation and animation. Digitised fossil tracks were used to reconstruct three-dimensionally the path of the foot. This foot motion was then used to generate virtual tracks that show similar track morphologies to those seen amongst the Amherst collection.

Paleoniches: using collection data to study species' distribution through time

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A key evolutionary question is how species respond to environmental change through time. Museum collections of fossils, along with their associated locality data, provide millions of records representing data on the temporal and geographic distribution of species in deep time, which can be used to address this question. However, to reach their greatest scientific potential, these data need to be available online and in a format that facilitates quantitative biogeographic analyses. We describe our newly-funded NSF project that involves databasing and georeferencing palaeontological collections from six institutions with high-quality stratigraphic and locality data in order to enable Ecological Niche Modeling (ENM) analyses. The grant targets three important periods in the history of life: the Ordovician, Pennsylvanian, and Neogene, from three major palaeobiogeographic regions: the Cincinnati region, American mid-continent, and Gulf/Atlantic Coastal Plains. These digitized data can be used in conjunction with ENM, for example, to study the relative importance of abiotic versus biotic factors on species' distributions, whether species respond individually or as a community to environmental change, and whether species' niches evolve with changing climate. Furthermore, our project results will be used to make digital atlases for hundreds of species, of value to researchers and the public.

The importance of deep time data when reconstructing body size: insights from the Canidae (Mammalia, Carnivora)

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We are increasingly able to reconstruct phylogenies for large data sets and more comprehensive surveys of extant taxa. Many studies attempt to leverage this improving knowledge of evolutionary histories to analyse character evolution, but do so solely from databases of extant taxa, ignoring deep-time information. Excluding fossil taxa implicitly assumes that living taxa record an unbiased estimate of a clade's entire evolutionary history. Many factors can make this assumption problematic. Here, we analyse body mass data for extant and fossil canids (dogs, foxes and relatives) for changes in mean and variance through time. AIC-based model selection recovered distinct models for each of eight canid subgroups, with trended random walks being the most prevalent mode selected. We compared model fits for data sets with parameters estimated by 1) extant data alone and 2) extant+fossil data, demonstrating that the latter performs significantly better for both the extant subfamily Caninae, as well as all Canidae. Moreover, living taxa considerably underestimated ancestral masses. Fossil taxa do not simply lead-up to extant taxa; they can actively shape our interpretations of evolutionary history. And although fossil data are not always available, we argue for their inclusion wherever possible in macroevolutionary studies.

To see and be seen: sight and stripes in early vertebrates

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Jawless vertebrates provide critical evidence for understanding the assembly of the vertebrate body plan. Today, all that remains of this once diverse evolutionary grade are hagfish and lampreys, and contrary to previous evidence that they were separate clades among the paraphyletic jawless fishes, recent micro-RNA analyses show that hagfish and lampreys are united as a monophyletic Cyclostomata. Whilst molecular phylogenetics is a powerful tool in determining relationships, fossils have a critical role to play in determining the tempo and sequence of character acquisition through the vertebrate, gnathostome and cyclostome stem lineages. Greater knowledge of cyclostome visual systems provides evidence for evolutionary pressure to see and be seen in the early vertebrate world. To date, only data from extant taxa have been considered but we have investigated in microscopic detail the eyes of fossil cyclostomes (Carboniferous, Mazon Creek) providing a deep time perspective on early vertebrate vision, ecology and behaviour. Uniting hagfish and lamprey as cyclostomes suggests that the last common ancestor of vertebrates was more anatomically complex than previously thought. Our analysis of fossil cyclostomes provides direct evidence for this, supporting the hypothesis that extant hagfish eyes are degenerate and that the ancestral vertebrate had a functional visual system.

Burgess Shale-type Preservation

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Exceptionally preserved biotas found in the Burgess Shale and other similar Cambrian deposits, provide rare but critical insights into the early diversification of the Metazoa. Sedimentologic and geochemical data from the Chengjiang, Burgess Shale and other principal Burgess Shale-type deposits yield clear and consistent patterns that illuminate the mechanism of Burgess Shale-type preservation. Extraordinary fossilization of organic remains as carbonaceous compressions resulted from early restriction of microbial decomposition in the sediments by means of oxidant deprivation. Low sulphate concentrations in the global ocean and low-oxygen bottom water conditions at the sites of deposition resulted in reduced oxidant availability, while rapid entombment of fossils in fine-grained sediments and early sealing of sediments by pervasive carbonate cements at bed tops restricted oxidant flux into the sediments. $\delta^{34}S$ pyrite confirms that these combined effects resulted in early restriction of microbial activity and the conservation of soft-bodied assemblages as carbonaceous remains. The critical step in fossil preservation, early pore water isolation by carbonate sealing, is unlike modern analogues, and was promoted by transient alkaline conditions in the Cambrian and Early Ordovician oceans. These results predict that younger Burgess Shale-type biotas should be present in rare outer shelf mudstones of Late Cambrian and Early Ordovician age.

Solving Darwin's dilemma: new Mesozoic barnacles fill in phylogenetic gaps

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Charles Darwin, in his masterly monographic treatment of living and fossil cirripedes (1851-4), had a problem. He had undertaken the study partly to see if he could find evidence of evolution in the fossil record, but was unable to find anything intermediate in form linking the Mesozoic–Recent stalked barnacles (scalpellomorphs) to the Cenozoic–Recent acorn barnacles (balanomorphs). Two recently discovered barnacle assemblages, one from the deep shelfal Kimmeridge Clay (Tithonian) of Dorset, the other from a Campanian rocky shoreline in southern Sweden, include new taxa which provide evidence for two critical morphological transitions in barnacle phylogeny. The first of these, from Kimmeridge, has affinities both to living stalked intertidal barnacles (Pollicipeidae) and the dominantly Cretaceous Brachylepadidae, believed to be sister group to the balanomorphs. The Swedish rocky shoreline yields abundant new brachylepadids, which show morphological progression towards the balanomorph condition, and yields the oldest balanomorph, a huge multiplated species (up to 10 cm maximum diameter), which lived attached to intertidal boulders. These new discoveries are interpreted with reference to a recent molecular phylogeny for the barnacles, with implications for the traditional morphological classification of the group.

The first stem-harvestman

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The harvestmen are the third most diverse arachnid order, with more than 6,400 described species, found in four suborders. Despite this diversity, a terrestrial habit and poorly sclerotized exoskeleton means that harvestmen have a limited fossil record, and all known fossil taxa have been placed within one of the four extant lineages. Here we describe a new fossil harvestman from the Late Carboniferous Montceau-Les-Mines Lagerstätte in France with the aid of X-ray micro-tomography. The exceptional preservation reveals eyes situated on an anterior projection, raised ozopores on the lateral carapace, and an open gonostome from which the penis is protruding. This combination of character precludes placement within extant suborders. This fossil thus represents either a stem-harvestman, or a stem-phalangid (a clade comprising three extant suborders), and allows speculation regarding the position and morphology of the earlier Rhynie Chert taxon, *Eophalangium sheari*. It provides the first details of harvestman evolution through stem group taxa, and is coupled with cladistic and molecular clock analyses, whilst our speculation is informed by novel evolutionary developmental experiments regarding the nature of eye development. This combined analysis provides a unique insight into the origins of this important arachnid group.

talks

Early Silurian (Aeronian) faunas of north-eastern Iran: a new insight on post-extinction recovery patterns in temperate-latitude Gondwana

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Studies of the faunal recovery after the terminal Ordovician mass extinctions are mainly focused on low-palaeolatitude regions (*e.g.* Laurentia, Baltica, South China). Biotic recovery patterns in temperate-latitudes are poorly known. Rich Early Silurian (Llandovery) faunas recently discovered in Northern Khorosan Province provide a window onto the recovery and initial biogeographic differentiation of post-extinction biota in temperate latitudes. The early Aeronian age of the base of the sequence is confirmed by the occurrence of graptolites of the *triangulatus* Biozone. Carbonates resting on the graptolitic shales contain recurrent, medium diversity *Clorinda*, *Pentamerus* and *Stegocornu* brachiopod associations. They occur in association with tabulate and rugose corals, a low diversity trilobite fauna dominated by *Calymene* and *Stenoparea*, bryozoans (trepostomes and cystoporates including *Hallopora elegantula* and *Lichenalia concentrica*) and echinoderms. Cephalopods are fairly common and dominated by the orthocerid *Polygrammoceras* with subordinate numbers of possible geisonoceratids, the oncocerid *Eotrimeroceras* and the barrandeocerid *Uranoceras*. Major components of the benthic fauna are new to the region and show clear links to contemporaneous low latitude faunas (*e.g.* Laurentia, Baltica and South China). Proliferation of the endemic rhynchonellide *Stegocornu* can be taken as an early sign of increasing biogeographical faunal differentiation of temperate latitude faunas.

Non-shelly "small shellies": demineralized paraconodonts, palaeoscolecids, and ?*Anatolepis* from the Deadwood Formation (Middle to Late Cambrian) of subsurface Saskatchewan, Canada

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Phosphatic microfossils are routinely studied as a window onto the Cambrian Explosion, but their demineralized counterparts have been largely overlooked. Hydrofluoric acid processing of mudstones from the Deadwood Formation of Saskatchewan has yielded diverse Small Carbonaceous Fossils (SCFs), many of which represent the isolated organic components of once-biomineralized structures. In some samples, extracted specimens retain their original three-dimensionality, along with an altered mineral component. Many samples, however, yield well-preserved specimens that are flattened and entirely carbonaceous, pointing to early diagenetic demineralization, and providing a novel view of

familiar fossils. In particular, we have recovered extensive assemblages of paraconodonts, the more weakly-phosphatized precursors to conodont elements. These extend the known range of morphologies, and offer a detailed view of growth lines for testing patterns of development. Other extinct biomineralizers include palaeoscolecid worms, which occur as i) isolated, demineralized sclerites; ii) demineralized sclerites surrounded by "soft" cuticle; iii) composite specimens with remnant mineral sclerites. Together these shed new light on cuticle construction and diversity. More enigmatically, we have recovered a large population of demineralized "sheets", which bear ornamentations that grade between those that typify *Anatolepis* (a proposed early vertebrate), and those that occur among confirmed aglaspidid arthropods – reopening an old debate.

The Fossil Record of Bioirrigation

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Most bioturbating aquatic organisms ventilate their burrows to permit long-term occupation. This process – bioirrigation – removes waste material from, and replenishes nutrients within, the burrow system. Indirectly, it also helps create habitats for microbes and larger organisms within and around the burrow. Ecologically and sedimentologically, therefore, bioirrigation is an important endobenthic process. The global distribution of such burrows is so widespread, particularly in shallow marine environments, that it is probably one of the highest-impact ecological phenomena on the planet.

Common trace fossils, such as *Thalassinoides*, *Ophiomorpha* and *Polykladichnus*, represent structures that must have been bioirrigated. Despite its potential importance through geological time, though, the fossil record of bioirrigation has never been examined.

In this study, I will use palaeontology, ichnology and sedimentology to examine the evolutionary history of bioirrigation, and show its significant role in the evolution of benthic ecosystems. It evolved in the Ediacaran, and was of particular importance in fine-grained, diffusive sediments during the Cambrian Explosion. Increasingly efficient bioirrigation probably also enabled the colonization of new sedimentary environments through the Phanerozoic.

Conservation of substrate affinity within marine invertebrate genera during the Phanerozoic

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Recent studies have shown that substrate affinity has a strong impact on Phanerozoic-scale diversity dynamics. However, despite the common occurrence of habitat shifting and invasion in fossil and recent taxa, substrate affinity has been assessed only for genera over their entire durations. Here we use occurrences from the Paleobiology Database to investigate the frequency with which marine invertebrate genera change their habitat preferences throughout their durations.

Affinity was estimated using a Bayesian approach that yields a value ranging between 0 (strong preference for clastic environments) and 1 (strong preference for carbonate

environments). The average within-genus shift in affinity in adjacent stages is close to zero. Using this range to assign categorical per-stage affinities, we find that 35% of genera maintain their affinities. Of the genera that are assigned an affinity in at least one stage, 83% are assigned to only one affinity. Shifting from one affinity to the other occurs at low rates.

These results suggest that substrate affinity is conserved within marine invertebrate genera. Genera may survive environmental change by shifting far enough into other environments that they effectively show no affinity. However, the complete adaptation to new substrate types appears difficult, which has implications for conservation biology.

Virtual Palaeontology and the largest collection of 3D digital fossils? – The GB/3D fossil types online portal

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The ICZN and the International Code of Nomenclature for algae, fungi and plants require that every species or subspecies of organism should have a type specimen to define its characteristic features. These specimens are held in collections and must be available for study. Over time, collections have been moved or amalgamated, and type specimens can deteriorate or become lost.

The British Geological Survey, the National Museum Wales, the Sedgwick Museum, Cambridge and the Oxford Museum of Natural History are working together in a JISC-funded project to create an online database of the type fossils they hold. The web portal provides data about each specimen, searchable on taxonomic, stratigraphic and spatial criteria. High-resolution photographs and stereo anaglyphs may be viewed and downloaded, and many 3D scans are available. For more information about the project, see <**http://gb3dtypefossils.blogspot.co.uk/**>.

The Web has transformed expectations in accessing information and is now usually the first port of call. Many museums are providing web-searchable text catalogues, but few have undertaken a large-scale programme of providing images and 3D models. This project represents the largest exercise to date in assembling 3D digital models, images and anaglyphs, and will provide a major resource for Virtual Palaeontology.

Mid Ordovician biodiversity in the Amadeus Basin, central Australia: What can we learn from local faunal indications in this shallow water clastic setting?

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During the Mid Ordovician marine sand- and siltstones were deposited in an epicontinental sea penetrating profoundly into the Australian continent. The Middle Darriwilian Stairway Sandstone of the Amadeus Basin has been sampled stratigraphically to track marine benthic biodiversity in this shallow water succession in Eastern Gondwana. The causes for the Ordovician radiation (GOBE) have yet to be determined definitely; however, the

evolutionary change coincided with increased global tectonism. Erosion of source areas uplifted during orogenic activity increased the siliciclastic component of marine substrates and it has been hypothesized previously that taxa with affinities for siliciclastics diversified in association with these environmental changes. The Stairway fauna is dominated by richly diverse bivalves, but also includes trilobites, brachiopods, rostroconchs, gastropods, cephalopods, monoplacophorans and rare bryozoans as well as sponges. Trace fossils are abundant at certain levels, whereas bivalves dominate the horizons containing body fossils regardless of facies type, varying from siltstone, calc-arenite, quartz-arenite to dolomitic calc-sandstone. The fossil macrofauna from the Stairway Sandstone displays a high degree of endemism at species level (about 95%). The rare species in common with faunas from nearby basins are generally cosmopolitan. New species of trilobites and brachiopods have now been described from the material.

Dietary change and diversity in Palaeotheriidae (Mammalia, Perissodactyla) across the Eocene–Oligocene transition

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The mammalian fossil record shows evidence of a number of faunal turnover events that have alternately been explained by climatic change or competition by invading species. One such event, the Grande Coupure, occurred in the earliest Oligocene of Europe, coinciding with the first Oligocene Antarctic glaciation (Oi-1) and with the extinction of much of the endemic European mammal fauna and the migration into Europe of Asian taxa. Among the larger mammals most affected, the Palaeotheriidae (Perissodactyla) showed a pronounced fall in species diversity with *Plagiolophus minor* being one of the few species to persist into the Oligocene. The diversity of European Eocene–Oligocene transition perissodactyls and artiodactyls is presented here with refined correlations based on a study of the Solent Group, Hampshire Basin. Previous studies have concentrated on tooth structure; however here dental microwear, an independent source of evidence for diet, is included. An integrated mesowear and microwear study of four palaeothere species is compared with artiodactyls. Each palaeothere species displayed significantly different diets within localities. Major dietary change took place before the incoming taxa arrived from Asia at the Grande Coupure and coincided with global cooling events, and there was no climate or dietary change immediately after the Grande Coupure.

The late Palaeozoic amalgamation of Pangaea: the view from the tropical riverbanks

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Late Palaeozoic wetland floras are well studied as the source of much modern day coal, created from the huge peat reserves laid down over their *c.* 70 Ma dominance of low latitude coastal zones.

This – the first study to statistically analyse late Palaeozoic wetland flora from across the globe – has supported strong linkages between the ancestral Euramerican "coal swamps" and those found in China ("Cathsyisa"), in the latest Carboniferous. A series of analyses of adpression macroflora spanning the middle Pennsylvanian to the end of the Permian has pinpointed an intersection between the so-called "Euramerican" and "(North) Cathaysian" floras, in the Stephanian (*c.* 305–300 Ma), indicating tectonic connection much earlier than previously thought from other lines of evidence. Furthermore, the enduring similarity of the core wetland floras of Euramerica and Cathaysia would suggest repeated connections over a prolonged period, until the extirpation of wetland floras in Euramerica around the end of the Carboniferous, with the direct evidence having been lost to the vagaries of a highly active and tectonically complex region. This emphasises the remarkable resilience and migrational capacity of these ecosystems under the stress of habitat and climatic pressure, and provides a viable framework for the assembly of eastern areas of Pangaea.

Soft-part preservation in heteromorph ammonites from the Cenomanian–Turonian Boundary Event (OAE 2) in the Teutoburger Wald (Germany)

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Excellent preservation of ammonites in Cretaceous rocks has been documented before. For instance, Lebanese Plattenkalke yielded heteromorphs with phosphatised soft tissues and North American baculitids with perfectly preserved radulae have been reported. Long ago, WR extracted 17 flattened baculitids with soft parts from laminated marlstones belonging to the OAE 2 of the Hesseltal Formation of Lengerich (Teutoburger Wald). Their shells have dissolved, but were deposited with the soft parts: the shell outline is visible with some organic structures (siphuncle, melanin-rich parts of megastriae and aperture). Several of these ammonites preserve the jaws and radulae. Soft part remains have been found, too, which are difficult to homologise with organs of their Recent relatives: behind the jaws, two specimens display paired lateral, oval structures. They are linked with each other and this connection covers the supposed oesophagus. Accordingly, these structures are interpreted as remains of the cephalic cartilage with the eye capsules (previously unknown from ammonoids). Further soft-parts include the digestive tract including oesophagus, crop, stomach and possibly the caecum. These cephalopod remains were deposited in an epicontinental setting, at a palaeodepth between 200 and 600 m. In this lagerstätte, ammonite upper jaws and anaptychi are among the most abundant macrofossils.

Golden goose or bad egg? Juvenile eurypterids from Cottonwood Canyon, Wyoming, and the influence of ontogeny on phylogeny

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The description of new eurypterids from the Lower Devonian Cottonwood Canyon Formation of Wyoming reveals that at least some species underwent relatively drastic changes in morphology from juvenile to adult stages. Ontogenetic data can be a great source of information for reconstructing the relationships of organisms, with modern

evolutionary theory recognising the importance of heterochronic changes in producing novel morphologies and that juveniles can sometimes exhibit plesiomorphic characteristics absent in adults. Furthermore, the juveniles of some arthropod groups exhibit potentially clade-defining characteristics that are not expressed in adults. The impact that ontogenetic data can have on phylogenetic reconstruction of relationships has received relatively little attention among palaeontologists, for whom such data are usually sparse or lacking altogether. Consequently, it is unclear how coding juvenile instars into a phylogeny of adult exemplars would affect the relationships and character polarity of ingroup taxa. Using the example of the Cottonwood Canyon eurypterids, the impact of coding juvenile individuals into established parsimony-based eurypterid phylogenies is explored and a method for dealing with phylogenetic data in morphological phylogenies is suggested. The potential impact of paedomorphosis and peramorphosis on tree topology is discussed and the importance of differentiating between adult and juvenile arthropod morphologies is highlighted.

The biomechanics of herbivory – a case study on therizinosaur dinosaurs

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The transition from non-avian to avian theropods is defined by a plethora of anatomical specialisations linked to the evolution of flight. Several skeletal adaptations, however, occurring within Maniraptoriformes, appear to have been triggered by dietary diversification. Therizinosauria – an enigmatic clade of Cretaceous theropods – possesses a suite of skeletal modifications thought to be related to the acquisition of herbivory.

Based on CT-scanning of the therizinosaurid *Erlikosaurus andrewsi* we investigated the biomechanical performance of the cranial skeleton using Finite Element Analysis. By employing detailed simulations of the hard- and soft-tissue structures, we evaluated different morphological configurations and biting scenarios, including hypothetical models with morphological features considered to be indicative of herbivory.

Our results show that the cranial skeleton would have to sustain increased stress during caudal biting scenarios. Considered with other evidence, this indicates that food processing was most likely restricted to the edentulous tip of the snout. The presence of a keratinous rhamphotheca, however, would help to dissipate stress and make the snout less susceptible to bending. The development of a rhamphotheca is thus not only advantageous for weight reduction requirements for the evolution of flight in the avian lineage, but also to increase cranial stability.

talks

Inside the Cambrian explosion: the diversity of midgut morphologies in Cambrian arthropods

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The Cambrian Explosion refers to the rapid appearance of a great diversity of body plans in the fossil record, including nearly all that typify modern animals. It indicates the development of complex marine ecosystems. This morphological diversification of metazoans has been extensively documented with fossils from Konservat Lagerstätten, but chiefly through the study of their external morphologies. Indeed, internal organs are almost never preserved in these fossils, except for digestive structures that have been occasionally observed in a number of taxa. Here we review the variety of midgut morphologies in Cambrian arthropods to assess if the variation of internal anatomy mirrors the diversity of external body shape. Six types are recognized based on the absence/presence of digestive caeca, their distribution along the tract, and their morphologies. The different midgut morphologies possessed by Cambrian arthropods attest to the diversification of their feeding habits. We hypothesize that the digestion and absorption of food were improved by the development and sophistication of structures (*i.e.* the digestive caeca) dedicated to them, which in turn might have allowed exploitation of new food sources. This suggests that internal innovations might also have played an important role in the ecological revolution associated with the Cambrian Explosion.

Reconstructing the genome size of early angiosperms

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Darwin in his often quoted letter, dated 22nd July 1879, to J.D. Hooker remarked that "the rapid development, so far as we can judge, of all the higher plants [angiosperms] within recent geological times is an abominable mystery". Today, some 130 years later, scientists are still grappling with this key question.

Recent sequencing work suggests that the angiosperm diversification event was accompanied by successive whole genome duplication events, suggesting that polyploidy may have played an important role in this diversification event. The relationship between cell size and genome size is well-known and has been used to reconstruct the palaeogenome size of a range of disparate fossil animal groups. Recent experimental work using *A. thaliana* has shown that the relationship between guard cell length (GCL) and genome size is independent of environment, with GCL showing minimal variation when exposed to a wide range of ecologically and geologically relevant environmental perturbations (*e.g.* CO_2, drought, UV-B radiation).

This presentation will outline how through the integration of fossils and experimental data advances are being made in this area, leading to the reconstruction of angiosperm genome size as they radiated.

Mass Extinction of Lizards and Snakes at the Cretaceous–Palaeogene Boundary

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The Cretaceous–Palaeogene (K-Pg) boundary is marked by a major mass extinction, yet this event is widely believed to have had little effect on the diversity of lizards and snakes (Squamata). A revision of fossil squamates from the Maastrichtian and Palaeocene of western North America shows that lizards and snakes suffered a devastating mass extinction that coincided with the Chicxulub asteroid impact. Species-level extinction is 83%, and the K-Pg event resulted in the elimination of many lizard and snake lineages, and a dramatic decrease in morphological disparity. Survival is associated with small body-size and perhaps large geographic range. The recovery is prolonged; diversity does not approach Cretaceous levels until 10 million years after the extinction, and results in a dramatic change in faunal composition. The squamate fossil record shows that the end-Cretaceous mass extinction was far more severe than previously believed, and underscores the role played by mass extinctions in driving diversification.

A new non-minimal algorithm for dating phylogenies of fossil taxa

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Palaeontologists are increasingly adopting the powerful tool of phylogenetic comparative methods to answer macroevolutionary questions. Underlying all such approaches is a phylogeny with branch lengths scaled to time, but historically these have been extremely conservative. For example, the most widely used method is simply to date an internal node as equal to its oldest descendant, making at least half of all internal branches zero length. More recent methods have done little to remedy this problem, being essentially minimal themselves, introducing some *ad hoc* addition to each node or requiring an additional estimate of sampling rate. Here we introduce a new method that only requires a tree structure and tip ages, but more accurately reflects uncertainty in dating and is explicitly non-minimal in its estimates. In addition, the approach does not provide just a single age estimate for each node, but rather a distribution of ages that can be interrogated for any desired average or confidence intervals. In practice we show, using an informal supertree of mammals, that such an approach leads to closer convergence between palaeontological and molecular clock estimates, but with the additional advantage of being able to date nodes not bracketed by extant taxa.

Spectacular preservation of an Ediacaran rangeomorph community: The MUN Surface, Bonavista Peninsula, Newfoundland

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At many Ediacaran fossil localities around the world, the fidelity of soft-bodied macrofossil preservation is often constrained by the grain-size of the casting medium, as coarse-grained

tuffs (Newfoundland) or sandstone event beds (Australia and Namibia) represent the most common lithologies found in association with fossils.

The new discovery of a remarkable bedding plane within the Trepassey Formation, Newfoundland, reveals some of the most extraordinarily preserved soft-bodied macro-organisms yet seen within Ediacaran siliciclastic successions. The surface possesses a diverse fossil assemblage comprising over one hundred rangeomorph specimens, and provides one of the most spectacular and ecologically complete Ediacaran assemblages found to date. The exquisite preservation of sub-0.1 mm morphological features is explained by the fine-grained nature of both the substrate and the covering tuff.

Preserved alongside the rangeomorphs, and forming a dense "mesh" over the entire surface, are abundant long and thin (< 1mm wide) filamentous structures. These filaments appear to lie beneath fronds, and have since been found in abundance on multiple bedding planes throughout the late Ediacaran strata of Newfoundland. They are interpreted to record elements of the microbial communities that have long been inferred to inhabit these deep marine ecosystems.

Classification of grass pollen using pattern analysis of texture

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Grasses are an extremely successful group of plants. They occupy a wide range of habitats from the poles to the tropics, and the grass family includes more than 11,000 recognised species. However, the morphology of grass pollen is remarkably similar throughout the family, and is generally spheroidal with a single pore surrounded by an annulus. This simple morphology has proved difficult for palynologists to cope with, and some workers have suggested that pollen morphology is uniform within the entire grass family. In order to address this problem, we have developed quantitative morphometric methods to classify grass pollen grains. In this paper we present a classification of 12 species of grass pollen from three sub-families. We imaged 240 specimens of grass pollen using scanning electron microscopy, and this indicates that grass pollen is characterised by a surprisingly high level of morphological diversity. Our classification of grass pollen is based on the size and density of sculptural elements that cover the pollen surface, and the complexity of grass pollen texture. This approach will allow pollen grains to be used to understand the diversification history that underlies the evolutionary success of grasses.

Exceptionally preserved red algal fossil *Leveilleites hartnageli* from Kalana quarry, Estonia

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The Early Silurian algal lagerstätte in Kalana, Estonia, has revealed rich non-mineralized algal flora, which are assigned to Rhodophyta and Chlorophyta. The most common algal fossil in these shelf carbonates is a red algal species, *Leveilleites hartnageli*, which was originally described by Foerste in 1923 from roughly coeval sediments in southern Ontario, Canada. The biological affinities of this species have caused some problems, as in the

original description its probable sponge affinities were discussed, but in Estonian core-sections similar fossils have also been characterized as probable "graptolites".

Our collection of *L. hartnageli* consists of more than one hundred rock samples covered with specimens of different preservation. Nearly 20% of these samples show exceptional three-dimensional preservation. The thalli of this type are up to 7 cm high, with a 1-2 mm wide central axis. Each specimen has 10-20 primary branches, most of them about equal in length and 12-25 mm long. Branches bear 10-30 so-called tufts, which are rounded and situated alongside the regular line. Most of the material occurs within the light to dark brown organic-rich, microlaminated, partly dolomitized limestones. Chemical analysis shows that the algal fossils are preserved mostly as carbon with a small addition of pyrite.

Arthropod and fungal interactions with gymnosperm roots in a Triassic permineralized peat from Hopen, Svalbard Archipelago

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Thin-sectioning of a Late Triassic (Carnian) siliceous permineralised peat block derived from the De Geerdalen Formation on Hopen Island, Svalbard Archipelago, reveals abundant fine roots preserving fine anatomical details of various stages of primary and secondary vascular tissue development. Moderately defined rings with few latewood cells in the secondary xylem indicate growth in a seasonal environment. The peat also preserves isolated spores, pollen, sporangia, and leaves of bryophytes, lycophytes, conifers and probable bennettitaleans. The peat hosted a rich fauna of invertebrate detritivores evidenced by extensive damage to cortical tissues of dead roots, and abundant coprolites preserved both within chambers excavated in the plant tissues and in the peat matrix. Less common gall-like structures within the roots indicate the presence of parasitic organisms in the palaeo-peat ecosystem. Several groups of fungi, including probable chytridiomycetes, are preserved within plant tissues and in the surrounding organic matrix. One of these fungi may represent the oldest example of an ectomycorrhizal association with plants evidenced by hyphae forming a mantle enveloping very fine rootlets that show extensive ramification, an absence of root hairs, and cortical cell hypertrophy. Associated spores resembling those of extant Tuber indicate a possible ascomycete affinity for the fungus.

Traces of early land plants from the Silurian of Sweden

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On the Swedish island of Gotland, situated in the Baltic Sea, extensive Silurian successions of late Llandoverian–P□ídolí age are exposed. Plant remains were recovered from the

Ludlovian Burgsvik beds exposed on the southern part of the island. These plant fossils consist of sporangia, with *in situ* cryptospores, spore masses, and a possible axis. In the same beds, naked spore masses consisting of cryptospore monads shrouded in amorphous organic material were identified. These probably represent coprolites of terrestrial arthropods and are the first examples of definite Silurian land plants in a terrestrial ecosystem from Baltica and an early example of plant-animal interactions.

Coeval deposits from southern Sweden, Skåne were studied for palynology and reveal well-preserved spore assemblages produced by early land plants co-occurring with cuticles of *Cosmochlaina*, marine microfossils such as acritarchs and chitinozoans making a correlation between marine and terrestrial realms possible for these early ecosystems. The palaeoenvironment is interpreted as predominantly nearshore marine to intertidal lagoonal. Additionally, global comparisons with coeval spore assemblages are discussed.

Palaeocommunity analysis of the Burgess Shale Tulip Beds locality

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Burgess Shale-type deposits provide direct evidence about the early evolution and ecology of metazoans in the aftermath of the Cambrian Explosion. The Burgess Shale itself has been intensively studied, but our understanding of ecological patterns at the scale of entire fossil assemblages remains limited, geographically and temporally, to the Walcott Quarry. Here we investigate the community structure and composition of the Tulip Beds locality on Mount Stephen. This locality is stratigraphically older and more distal – relative to the Cathedral Escarpment – than the Walcott Quarry and thus allows examination of changing patterns in ecological or sub-evolutionary time on a small regional scale. Almost 110 species have been identified from *c.* 9,200 specimens, representing at least 12 phyla. As at the Walcott Quarry, arthropods and sponges dominate in diversity and abundance of specimens, although one of the most abundant taxa, the problematicum *Siphusauctum gregarium* is only known from the Tulip Beds. Although the two localities show similar disparity and diversity levels, they differ in the identity of many species and certain ecological attributes. These results suggest that the overall ecological structure of the Burgess Shale biota remains relatively stable despite some variations that may reflect fluctuating ecological or environmental gradients.

Sexual selection in prehistoric animals: misidentifications and false positives

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Darwin acknowledged that the roles of some morphological structures are difficult to determine. But he was clear about what sexual selection is, and the role of sexual dimorphism in it. Because Darwin invented sexual selection, and based it on observations that have never been falsified, his definition cannot be wrong. It has three components: (1) *it explains why sexual dimorphism exists*, and its central role in sexual selection; (2) the dimorphic structures or behaviours are used by one gender *to attract mates or repel rivals for mates*; and (3) these structures and behaviours help the bearer *gain access to mates*.

Strangely, palaeontologists and neontologists have largely ignored him. Assertions of sexual selection/dimorphism in the fossil record suffer from a lack of statistical rigour and an unwillingness to test hypotheses through independent lines of evidence. No such study has had any independent assessment of the chronological age or stage of its individuals, although such information is frequently available. We show why much alleged sexual dimorphism in fossil tetrapods is more likely simply ontogenetic change, and why both a statistically significant population sample and an independent assessment of age of specimens are needed before the hypothesis of sexual dimorphism can be tested.

Cretaceous forest composition and productivity inferred from a global fossil wood database

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Global patterns of Cretaceous forest composition and productivity are analyzed using a comprehensive fossil wood database (n = 2238). To ascertain forest composition, records were classified by botanical affinity, plotted on georeferenced palaeomaps, and analyzed with ArcGIS tools. Results confirm previous conjecture that araucarioid and podocarpoid conifers were globally codominant in Early Cretaceous time in humid tropical and paratropical biomes, but drastically reduced in numbers during the Late Cretaceous. Cupressoid conifers, which were most common in seasonally dry mid-latitudes and pinoid conifers, which were associated with temperate conditions at higher northern latitudes, declined at the same time. Spatial analysis suggests that the loss of conifer forests was linked to the rise of co-occurring angiosperms. Our data also show that while angiosperms explosively diversified in mid-Cretaceous time, they did not become forest dominants until the latest Cretaceous, by which time the modern relictual pattern of conifer distribution had been established. To ascertain forest productivity, mean tree-ring width data were obtained from direct measurements and literature reviews (n = 284) and plotted by palaeolatitude. Comparison with modern data shows that Cretaceous forest productivity was significantly elevated in mid- and high palaeolatitudes, implying a poleward displacement of the temperate zone by >15°.

Palaeobiogeographic implications of the middle Cretaceous sauropods from the Winton Formation of Queensland, Australia

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Several incomplete sauropods have been discovered near the town of Winton, Australia. One site on Belmont Sheep Station yielded a braincase, cervical and dorsal vertebrae, and pelvic girdle elements from a small sauropod, and appendicular elements and a single cervical centrum from a larger sauropod. The provenance of some Queensland Museum specimens (specifically, a scapula and a coracoid) collected during the 1970s without accurate site information was determined as a result of excavations on Elderslie Sheep Station. Another site on the same property has yielded a tibia and fibula ~25% larger than the corresponding elements in the holotype of *Diamantinasaurus matildae*. Sauropod diversity during the middle Cretaceous in Australia has been hinted at through the description of *Austrosaurus mckillopi*, *Diamantinasaurus matildae* and *Wintonotitan wattsi*. A full revision of the Australian Cretaceous sauropod fauna is currently being

undertaken to determine the significance of Australia's sauropods for sauropod evolution and dispersal. A revision of *Austrosaurus* is being undertaken and the type site may be revisited; additional elements from *Diamantinasaurus* have been identified from the type locality; and material from the "Elliot" site on Belmont Station has provided us with much-needed information on the presacral axial skeleton of an Australian sauropod.

talks

Experimental decay of velvet worms (onychophorans) and taphonomic bias in the lobopodian fossil record

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In terms of phylogenetic placement, fossil lobopodians are hard to pin down: recent evolutionary analyses suggest that they might include stem-arthropods, stem-onychophorans, and stem-panarthropods. Finding the correct place(s) for fossil lobopodians in the Tree of Life has the potential to reveal the sequence in which important characteristics of arthropods and onychophorans were acquired. But lobopodians are almost entirely soft-bodied, and although they include classic examples of exceptional preservation, the degree to which the anatomical content of the fossils is biased by processes of decay has yet to be tested. We have conducted a character-based experimental analysis of onychophoran rotting, providing a first test of the hypothesis that anatomical and phylogenetic interpretations of fossil lobopodians have been affected by non-random patterns of taphonomic character loss. Our results suggest that some features of fossil lobopodian anatomy are artefacts of decay, and that some characters are lost so quickly that their preservation in fossils is unlikely. Anatomically, character loss is not randomly distributed. Do lobopodians exhibit stemward slippage? The nature of their fossil record coupled with phylogenetic instability make this specific hypothesis difficult to test, but our results suggest that few if any fossil lobopodians could be the remains of badly-rotted crown-group onychophorans.

Improving reconstructions of plant biodiversity from fossil pollen assemblages: super-resolution microscopy, machine learning, and bioimage informatics

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Although fossil pollen and spores comprise the most abundant and temporally continuous histories of terrestrial vegetation, the origination, turnover and extinction of taxa is masked by our inability to consistently recognize species from the fossil pollen record. As a result, plant communities appear more compositionally stable than they actually are, affecting both palaeoecological interpretations of ecosystem dynamics and palaeoclimatic reconstructions of environmental change.

We propose that the perceived taxonomic limitations of the palynomorph record are as much a result of methodological limitations in analyzing pollen as a lack of morphological differentiation in closely related species. We present results from three veins of research that address these limitations. The first applies a bias-optimized classification model that uses instance-based layered learning to identify Quaternary spruce pollen. The resulting supervised system not only automates the identification of the two species, it provides

explicit, quantitative assessments of classification confidence. The second vein is the development of new algorithmic measures of morphology. When applied to one of the most challenging pollen classification problems, the grasses, the results surpass the abilities of human experts. Finally, we present preliminary results with super-resolution imaging, which provides a new source of morphological data for these quantitative, high-resolution analyses.

Time series analysis in distal shelf sediments, Middle Ordovician, Baltica

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The Middle Ordovician, Baltoscandian Stein Formation has been investigated, via time series analysis, for evidence of orbital cycles. The two main goals of the present study were to detect if orbitally-induced climatic cycles occur in the distal shelf sediments of Baltica, and if so, to provide a more precise age-range for the different conodont species and biozones as well as the chronostratigraphic units. The Stein Formation probably represents the most complete Middle Ordovician limestone unit on the Baltica continent. The 25 m thick lithological column has been measured on a cm-scale and the lithological changes served as the framework for the time series analysis. The analyses were carried out by using Multitaper Spectral Analysis and Wavelet Analysis. Conodont biozones served as biostratigraphical control. Ongoing analyses show that 16,200-19,000 k.y. precession cycles are the only significant cycles in the late Dapingian sediments, while both 400,000 k.y. and 100,000 eccentricity cycles and 16,200-19,000 k.y. precession cycles are distinct in the early Darriwilian sediments. The average rate of sedimentation was shown to be in the order of 8-9 mm per 1000 years, which is considerably more than in the more proximal parts of the Baltic platform.

Early to Middle Miocene vegetation and climate at the Wilkes Land margin, East Antarctica

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The question of whether continental Antarctic climate was warm enough to support a substantial vegetation cover during the Neogene is of great significance to the ongoing

controversial debate on the behaviour of Antarctic land ice during the Miocene–Pliocene transition from dynamic to persistent ice sheets. Here we present palynological results from a Miocene sediment record provided by the Integrated Ocean Drilling Program (IODP) Expedition 318 to the Wilkes Land margin (East Antarctica). The reconstructed vegetation changes are compared with climate estimates derived from dinoflagellate cysts and MBT/CBT organic palaeotemperature proxies.

Analyses of pollen and spores indicate a low-diverse vegetation dominated by *Podocarpus*- and *Nothofagus*-trees and shrubs. Particularly high *Podocarpus* proportions occur during the Middle Miocene Climatic Optimum (MMCO). For this time period MBT/CBT suggests a cool temperate climate with increased mean air temperatures (MAT). Dinoflagellate cyst assemblages, dominated by autotrophic species, are indicative of ice-free surface waters. After MMCO a subsequent decline in MAT is indicated by MBT and dinoflagellate cyst assemblages, though pollen percentages (*e.g. Podocarpus*/*Nothofagus* ratio) remain relatively stable. However, very high *Nothofagus* and low *Podocarpus* pollen percentages may suggest lower temperatures towards the end of the Middle Miocene.

talks

Tempo and mode of biting performance evolution in sabre-toothed cats

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Sabre-toothed cats (Felidae; Machairodontinae) display extreme specializations in biting function: they have sabre-like canines, self-sharpening carnassials, and enlarged caniniform incisors. Despite this, sabre-toothed cats had lower bite forces compared to similarly-sized extant cats. While this reduction is well understood to be a trade-off with adaptations towards maximising gape, the tempo and mode of this shift away from a jaw adduction-driven biting remains poorly understood. Here, we used phylogenetic comparative methods to investigate the evolution of biting performance across phylogeny and through time. First, we tested whether evolutionary rates in canine and carnassial biting performance metrics were constant or variable across phylogeny. Second, we determined the best model of evolution via a model selection approach. Our analyses identified a major rate-shift for canine biting performance at the base of the sabre-toothed cat clade, but not for carnassial biting. Model selection determined that Felidae as a whole shows a directional trend towards decreasing biting performance, with sabre-toothed cats representing an extension of this. The shift away from a jaw adduction-driven canine biting likely occurred early and rapidly in sabre-toothed cat evolution, implying that their environment favoured strongly the benefits of an alternative form of canine biting.

Advances in understanding trilobite vision

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This paper is a summary of developments in the understanding of the eyes of trilobites, especially those of phacopids, and how they functioned. New knowledge derives from several sources, such as applying CT scanning and synchrotron radiation, which reveals the sublensar sensory structures for analysis, preserved as thin mineral films. Recent work

indicates that the nearest analogue for phacopid eyes is the apposition eye of *Limulus*, which seems to conserve an ancient structure. The internal differentiation of the lenses with their intralensar bowl, upper unit and core, also the trabeculae which we recently interpreted as a possible light guide system, indicate functionally highly specialised visual systems. For the basic holochroal eyes, from which the schizochroal derived by paedomorphosis, we demonstrate a wide variety of functional forms also and which are the subject of current investigations. The application of physiological methods – used for study of compound eyes in living arthropods – to fossils can be used to establish the light ecological environments to which the fossil arthropods were adapted. Such applications, in the study of holochroal eyes, indicated the invasion of trilobites into the planktonic niche before the beginning of the Ordovician. The magnificent holochroal eyes of the Furongian *Sphaerophthalmus* are now being investigated.

Asymmetry in conulariid cnidarians and some other invertebrates

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Deviations from symmetry occur in numerous invertebrates, including some conulariid cnidarians. These polyp stages of extinct scyphozoan cnidarians have conical external skeletons with a square cross-section. In the case of the Ordovician species *Metaconularia anomala* (Barrande, 1867) from Drabov (Czech Republic), the normal tetraradial symmetry is compromised in three ways: (1) the skeleton usually shows torsion; (2) the four sides may vary in width at the same level within one individual; and (3) one side may be deleted to give a triradial skeleton. From almost 2,000 specimens studied in museum collections, 56% had an anticlockwise (sinistral) torsion when viewed from the apex towards the aperture, 28% showed no torsion, 1% exhibited clockwise torsion (dextral) and the remaining 15% could not be classified. This asymmetry can be interpreted as a "fixed asymmetry" that was genetically controlled. Among other invertebrates, asymmetry has been documented in bryozoans (*e.g.* the helical Palaeozoic genus *Archimedes*), brachiopods (*e.g. Torquirhynchia inconstans* from the Jurassic), and sponges (*e.g. Marshallia tortuosa* from the Cretaceous). In some, the direction of asymmetry ("handedness") is random, but in others there is a preference for one direction over the other, suggesting differing levels of genetic control.

Understanding amber deposits through modern resin studies

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Amber is relatively rare in the fossil record, but at certain points in Earth History, remarkably large deposits are found, often in numerous localities worldwide. The most notable deposits are from the Late Triassic, the Early and mid-Cretaceous and the Eocene to Miocene. The causes of these extremely unusual deposits are not clear and there are several theories to possibly explain these extensive outpourings of fossil resin. From a biological perspective, there are two key questions: which plants produced the resins; and why did they produce such quantities? Ambers, particularly the older ones, were predominantly

produced by coniferous trees, where known. We start to address the question of why some conifers in their natural environment produce large quantities of resin. We show results from an initial study on modern highly resinous conifers, testing reasons for resin production. This study focuses on the highly resinous Araucariaceae family of conifers in New Zealand and New Caledonia since their resins have chemical similarities to ambers found from numerous different localities and geological ages. We focused on five hypotheses of resin production as a response to: disease, "natural disaster", insect damage, mechanical damage and fire; and evaluate these as reasons for resin outpourings.

Tannuolinids from Morocco and scleritome reconstructions of stem group brachiopods

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The first tannuolinid tommotiids from the Cambrian of Morocco have been found in the Amouslek Formation (Souss Basin) of the Anti-Atlas Mountains. The assemblage contains new species of both *Tannuolina* and *Micrina*. Tannuolinids are an exclusively Early Cambrian group of metazoans with organophosphatic sclerites. Together with other tommotiids, tannuolinids constitutes the stem group of the Brachiopoda. Tannuolinids display a number of characters, both morphological and ultrastructural, suggesting a particularly close relationship to linguliform brachiopods. Consequently, reconstructing the scleritome structure of this group of tommotiids is key to understanding the origin of the bivalved brachiopod shell.

Tannuolina have previously been described as having a bimembrate scleritome including bilaterally symmetrical sellate sclerites and asymmetrical mitral sclerites in an unknown configuration. The new Moroccan species of *Tannuolina* is unusual in having both symmetrical and asymmetrical sclerites, and may represent an early stage in the evolution of the tannuolinid scleritome. The new discovery, in combination with naturally fused sclerite pairs from China, prompts a novel reconstruction of the tubular scleritome. By comparing likely scleritome reconstructions of different species of *Tannuolina* and *Micrina*, we reconstruct the evolutionary process leading, through successive stages of simplification, to the bilaterally symmetrical brachiopod shell, forming a closed filtration chamber.

A new view on *Nematothallus*: non-mineralizing coralline red algae from the Silurian of Gotland

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The thalloid carbonaceous fossil *Nematothallus* Lang, 1937 has been widely interpreted as an early Palaeozoic land-plant, despite the absence of a convincing modern analogue. Exceptionally well-preserved nematophyte cuticle from the Late Silurian Burgsvik Sandstone Formation, Gotland provides additional insight into the organism's anatomy, phylogenetic affiliations and ecology. The organism was constituted of a close-packed layer of palisade-like filaments covered by a cuticle that bears a characteristic pseudo-cellular pattern on its inner surface. Apertures in this cuticle are often encircled by a ring of

multicellular filaments, which are sometimes associated with spheroidal, spore-like entities. In light of the conspicuous similarity of the palisade layers to the pseudoparenchymatous tissue of coralline red algae, and of the filament-fringed apertures to their reproductive conceptacles, we reconstruct the *Nematothallus* organism as an extinct rhodophyte, and re-evaluate the putative terrestrial habit of cuticular nematophytes in general. This interpretation would reconcile the presence of conspicuously similar cuticular sheets recovered from the Middle Cambrian of western Canada.

Head-butt for *Sidneya*

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Sidneya inexpectans is a fascinating trilobite-like arthropod from the Burgess Shale. It played an important role in influential hypotheses on chelicerate origins formulated in the mid-twentieth century. A detailed restudy in the 1980s revealed that *Sidneya*, as earlier understood, was a chimaera but also the new interpretation favoured a close relationship with the chelicerates. Particularly the structure of the appendages showed intriguing similarities with that of aquatic euchelicerates. But there remained puzzling aspects of the animal's morphology, notably the very short head, incorporating only the ocular and antennular segments. Moreover, the head was ventrally covered entirely by the doublure and seemed to lack a hypostome.

Here, I present new evidence that the appendage structure, instead of being chelicerate-like is but a variation on the 'artiopod' theme, as well as a new interpretation of the cephalic structures. In cladistic analyses, *Sidneya* is retrieved as a basal derivative of the mandibulatan stem-lineage.

The nature of fake predation traces in the Cambrian – implications for the early record of macrophagy

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Boreholes in mineralized shells are a widely recognized form of predation throughout the Phanerozoic. In fact, such borings are as old as the first mineralized shells dating back to the Ediacaran. Their occurrence among the earliest skeletal animals has been interpreted that protection against predators was one of the driving forces behind the evolution of mineralized hardparts. Hence, these early traces provide crucial clues in understanding the mysterious emergence of complex multicellular animals. However, new observations made on shells of linguliform brachiopods from the Middle Cambrian of Sweden suggest caution when interpreting perforations in shells as predatory or even as being organic. The recovered acrotretid assemblage is characterized by an unusual frequency of shells bearing circular to irregular circular holes. These holes resemble shell perforations interpreted in the literature as predatory borings and holes produced by a predator using a piercing appendage. However, close examination of the shells reveals the presence of pyrite crystals growing on the shell surfaces and within shell layers, thereby destroying the shell and producing the common perforations. It is proposed that pyrite crystal growth might be responsible for a variety of holes in fossil shells, holes previously interpreted to be predatory.

Is the world's oldest bryozoan actually the world's oldest pennatulacean?

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The undisputed fossil history of bryozoans begins in the Lower Ordovician. Nevertheless, several Cambrian fossils have, over the years, been attributed to this phylum, including most recently *Pywackia* from Mexico. This phosphatized fossil comprises small, narrow rods, tapering towards a style-like proximal end, with polygonal pits covering the distal part. Although *Pywackia* bears a superficial resemblance to some cryptostome bryozoans, it is sufficiently different in detail to raise doubts over its identity as a bryozoan. Chance discovery of a webpage illustrating the skeleton of a modern sea-pencil raises the possibility that *Pywackia* may instead be the axis of a pennatulacean octocoral. The fossil record of pennatulaceans has customarily been extended back to the Ediacaran to include such genera as *Charnia*, but recent interpretations have excluded these problematical fossils from Pennatulacea, leaving fossils from the Cretaceous as the oldest known pennatulaceans. If *Pywackia* really is a pennatulacean, then there is a troublesome 400 million year gap in the fossil record. The occurrence of modern pennatulaceans with unmineralized axes raises the possibility that biomineralization of the axis may have been lost and regained during the evolutionary history of these octocorals. Alternatively, perhaps *Pywackia* was a convergent octocoral with a pennatulacean-like morphology?

Revision of *Acrotreta socialis*, clarifying 150 years of confusion

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The lingulate *Acrotreta socialis* von Seebach, 1865 from the Middle Cambrian Andrarum Limestone from the island of Bornholm has had a long and complicated history since its original description nearly 150 years ago. The major problem with the early documentation of acrotretid brachiopods is that many species were described in the days before the advent of the SEM, resulting in uncertain morphological characteristics, especially concerning the internal morphology of both valves. Despite this, the species has since been redescribed, revised and divided into two species, a division that was reversed 50 years later on the grounds of ontogenetic variation. A detailed revision of the genus *Acrotreta* saw the species left out altogether, with species of *Acrotreta* proposed to be restricted solely to the Ordovician. The Bornholm acrotretid species has subsequently been floating in taxonomic limbo and, although it has been recently suggested to belong to the Cambrian genus *Treptotreta*, a firm generic placement awaits revision based on type and topotype material. Type material of *Acrotreta socialis* has been acquired and photographed, displaying previously undocumented morphological features that have finally put the taxonomic uncertainty about this widely quoted species to rest.

Palynological analysis of the 2004 tsunami deposits of Khao Lak coast Thailand: comparison with Jurassic palaeo-tsunami sediments from Sweden

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In December 2004 the Sumatra–Andaman earthquake with a magnitude of 9.3 on the Richter scale triggered seismic waves, which impacted coast lines distant from the epicentre. The tsunami deposits along the west coast of Thailand were investigated for palynology and sedimentology with the aim of improving the geological understanding of the principal sediment-depositing mechanisms of tsunami surges as a model to identify palaeo-tsunami successions. In the Khao Lak area the sheets of tsunami sand vary in thickness from centimetres to decimetres and only locally do the sand deposits reach over two metres. These tsunami deposits are characterized by sediments derived from mixed sources, such as plant fragments and soil fungi from terrestrial settings, and bioclastic sand eroded from shoreface deposits. The marine input is of much lower significance than expected, possibly as a result of the local onshore and offshore topography. Further, comparisons with Jurassic palaeo-tsunami deposits from Sweden will be outlined and discussed.

A new azhdarchid pterosaur from the Late Cretaceous of the Transylvanian Basin, Romania: Implications for azhdarchid diversity and distribution

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We describe a new taxon of a medium-sized (wing span *c*. 3 m) azhdarchid pterosaur from the Late Cretaceous Transylvanian Basin (Sebeş Formation) of Romania. This specimen is the most complete European azhdarchid yet reported, comprising a partially articulated series of vertebrae and associated forelimb bones. The new taxon is most similar to the Central Asian *Azhdarcho lancicollis* Nessov but possesses a suite of autapomorphies in its cervical vertebrae that include relative proportions (including of the cotyla) and the presence of elongated prezygapophyseal pedicles, amongst other characters. The new taxon is interesting in that it lived contemporaneously with gigantic forms, comparable in size to the famous Romanian *Hatzegopteryx thambema*. The presence of two distinct azhdarchid size-classes in a continental depositional environment further strengthens suggestions that these pterosaurs were strongly linked to terrestrial floodplain and wooded environments. To support this discussion, we outline the geological context and taphonomy of our new specimen and place it in context with other known records for this widespread and important Late Cretaceous pterosaurian lineage.

The Early Miocene Cape Melville Formation fossil assemblage from King George Island, Antarctica

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The Early Miocene Cape Melville Formation (King George Island, Antarctica) preserves one of the oldest glacio-marine assemblages found in Antarctica. The fossil community comprises taxa that are not found in recent Antarctic marine environments (brachyuran crabs), and taxa that are (bryozoans, corals, echinoids, brachiopods, gastropods, scaphopods and bivalves). The assemblage is dominated by infaunal nuculid bivalves (33.9% of recorded specimens), but also includes less abundant epifaunal elements such as the bivalve genus *Limopsis*, which is widespread in the Southern Ocean at the present day but has a poor fossil record. Brachyuran crabs are not found in modern Antarctic ecosystems, cooling temperatures have been cited as the reason for their absence, but the presence of brachyuran crabs in a glacial deposit indicates that the evolutionary history of this clade is more complex than we originally thought. The overall faunal composition is similar to recent soft sediment assemblages in the cold temperate Magellan region of South America. This similarity indicates that range expansion and contraction through the Scotia Arc to and from South America may have been an important pathway for organism movement in the Southern Ocean.

Microfossil adventures in the Iron Age

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Here we describe a unique application of microfossils for the provenance of artefacts in an archaeological setting. Burrough Hill, east Leicestershire, is a large Iron Age hill fort of the Corieltauvi people who occupied the East Midlands in the millennium prior to the Roman occupation of Britain in AD 43. From razors to roundhouses, excavations at the site are yielding new information about the nature of life in lowland Iron Age Britain. Among the materials discovered are the clay linings of storage pits, the clay linings of walls, floors and hearths, and pottery. Though more mundane than the spectacular finds of skeletons at the site, these materials still yield information about the lives of East Midlanders more than 2,000 years ago. Where were construction materials sourced? How was their pottery made? And what happened to Iron Age life after the Roman occupation? Many of the clay-based archaeological materials at Burrough Hill yield microfossils, and these provide information about the provenance of materials, processes of construction and manufacture, and information about the continuity of life in lowland Iron Age Britain.

Testing the phylogenetic position of Cambrian 'Orsten' pancrustacean larval stages using semaphoront coding

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Pancrustaceans (= crustaceans + hexapods) undergo some of the most radical ontogenetic changes seen in the Metazoa. The spectacular upper Cambrian "Orsten"-type faunas preserve phosphatized fossil larvae, including putative stem- and crown-group pancrustaceans with amazing developmental sequences. The putative presence of adult stages remains a source of debate. This causes spurious placements in morphological analyses. We introduce a new method of coding ontogenetic data where each semaphoront (discrete larval or adult stage) is considered an OTU. This decreases the reliance on continuous timing of developmental "events", avoiding *a priori* assumptions of heterochrony. Characters and states are carefully defined to identify specific putative homologies across taxa, as well as changes in morphology throughout ontogeny. Exemplar taxa from Pancrustacea are included (direct and indirect developers). Phylogenetic analyses of semaphoronts produced relationships of each Orsten fossil to the crown-group clade expected from morphology shared with extant larvae. *Bredocaris* is a member of the stem lineage of Thecostraca and/or Copepoda, and *Yicaris* and *Rehbachiella* are members of the stem lineage of Branchiopoda and/or Cephalocarida. The position of Phosphatocopina remains unresolved. A result consistent with fossil morphology was produced, suggesting this method may have broader applications to other phylogenetic problems that rely on ontogentically variable homology statements.

Abstracts of poster presentations

* Candidates for the Council Poster Prize are marked with an asterisk.

Intracellular complexity of Mesoproterozoic organic-walled microfossils from Shanxi, China

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Organic-walled microfossils have been uncovered from the Mesoproterozoic (~1.3 Ga) sediments of the Beidajian Formation in Shanxi Province, China. Material was studied under LM and SEM after processing with standard palynological techniques, aiming to determine biological affinity. The shallow-marine Shanxi biota is composed of sphaeromorphic and acantomorphic ornamented microorganisms exhibiting eukaryotic characteristics, and thus provides the timing for early eukaryotic evolution.

Observed morphometric size-classes suggest distinct growth stages attributed to discrete form-species, reveal a life-cycle, advocate a possible relationship to extant microalgae, and are compared to the present-day North Sea biota. Elaborate vesicle features and wall structure, such as a multi-layered wall reticulated by polygonal platelets of the *Dictyosphaera–Shuiyousphaeridium* plexus, are indicative of significant intracellular complexity and can provide the minimum age-constraint for the appearance of crucial organelles in the early Eukaryota.

Additionally, a newly discovered and currently the largest known Mesoproterozoic microfossil taxon is reported. The specific size (~430µm), energetically expensive robust vesicle, and additional membrane of this unicellular new specie suggest its protective role in sexual reproduction.

Albeit of low diversity, the Shanxi assemblage of the "Boring Billion" reveals a high degree of complexity, providing an insight into the ongoing eukaryotic (r)evolution and intricate life already present in Mesoproterozoic oceans.

Lagoon environment during the Kimmeridgian at Foncine-le-Bas, French Jura: Micropaleontology, sedimentology and palaeo-environment

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The sedimentology of three sections in lagoonal environments of the French Jura reveals small regional regressions on the carbonate platform, despite a general transgressive trend during the late Jurassic. As ammonites were not available, ages were evaluated using faunistic associations and/or reference stratigraphic layers, such as the "Marnes á virgula". During the lower and middle Kimmeridgian, a shallowing can be observed, from a shoal environment to a restricted lagoon, with condensed layers displaying wave ripples. Within the middle Kimmeridgian, a slight and progressive deepening is expressed by the increasing size of layers and the diversification of the fauna. At the end of the

sequence, a layer containing glauconite indicates a maximum flooding surface. Then, the upper Kimmeridgian, marked by the association of the *Clypeina* and *Campbelliella* algae defining the Beckeri ammonite zone, is once more a period of sea level drop where confined environments expand. This includes the "Marnes á virgula" or "virgulien" facies, indicative of the Kimmeridgian/Tithonian boundary. Finally, a carbonate layer with high concentrations of nerinean gastropods ("banc á nérinées") marks the limit between the lower and middle Tithonian, which is characterized by a last small deepening, and a semi-restricted lagoon environment containing *Campbelliella* algae.

Probable Testate Microfossils in the Neoproterozoic Bonahaven Formation, Scotland

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Microscopic spherules in mudstone horizons of the Neoproterozoic Bonahaven Formation, Islay, Scotland, are differentiated from their matrix by a sharp micron-scale, smoothly rounded boundary. These spherules were earlier interpreted as hollow bodies filled penecontemporaneously by glauconite and subsequently metamorphosed to phengite, but their origin remains a matter of debate. The spherules are predominantly rounded (~ 74%) but can exhibit a flat edge or protrusion at one end. In 11% of a sample population, two or more spherules are conjoined. X-ray diffraction indicates that spherule-bearing mudstones are mainly muscovite, with variable amounts of kaolin-group minerals and minor quantities of iron-chlorites. A range of physical origins for the spherules are considered but rejected on distributional, petrographic and geochemical evidence. These include origin as detrital grains, micrometeorites, microtektites, and diagenetic or metamorphic microstructures. Biological origins are considered most likely, especially protistan tests similar to the vase-shaped microfossils found in somewhat older Neoproterozoic rocks. If correct, this provides the first record of eukaryotic life in the Dalradian succession and new evidence for testate microfossils in post-Sturtian but pre-Marinoan aged rocks.

The Chelicerate Fossil Record: A Quantitative Analysis For Macroevolutionary Studies

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The Chelicerata have constituted conspicuous elements of ecosystems since the Ordovician, especially after the rise of the terrestrial arachnids from at least the Silurian onwards. A thorough study of their diversification across the Phanerozoic has been recently made possible by the compilation of a comprehensive dataset of their fossil record. This study presents a preliminary analysis of these data, aiming to identify the extent of diversification signal versus biases behind the diversity curves we obtained. We show that amidst a steady and ongoing research effort, intensively studied Coal Measures and Baltic Amber Lagerstätten have distorted estimates of the total synoptic diversity over the years. This hinders a uniformly representative signal across eras and also requires a differential analysis for marine and terrestrial chelicerates. Correlation with geologic time series of this raw record might then be only artefactual. Exponential descriptions of Mesozoic material coming from developing countries point in fact to an historical / geopolitical bias rather than a terrestrial sedimentary volume effect. Using a variety of analytical tools, such as Simpson's diversity index, we present simple methods to reshape synoptic curves that could be of use for other Lagerstätten-based records.

posters

Cyrtograptids from the Telychian (upper Llandovery) of Kinnekulle Mountain, southern Sweden

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The late Llandovery graptolite fauna of the Retiolites Shale on Kinnekulle Mountain (Västergötland) has long been known but never studied in detail. New collections of graptolites from the top of the exposed succession confirm previous reports of cyrtograptids making the shales on Kinnekulle the youngest Palaeozoic rocks in the area. The co-occurrence of *Oktavites spiralis* and *Cyrtograptus lapworthi* constrain the strata to the lower *lapworthi* Biozone of the upper Telychian. The associated graptolite fauna comprises numerous monograptids and *Retiolites geinitzianus* as well as a new species of *Cyrtograptus*. The new species is characterised by its open coiling and second order cladium. This early occurrence of a cyrtograptid species with a second order cladium on Baltica matches evolutionary patterns observed in Laurentia, suggesting that the ability to grow cladia, of both first and higher order, evolved approximately synchronously and at the very beginning of cyrtograptid evolution. Analysis of the positions of cladia in *C. lapworthi* indicates that the most proximal cladium was not necessarily the first to be formed. It appears that the first cladium originated distally, and more proximal cladia formed afterwards. It is proposed that cladia evolved as a counterbalance to compensate for the increasing length of the main stipe.

Latest Jurassic–Earliest Cretaceous Radiolaria from radiolarites of the Sevan ophiolite (Armenia): palaeoenvironmental and palaeobiogeographic implications

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Mesozoic radiolarians are nearly the only fossils preserved in the sedimentary cover of the Sevan ophiolite in Armenia. They are thus of importance for the investigation of the geodynamic evolution of the wider area between Eurasia and the South-Armenian Block, a Gondwanian micro-continent. Two latest Tithonian – late Valanginian faunas were recovered from the Tethyan suture zone situated north and east of Lake Sevan; both of them are characterized by the presence of *Obesacapsula cetia* and *Dicerosaturnalis trizonalis*. Radiolarians are relatively well-preserved and diverse; they were extracted from cherts that are intercalated with mafic rocks formed after episodes of submarine volcanic activity. Both radiolarite sequences contain rounded blocks of limestones (oolitic grainstone with fragments of crinoids); they provide evidence for shallow water platform carbonates in the neighbourhood, fragments of which slid into a bathymetrically complex oceanic sea floor. The assemblage from Dali appears to be more diverse, with over 30 species identified so far, amongst which *Parapodocapsa amphiterptera* is the most abundant. Dominant genera include *Archaeodictyomitra*, *Dicerosaturnalis*, *Emiluvia*, *Pantanellium*, *Podobursa*, *Sethocapsa* and *Tritrabs*. The rare presence of *Vallupus japonicus* at Dzknaged is of particular significance, as it suggests that these radiolarites accumulated in the tropical biogeographic realm of the "*Vallupus* territory".

Rugose corals from the Upper Ordovician Sholeshook Limestone of Wales

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Limestone horizons of Upper Ordovician (Katian) age in southwest Wales contain diverse fossil faunas including rugose corals. The existence of Ordovician Rugosa in Wales has been reported since Murchison's days but hardly any specimens were ever documented systematically. Newly collected material from the area around Llanddowror (Carmarthenshire) has now confirmed the diversity of rugose corals in the Sholeshook Limestone (Katian age), an arenaceous limestone originating from the shelf edge of the palaeocontinent Avalonia. The majority of the specimens are preserved as moulds. This means that in many instances preservation of the fossils was insufficient for specific identification; nevertheless, it was possible to document a previously unknown diversity of rugose corals, including *Helicelasma*, probable *Grewingkia* and *Kenophyllum*, and a potential early mucophyllid. While associated with considerable difficulties as some diagnostic features of Rugosa are not visible in moulds, it is demonstrated here that the work with such specimens can result in faunal information which would otherwise be unobtainable. The fauna has strong similarities with other Avalonian (Irish, English, Belgian) as well as Baltic (Estonian and Norwegian) rugose coral faunas. This work represents the first systematic study of Ordovician Rugosa from Wales since the middle of the 19th century.

Preservation of fossil insects from the Crato Formation (Early Cretaceous: Aptian) of northeast Brazil

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The Crato Formation (Early Cretaceous: Aptian) of northeast Brazil is a world-class konservat-lagerstätte. It is comprised of four distinct members, the lowest of which, the Nova Olinda Member, is a finely laminated limestone yielding an exceptional palaeobiota which includes more than 300 species of insects.

The insects are preserved as goethitic replacements in weathered rock with infills of diagenetic minerals (calcite and ?baryte), but in unweathered rock, the insects appear to be carbonaceous and perhaps Fe sulphide rich. Interestingly, details of insect microstructures and ultrastructures are seen in both preservational styles. Insect soft tissues (*e.g.* muscle) are occasionally found replaced by calcium phosphate. This project examines the fidelity and mode of preservation.

High-magnification SEM studies reveal micrometre- and nanometre-scale details. Individual cuticular plates are visible and setae are preserved with clearly defined parallel ridges. Many structures that should have broken down within hours of death are present (*e.g.* muscles and genitalia) and show remarkable preservation. This mode of exceptional preservation is not fully understood and may be unique to the Crato Formation.

posters

Ichthyosaur Ontogeny, a Morphometric Approach

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Ichthyosaur specimens are abundant and often exceptionally well-preserved, but surprisingly little is known about their ontogeny. Here, we present a morphometric study of four Lower Jurassic genera (*Stenopterygius*, *Ichthyosaurus*, *Temnodontosaurus* and *Suevoleviathan*), based on measurements from individual skeletal elements and composite body parts. These were analysed using a variety of multivariate and bivariate statistical techniques. It was determined that individual skeletal elements both grew isometrically or very slightly allometrically and did not experience significant shape change during the life of the animal. By contrast, several other features did change dramatically during growth. In comparison to body length, the skull exhibits negative allometry, becoming relatively smaller in larger individuals. Furthermore, in comparison to skull length, the external diameter of the sclerotic ring also exhibits negative allometry, becoming relatively smaller in individuals with longer skulls, leading to an increased gap between the external margin of the sclerotic ring and the orbital margin. Using these features the relative ages of ichthyosaurs can be more reliably established. These results are potentially beneficial for testing taxonomic hypotheses based in part on differences in body size by enabling the recognition of individuals as potential ontogenetic variants of a single taxon or not.

Microfabrics of non-skeletal body-parts in rotten fishes and exceptionally preserved early vertebrates

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Like many basal members of extant phyla, early chordates and early vertebrates were entirely soft-bodied. It follows from this that some of the most important fossil vertebrates, in terms of their broader evolutionary and phylogenetic significance, are specimens that preserve the remains of non-biomineralized tissues. Unfortunately, many of these fossils are also amongst the most controversial, with considerable disagreement concerning the homologies of the anatomical characters preserved, leading to equal uncertainty and debate over their correct phylogenetic placement. Topological relationships – similarities in the spatial juxtaposition of body parts – are crucial in establishing structural correspondence and putative homology between body parts in two or more organisms. However, in fossils which lack well-preserved skeletal landmarks (*i.e.* non-biomineralized taxa) topological data are sometimes equivocal or unobtainable. In such cases other criteria assume greater importance. These include the intrinsic properties of body parts, such as compositional or microstructural evidence. Understanding how the processes of decay and preservation influence compositional and microstructural evidence is obviously critical in this context. We show how experimental decay combined with high magnification imaging (optical and SEM) of fossil and extant remains provide important constraints on the homology of non-skeletal characters in early vertebrates.

Constructing Cambrian body-plans: critical evaluation of tommotiid and stem-brachiopod character homologies

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The origin and evolution of Brachiopoda can be traced to the plethora of lower Cambrian scleritome and brachiopod-like taxa. We aim to determine the characters suites linking these stem-lophotrochozoa to crown brachiopods and other lophotrochozoans. This is achieved by comparing records of exceptional preservation, most conspicuously members of Lagerstätten such as the Burgess Shale type faunas, with more widespread Cambrian stem-brachiopods and small shelly fossils. This determination is crucial to reconstructing the brachiopod stem-group and in polarising character changes associated with the putative transition from scleritome organisms to crown-group brachiopods.

Major critical features examined include those of fossilised setae, structures commonly found across Lophotrochozoa. Exceptionally preserved *in-situ* setae can be found in both brachiopods and tommotiids, implying a close affinity. The addition of 3D microCT data provides novel information on ontogenetic growth trajectories and the arrangement of phosphatised shell structures, including so-called 'acrotretid type' columns and the conformation of associated lamellae.

Such new data facilitates further critical anatomical comparison of tommotiids including *Micrina*, *Sunnaginia* and *Eccentrotheca* with stem-group brachiopods such as *Mickwitzia* and *Setatella*.

These suggested homologies are of phylogenetic significance, and shed further light on the early evolution of the lophotrochozoan body plan in the Early Cambrian.

Three-dimensional computer reconstruction of a lower Palaeozoic trepostome bryozoan

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Examining the exterior of trepostome bryozoans does not typically reveal sufficient characters to identify specimens to below order level. Currently, trepostomes are identified using three oriented thin sections: transverse, longitudinal and tangential. Usually this is sufficient; however, there are genera in which the internal morphology is highly complex and cannot be fully understood using these methods. In such cases, tomographic techniques, which enable the imaging of parallel serial sections, are the optimal means of reconstructing the internal form of three-dimensionally preserved fossils. Here we present a combined X-ray and physical-optical tomographic approach applied to an Ordovician trepostome bryozoan. X-ray microtomography (XMT) enabled accurate reconstruction of the exterior of the fossil, but could not resolve interior details because there is weak internal density contrast. Destructive physical-optical tomography using serial grinding and digital photography yielded high-quality images of the interior of the fossil; these were combined with XMT data to generate a high-resolution, three-dimensional digital model of the fossil showing internal and external characters. Virtual dissection of this digital fossil allows the tracking of individual chambers through an entire colony. This study demonstrates the potential of tomographic techniques for reconstructing the internal structures of Palaeozoic bryozoans in three-dimensions.

posters

Irregular holes in beached shells produced by aeolien sandblasting

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Holes in shells are produced by both biological and mechanical factors. Pratje (1929) previously studied holes in empty cockle shells produced in the coastal zone by surf and currents, and suggested they indicated shallow seas with tidal currents, as they were absent in the Baltic. Later experimental and field research dealt always with shell abrasion under water.

I observed sandblasting on an exposed beach on Texel also producing irregular holes in cockleshells. Most parts of the Dutch coast are eroding and retreat is counteracted by beach nourishment. However, the southern part of Texel is growing, resulting in a wide beach area with a shell plaster surface. Shells are mainly in stable, convex-upward position and abraded by sandblasting. In particular cockleshells (*Cerastoderma edule*) show clearly abrasion of their surface sculpture, followed by formation of an irregular hole on the convex side.

Holes observed in (fossil) shells can be due to quite different causes, which makes (palaeo)-environmental conclusions more difficult than thought before.

Machaeridians from the Early Silurian of the Pentland Hills, Scotland: new data and revision of *Plumulites ruskini* Lamont

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Disarticulated sclerites of plumulitid machaeridians were collected from the Wether Law Linn in the Pentland Hills, Scotland. This formation has yielded an abundant and diverse macrofauna of mainly brachiopods, molluscs and trilobites. An assemblage of sponges was also found in close association with the machaeridians: this includes a new genus of non-lithistid sponge currently under review. Although neglected, machaeridians form an abundant part of the fossil benthic assemblage. The present specimens were described and compared closely to those collected by Lamont (1978) and to other specimens referred originally to *Turrilepas haswelli*, all from the same horizon and locality. The latter are here described and figured for the first time since they were mentioned over 130 years ago. The micro-ornament on these machaeridians is also documented here for the first time. Seven sclerite types are identified and grouped into scleritomes. Comparison with other Ordovician and Silurian collections indicates that the present material may constitute a new taxon. So far, evidence for the machaeridians' spatial and temporal distribution, their faunal importance and environmental preferences has come only from isolated sclerites. For confident taxonomic identification, complete individuals will need to be found.

Save the fishes! A rescue palaeontology operation to recover potentially significant Devonian fish fossils from Caithness flagstones used to pave a central Edinburgh street

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Rescue digs are routine in archaeology, often yielding important finds that would otherwise be lost to science. Work to save Devonian fish fossils found in Caithness flagstones in East Market Street, Edinburgh, is a rare example of a rescue operation in palaeontology. This partly reflects the limited value placed on geodiversity compared to cultural heritage despite the cultural history of the quarries associated with the extraction of the stone. After finding one well-preserved fish specimen in East Market Street Mr Ken Shaw of the Edinburgh Geological Society contacted AJM, whom he had previously met at a society field trip. This specimen and other subsequently-discovered specimens preserve cranial remains and other significant morphological data. A further search of similar flagstones throughout Edinburgh located numerous other specimens. Four of the slabs were selected for recovery, their positions recorded and the fossils consolidated prior to removal. The recovery operation involved the authors and their institutions, supported by City of Edinburgh Council, Tarmac and the British Geological Survey. Besides the scientific value of the

material recovered, the operation generated valuable insights into the logistics of organising such works in a city centre and the opportunities for public engagement afforded by such endeavours.

How long did stem penguins persist in South America? Looking at the evidence

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One of the most important events in the evolution of seabird faunas during the Cenozoic has been the change in dominance from extinct to extant families. In the North Pacific this event occurred during the Middle Miocene, with the extinction of Plotopteridae and decline of Pelagornithidae. It is possible to identify a similar pattern in South America, with the dominance of stem Sphenisciformes and Pelagornithidae before the Middle Miocene, and crown Spheniscidae and modern families after. Nevertheless, the stem Sphenisciformes *Paraptenodytes* and *Palaeospheniscus* have been reported during the Late Miocene of Chile (Bahia Inglesa Formation and Coquimbo Formation) and Argentina (Puerto Madryn Formation), suggesting a coexistence of stem and crown-taxa since the Early Pliocene. A revision of this putative record refutes the presence of both genera during the Late Miocene. According to this, the stratigraphic range is restricted to the Lower Oligocene and Upper Miocene of Argentina for *Paraptenodytes*, and Lower Miocene of Argentina and the Middle Miocene of Peru for *Palaeospheniscus*. This suggests that the change of dominance from stem Sphenisciformes to crown Spheniscidae in South America occurred during the Middle Miocene, similar to the change from extinct to extant families described for the North Pacific.

Adventures in the Atacama: a high fidelity record of Neogene seasonality for the East Pacific

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Darwin's November 1834 entry in the log of his voyage on the HMS *Beagle* records that, "*Along hundreds of miles of coast is one great deposit, including many Tertiary shells, all apparently extinct*." These molluscan assemblages are custodians of a huge potential repository of palaeoclimate data. Do they provide a new and potentially accurate measure of the full seasonal temperature variation for time intervals from the late Miocene, Pliocene and early Pleistocene? Can they be used to assess the climate state of the East Pacific during the critical time interval of the warm Pliocene? Here we present new data on seasonal marine temperature variations derived from fossil *Argopecten* and "*Chlamys*" bivalves from coastal Chile.

Oberhauserellidae (benthic foraminifera) blooms during the environmental perturbations at the Triassic–Jurassic boundary: palaeoecological implications

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The Oberhauserellidae (particularly, the transitional form Praegubkinella racemosa) have been considered as the benthic ancestor stock of Jurassic planktonic Favusellacea (Conoglobigerina, Globuligerina). In 2003, Hart *et al*. questioned if such Oberhauserellidae from the early Toarcian of northwestern Europe were mero-planktic forms, implying that it was a first experimentation of a planktic mode of life, linked to stressful anoxic conditions. The distribution and abundance of robertininid foraminifera (*Oberhauserella* spp. and *Reinholdella* sp.) at the Doniford section (southwestern England), during the major perturbations of the Triassic–Jurassic (Tr-J) boundary were investigated. In addition, geochemical and sedimentological analyses ($\delta^{13}C$ and Total Organic Carbon) were made to understand better the palaeoecological preferences of these organisms as well as their environmental affinities. Results have been correlated with the distribution of *Oberhauserella* sp. and *Praegubkinella turgenscens* across (1) the Tr-J boundary in the Northern Calcareous Alps, and (2) the Pliensbachian–Early Toarcian interval from Yorkshire (UK), indicating a close link between Oberhauserellidae occurrences and environmental stress conditions, such as oxygen depletion. The planktic or mero-planktic mode of life of Oberhauserellidae is further discussed. Finally, since Favusellacea are differentiated from Oberhauserellidae by different important morphological features pertaining to both gross architecture and wall ultrastructure, we conclude that a direct evolutionary relationship between both groups cannot be demonstrated at present.

Examining the Triassic–Jurassic Boundary extinction

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The Triassic–Jurassic extinction is recognised as one of the major five extinction events to have affected life on Earth. It differs, however, from other major extinction events as it is difficult to study in detail because of the lack of normal marine successions that cross the boundary. We are largely left instead, comparing marine faunas of Late Norian age with Late Hettangian or Early Sinemurian faunas. Major palaeogeographical changes in latest Triassic (Rhaetian) to earliest Jurassic (Hettangian) produced the quasi-marine "Rhaetic" facies widely found north of the Tethys; its restricted fauna can contribute little to extinction studies. The Hettangian seafloors of areas north of the Tethys were often anoxic or dysoxic and it is not until the Sinemurian that fully marine faunas were re-established. It seems likely that many Jurassic fossils are effectively Lazarus taxa, as their ancestors disappeared in the Norian, but continued to evolve in areas for which we have no record and then appeared as "new" taxa in the Early Jurassic. Such a model explains the fact that studies at higher taxonomic levels show remarkably few extinctions across this boundary.

Reproduction and ecological dispersal of the Ediacaran sedentary animal *Cloudina*

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Although *Cloudina* is the best-known biomineralizing metazoan in the Ediacaran Period, many aspects of its biology remain poorly understood. Previously reported material shows that *Cloudina* tubes grow from a funnel with a closed base and occasionally branch dichotomously (implying asexual division). However, beyond the branching point, fully developed tubes have never been observed.

New material from the Ediacaran Beiwan Member (Dengying Formation, South China) includes two morphotypes of *Cloudina*, which yield new information about its basal (apical) morphology. Some have a spherical apex (about 200-300 μm in diameter), whereas others have a narrow conical apex (about 50 μm in diameter). We speculate that the round-based tubes are incipient *Cloudina*, with its spherical apex representing the embryonic shell, whereas the conical-based tubes are "daughter buds", the result of dichotomous branching, disengaged from their parent tubes to enhance dispersal. This interpretation explains why no *Cloudina* specimens with fully developed dichotomous branching have been found. It also implies that both sexual and asexual reproduction, respectively represented by the spherical embryonic shell and conical propagule, may have served to enhance dispersal. This highlights the ecological importance of dispersal for early animals such as *Cloudina* that were gregarious sedentary organisms.

posters

Towards the Arthropod Supertree of Life: A Prototype Online Resource

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Arthropods are the most abundant and diverse of all animal phyla containing *c*. 30 million species. Despite a century of study, there is still no consensus on their relationships, and their radiation has been the focus of debates concerning the overall pattern of the diversification of life. A supertree of all arthropods has never been attempted before, yet searches of the scientific literature suggest a massive number of source trees.

We have developed and extended the existing *Supertree Toolkit* software to include a GUI that enables more user-friendly functionality. The prototype incorporates all curatorial meta-data such as bibliographic information, character types, analysis type and a tree string in Newick format. It can also be used to create a MRP (matrix representation with parsimony) matrix directly from the stored data. We have developed a prototype website that harnesses these applications to a database of over 350 source trees for Anomura (hermit crabs and allies) and Brachyura (true crabs). This enables any user to generate supertrees of crabs to their specifications online (*e.g.*, limited to molecular or morphological trees).

Finally we present a preliminary supertree of crabs synthesising >350 source trees and comprising >2,000 taxa created using the dataset and tools described above.

Late Mississippian to Early Pennsylvanian conodonts from western Ireland

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During middle Carboniferous (Serpukhovian to Bashkirian) times a widespread unit of non-calcareous dark organic-rich shales was deposited in the Shannon Basin in western Ireland. Mapped regionally as the Clare Shale Formation [CSF], they succeeded an earlier phase of extensive carbonate sedimentation during Tournaisian and Viséan times. While Carboniferous conodont faunas are fairly well documented from the latter (older) carbonate lithologies, they remain poorly understood from younger (largely non-calcareous) strata.

Three stratigraphic sections through the CSF were examined and logged at Paradise House and Inishcorker (both south-central Clare) and also at Ballybunion, Kerry. The unit is largely barren and pyritous; however, discrete bands occur containing a predominantly pelagic fauna of goniatites and thin-shelled bivalves. Previous workers established a detailed biostratigraphic zonation based on these goniatites and suggested a total age of E1c to R1a (Pendleian to Kinderscoutian) for all three sections (combined). Importantly, the CSF at these locations also contains several calcareous nodules which have produced conodonts, including *Gnathodus bilineatus* and *Declinognathodus noduliferus*. In addition to allowing the first detailed assessment of conodont biostratigraphic zonation for this part of the Irish Carboniferous, it is expected that the results may also shed light on several conodont evolutionary trends, particularly the *Gnathodus–Declinognathodus* transition.

Stars point the way

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The large, distinctive nodal columnals of *Floricolumnus* (col.) Donovan & Clark, 1992, are well documented from close to the Rhuddanian/Aeronian (Lower/Middle Llandovery) boundary in Scotland, Wales and North America. Silurian rocks of the Cincinnati Arch in Ohio, Kentucky, and Indiana have been studied for nearly two centuries and have recently undergone intensive review and significant revision. The occurrence of the crinoids "bead" is well known from both the "Upper Shaly Member" and the "Upper Massive Member" of the Brassfield Formation and occurs throughout east-central Kentucky and southern Ohio. Regionally, the Brassfield is interpreted to be upper Rhuddanian to Aeronian age (McLaughlin *et al.* 2011).

The discovery of the holdfast structure and most proximal columnal (Fearnhead *et al.* in press) from Girvan, Scotland, UK and new specimens collected from central Kentucky, U.S.A. (Thomka *et al.* work in progress) offer new hope for finding the crown and extending the knowledge of this group. We promote the use of these distinctive columnals as biostratigraphic markers to assist problematic stratigraphy for the Rhuddanian/Aeronian boundary.

Recent benthic foraminifera assemblages form shallow marine environments of the Arabian Gulf (United Arab Emirates)

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Recent and living (rose Bengal-stained) benthic foraminiferal assemblages and sedimentary facies were investigated in several shallow-marine environments of the Abu Dhabi region (United Arab Emirates). This research was carried out to construct a taxonomical data bank of benthic foraminifera that can be used in palaeoenvironmental reconstructions of Quaternary sediments from the same area. In addition, as anthropogenic activities have modified the coastal sedimentary systems in the Abu Dhabi area during the last 50 years, we have compared our data with studies conducted in the same area during the 1960s to assess the modifications in the distribution of benthic environments.

The studied samples were collected in nearshore shelf, beach-front, channels, lagoons and hypersaline ponds.

The living foraminifera are present in low percentages and no living foraminifera was recorded in the coarser sediments of the beach front and channels. Miliolid genera *Quinqueloculina*, *Triloculina*, *Spiroloculina*, *Spirolina* and *Peneroplis* constitute very high abundances in most of the studied samples. Species belonging to the genera *Elphidium*, *Ammonia* and *Rosalina* are also common, particularly in the nearshore shelf. Agglutinated foraminifera are present only in low percentages. Abundant Miliolidae with abnormal test morphology were found living in hypersaline ponds of the intertidal area.

Coleoid cephalopod phylogeny: fossils join the party

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The coleoid cephalopods comprise the Decabrachia (squid) and the Vampyropoda (octopi and the vampire squid). Previous cladistic phylogenies have been based almost exclusively on molecular and (to a lesser extent) morphological data from living taxa. However, Coleoidea has a diverse fossil record reaching back to the Carboniferous, which has great potential as a further data-source. The internal shell ('gladius') dominates this record, although it is supplemented with many examples of exceptional preservation, in particular from the Mesozoic of Germany and Lebanon. Relationships between fossil taxa, as well as their position in broader coleoid phylogenetic schemes, have been vigorously debated. Much of this debate has centred on the identification of fossil taxa as ancestors of either the Decabrachia or Vampyropoda, on the basis of a small number of individual characters. A new cladistic dataset, which comprises 107 characters from over 100 recent and fossil taxa, will help resolve these debates by incorporating all available fossil data into a phylogenetic scheme for the coleoidea as a whole. Preliminary results place the enigmatic vampire squid as the sister taxon to the Octobrachia, in accordance with previous morphological studies, and the Prototeuthida, a major group of Mesozoic coleoids, as ancestral to the Octobrachia.

The endoskeletal anatomy of *Cheirolepis*, the earliest ray-finned fish

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Ray-finned fishes account for over half of living vertebrate diversity, but the early origins of the group are poorly understood. The Middle Devonian *Cheirolepis* is sister taxon to all other ray-fins, and thus occupies a critical position in the group's phylogeny. Despite its importance, the anatomy of this fish is poorly known, especially that of its endoskeletal structure (the internal skeleton). Consequently the sequence of character evolution leading to the ray-fin crown cannot be understood, and the deficit of endoskeletal characters makes it impossible to compare *Cheirolepis* to outgroups such as the chondrichthyans. To rectify this problem, we subjected several specimens of *Cheirolepis* to high-resolution lab-based and synchrotron computed tomography, thus revealing previously undescribed aspects of the neurocranium and pectoral fin endoskeleton. The scapulocoracoid bears a narrow, undivided articular surface for the radials, and the propterygium is imperforate. The braincase is similar to later ray-fins, for example in its well-developed spiracular canal, although preserves unusual aspects of anatomy which may represent the plesiomorphic bony fish condition. These new data help us build a more comprehensive picture of the primitive condition within bony fishes, and thus develop an understanding of character evolution leading to the ray-fin crown.

The interpretation of a new enigmatic arthropod from the Cambrian Weeks Formation, Utah

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How does one interpret an ambiguous fossil? Whenever a palaeontologist approaches a bizarre fossil, the interpretive steps that are taken become even more important – and often include answering questions that are trivial with more straightforward remains. Does the fossil represent one individual or several? A whole organism or only a part? Are there repeated organs or structures? What is the symmetry of the organism? What does the present state of the remains suggest about their original composition?

Some unusual fossils from the Cambrian Weeks Formation Konservat-Lagerstätte in Utah provide an opportunity to discuss these interpretive steps. The most complete specimen is inferred to be a single organism, based on the presence of a possible plane of symmetry. The repeated structures on both sides of this plane are suggestive of paired arthropod limbs: two pairs of antennae-like structures and six robust, grasping-type appendages. The second specimen is inferred to be a single appendage, similar to the grasping-type appendages mentioned above. However, it also exhibits some similarities with the grasping appendages of some better-known euarthropods (*e.g.* anomalocaridids), and therefore its identity remains obscure.

Stick or twist: were microbial mats players in Green River preservation?

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The famous fossil fish from the late Lower Eocene Green River Formation, Wyoming are preserved in exquisite detail, but the taphonomic processes responsible remain poorly understood. Two observations are key. Approximately 95% of the fish are both complete and fully articulated. Among those fish that are disarticulated, what we term 'half and half' preservation is common: the anterior part of the fish is extensively disarticulated although rarely incomplete, and the posterior half complete and fully articulated. Neither observation is adequately explained by existing models that envisage rapid burial of carcasses and disarticulation having resulted from scavenging. Further, experimental analogues indicate disarticulation would have occurred, even without current activity, unless decay was halted within a matter of days (which the absence of non-mineralised tissues indicates did not occur) or a 'binding' agent was involved. We propose that microbial mats on the floor of Fossil Lake held the various skeletal elements of the fish in place while decay progressed, inhibiting disarticulation. 'Half and half' specimens are those that did not fully adhere along their length and either curved laterally or became partially buoyant, thus only that part that was in contact with the substrate (typically the posterior) retained a high degree of skeletal fidelity.

posters

Conodont and trilobite biostratigraphy across the Cambrian–Ordovician boundary in Deh-Molla, eastern Alborz, Iran

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The study of the Cambrian–Ordovician boundary beds in the Deh-Molla section, west of Shahrud, reveals that the first euconodonts – including *Proconodontus muelleri* – occur in the upper part of the Mila Formation Member 4 together with the monotaxic *Alborsella* trilobite assemblege. Higher up the sequence this fauna is succeeded by the appearance of *Eoconodontus notchpeakensis* and the first poorly preserved *Cordylodus*. The overlying Mila Formation Member 5 comprises exclusively barren siliciclastic sediments with abundant *Cruziana* trace fossils representing a shoal complex. The Lower Ordovician boundary is defined in the succession by the appearance of the characteristic *Asaphellus–Dactylocephalus* trilobite Association in overlying argillites, deposited in an open marine environment. Conodonts reappear in the middle part of the argillaceous unit, where they are represented by a medium-diversity association characteristic of the *Paltodus deltifer* Biozone, which occurs in tempestite limestone beds together with a trilobite assemblage

dominated by *Asaphellus*, *Asaphopsis* and *Conophrys*. Data from the Deh-Molla section suggest that carbonate sedimentation in Alborz terminated well before the end of the Cambrian, whereas the beginning of the Ordovician was marked by a marine transgression and an invasion of the deep water trilobite fauna with close links to South China on the generic and species levels.

A new collection of exceptionally preserved fossils from the roof shales of the Wigan Four Foot Coal Seam (Upper Carboniferous), Westhoughton, Lancashire, UK

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The Upper Carboniferous deposit at Westhoughton, UK is a site of exceptional preservation. This site was an opencast coal pit, until the end of operations and subsequent backfilling in the late 1990s – there are now plans to build on the site. Only one major study has previously been conducted on the palaeontology of this site, in 1999 by Anderson *et al.*, in which they logged an exposed sequence and described the fauna and flora from a collection (*c.* 120 specimens) which is now housed in the Manchester Museum (Carl Horrocks Collection). Recently a collection, which more than doubles that of the previously known material, has been donated to the Manchester Museum. This collection contains some exceptionally-preserved material, including articulated arachnids, millipedes, a complete scorpion, and the first record of insects from this site (both adults and nymphs). The new material is dominated by arthropods; however rare vertebrate material is also present, including skull material and egg cases, as well as plant fossils, and coprolites. This new material forms the basis of a new study on the palaeontology, palaeoecology, and palaeoenvironment of the Westhoughton locality, updating and expanding the previous work.

Evidence and reason for cool winter conditions in the Pliocene North Sea from bivalve sclerochronology

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The $\delta^{18}O$ of deep-sea benthic forams indicates lower global ice-volume and higher mean surface temperature in the early-mid Pliocene (5.3-3 Ma) compared to present. Assemblage evidence from the Ramsholt Member, Coralline Crag Formation, Suffolk (*c.* 4 Ma), generally confirms warmer conditions in the North Sea area during this interval. However, oxygen-isotope evidence, including new data from the long-lived boreal bivalve *Arctica islandica*, disagrees. Isotopic evidence of modest Summer seafloor temperatures can be reconciled with evidence of high surface temperatures from planktonic dinoflagellate assemblages by invoking seasonal stratification. Low isotopic Winter temperatures can be reconciled with the presence of subtropical bryozoans (benthic) by invoking fluctuations in Winter climate. Winter temperatures in the North Sea area are strongly influenced by dominant wind

direction, which relates to the Winter North Atlantic Oscillation index, a measure of the pressure difference between the Azores High and Icelandic Low. This can be estimated from profiles of annual increment size in *A. islandica*. Data from Ramsholt Member specimens imply that the index was generally low when they were alive, suggesting that low Winter temperatures were caused by cold winds from the European continent. The high Winter temperatures indicated by bryozoans may relate to a warm south-westerly airflow.

Carbonates, ammonites and missing molluscs: a new perspective from Lyme Regis

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The Lower Jurassic Blue Lias Formation at Lyme Regis, Dorset, preserves a diverse assemblage of invertebrate and vertebrate fossils within rhythmic packages of shales, marls and carbonates. One limestone bed in particular, Bed 29, or colloquially the "ammonite bed", is well known for containing an unusually high density of ammonites. These reach diameters greater than 50cm, and cover approximately 40% of the exposure at Seven Rock Point to the west of Lyme Regis Harbour. The abundance of these fossils is most likely due to condensation, but the preservation of aragonitic molluscs in such a setting presents a challenge for conventional taphonomic models.

Following detailed field observations, we present evidence for a new model of aragonite preservation within a cyclic anoxic–oxic carbonate environment, in which carbonate sediment provides a geochemical buffer that militates against the dissolution of aragonite in some conditions. The broader implications of this model for the preservation of molluscan shells in carbonate environments, and hence for the "missing mollusc" debate, are discussed.

Asexual reproduction via somatic embryogenesis reveals the ontogeny of vegetative tissues in the early Devonian Rhynie chert plant, *Rhynia gwynne-vaughanii*

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The Early Devonian Rhynie chert has proven to be an invaluable source for studying the morphology, ecology and life cycles of early land plants. Now the life cycle of the chert plant *Rhynia gwynne-vaughanii* can be shown at a deeper ontogenetic level with the discovery of asexual propagules developing from multiple cell layers in its aerial axis. Three distinct stages of development observed in the propagules document the formation of stomata, rhizoids, vascular tissue and apical growth. The developmental pattern of the propagules strongly resembles somatic embryogenesis, a form of asexual reproduction that occurs in extant plant species in nature as well as *in vitro*, which is important in the propagation of commercially important crops. The occurrence of somatic embryogenesis in the primitive *Rhynia gwynne-vaughanii* reveals that this is a fundamental form of asexual reproduction conserved over millions of years of plant evolution, and it marks a significant step towards understanding how the tissues and organs of early land plants formed. This also allows us to compare the ontogeny of *Rhynia gwynne-vaughanii* with that of morphologically simpler plant groups such as the bryophytes, as well as with more complex groups such as the gymnosperms and the angiosperms.

Hominin fossils from the Malapa cave site, South Africa: Examining the preservation potential of soft tissue

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The near complete Plio–Pleistocene aged *Australopithecus sediba* hominin specimens from the Malapa site, South Africa were analysed to determine whether soft tissue in the form of fossilised skin may have been preserved. The taphonomic condition of the fossils suggests rapid burial, lack of predation, but some insect damage, making the preservation environment at Malapa exceptional. Any soft tissue found with the hominins, represented by MH1 (Malapa Hominid 1) and MH2 (Malapa Hominid 2) would be of some considerable value, although such preservation is at present unrecognized in the early hominin record. A multidisciplinary approach that combined morphological and molecular imaging techniques investigated whether original organics may be recovered. The overall study produced a provocative body of evidence that the specimens were indeed organic in origin. The significance of such a discovery could provide insight into our understanding of ancient hominin behaviour, biological pathways and taphonomic processes.

Basil Brushes: painting a new picture of the Ediacaran macrofossils of Charnwood Forest, UK

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The Avalonian Assemblage of Charnwood Forest, UK and Newfoundland comprises one of the oldest known occurrences of Ediacaran macrofossils. Although long considered the poor cousin of the Newfoundland succession, recent cleaning of bedding surfaces in Charnwood Forest has uncovered an unexpectedly diverse and well-preserved fauna, including at least seven previously undescribed taxa. One of these is the intriguing Basil Brush, of which thirteen specimens are known.

A variety of imaging techniques including 3D laser scanning, polynomial texture mapping, high-resolution photography and camera lucida drawing have been employed to aid visualisation of both the detailed and underlying structure of the Basil Brushes. Their principal characteristic is a sheet-like structure comprising a series of undulose grooves separated by alternating higher- and lower-relief ridges. Although superficially similar to a number of sedimentary features such as *Arumberia*, the Basil Brushes are distinguished by the alternating relief of the ridges, the truncation of ridges against others, and evidence of a basal holdfast and stalk. The consistent association of these fossils with fractally-divided frondose elements identifies this form as a novel rangeomorph taxon with a uniquely complex external sheath or veil. This has significant implications for the level of morphological complexity expressed by early Ediacaran rangeomorphs.

The Burgess Shale's little brother: A new Lagerstätte from the Middle Cambrian of the Mackenzie Mountains, Northwest Territories, Canada

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Burgess Shale-type Lagerstätten are known from the Cambrian and Ordovician of most continents, and these snapshots of benthic marine communities are critical for the understanding of the early evolution and diversity of life. Here we present a new Lagerstätte in the Rockslide Formation of northwestern Canada. It is of similar middle Cambrian age as the Burgess Shale itself, but is non-metamorphosed. Fossils include hyolithids, agnostoid and ptychoparioid trilobites, Isoxys and one or two other arthropod taxa, priapulids, sponges, lingulid brachiopods, *Margaretia*, and circular organic blobs that represent microbial mats or coprolites or regurgitites. The fossils occur in a unit of greenish siliciclastic mudstone, *c.* 1 m thick, that is part of a deeper water succession of shales and lime mudstones that onlaps a fault scarp cutting lower Cambrian sandstone. The host beds consist of illite, quartz, clinochlore (Mg-rich chlorite), and dolomite. Trace element analysis shows an oxygenated water column but with some fluctuations, and there is also variation in the total organic carbon content of the fossil-bearing beds.

Freshwater pearl mussel shells as recorders of environmental change in the River Kerry, NW Scotland

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The fundamental premise of conservation palaeobiology is that data garnered from the fossil record can aid in the conservation and management of extant populations and ecosystems. Our study focused on vulnerable populations of *Margaritifera margaritifera*, commonly known as the freshwater pearl mussel, in several Scottish rivers, which is a priority species for Scottish Natural Heritage. Our work had two main objectives: 1) to demonstrate the potential for evidence drawn from taphonomic work, morphometrics and museum collections to add to the evidence base for the management of extant populations; 2) to test whether the mussels preserved a signature of increased growth rate in response to the damming of the River Kerry in the 1950s. To investigate this a number of shells from the Kerry and the Moidart were sectioned and treated with Mutvei's solution to allow counting of growth lines to age the specimens, and the distance between growth lines was measured using microscopy. The Kerry specimens did indeed show increased growth rates in the first few years after the construction of the dam. This pilot study has demonstrated the unique contribution conservation palaeobiology techniques can make to the study of the ecology of this threatened species.

Exceptional preservation of lobopods and the sedimentology of the Eramosa Lagerstätte

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For many Lagerstätte the influence of the depositional environment on the preservation of soft body fossils is poorly understood. Indeed, detailed studies of the sedimentology of Konservat-Lagerstätte deposits are themselves rare. In many cases, it is not known how the environmental context of the fossil – both at macrofacies and microfacies scales – controls its taphonomy. The "lobopod bed" of the mid Silurian Eramosa Lagerstätte of Ontario, Canada exemplifies this problem. This is a particular horizon within the Lagerstätte that preserves relatively abundant lobopodians, and it is unknown whether this abundance is due primarily to taphonomic factors linked to enhanced preservation, or because of environmental and ecological factors. The lobopod bed is in a sequence of shallow marine micritic carbonates, with a high organic content that is present in sub-millimetre thick laminations. By placing an emphasis on the relation of fossils to the sedimentary and environmental conditions they were deposited in, we illustrate the complex interaction between fossil preservation and short-term changes in the depositional environment.

Normal salinities for Pennsylvanian basins in north-west Europe: evidence from new ammonoid-bearing horizons in the Carboniferous Shannon Basin, Ireland

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The Shannon Basin, located in Western Ireland, developed in Early Carboniferous times and is floored by shallow and deep-water Dinantian limestones. The basin fill succession consists of deep-water shales which blanket the basin floor, succeeded by basin floor turbidite sandstones (Ross Sandstone Formation), followed by slope and delta deposits in an overall shallowing-upward trend. Ammonoids and thin-shelled bivalves have long been known from widespread, black, carbonaceous shales known as "marine bands". These faunas were previously thought to be restricted to these intervals of sediment starvation in the Shannon Basin and elsewhere in NW Europe.

However, several new ammonoid-bearing horizons have been found in between the "marine bands" in the Shannon Basin, showing that waters were not devoid of normal marine fauna during times of higher sedimentation rates between the ammonoid-rich layers. Ammonoids have been found in muddy siltstone horizons and are preserved as bounce casts at the base of sands. The presence of normal marine faunas outside the traditional "marine bands" suggests that salinity values of the Shannon Basin and, by implication, of other deep water basins were normal in between periods of sediment starvation, and that sedimentation rates served as the primary control on ammonoid preservation.

Dark and Disturbed or Sunny and Bright: A New Approach to Determine Early Angiosperm Habitat

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Whether the earliest angiosperms functioned with high or low photosynthetic gas exchange capabilities remains a key debate in the on-going research into angiosperm origins. The high gas exchange hypothesis supports the notion that the first angiosperms existed as opportunistic weedy species favoured in exposed sunny environments. Conversely, the low gas exchange hypothesis would infer that the earliest angiosperms existed in understory forest canopies with low transpirational demands. We have devised a novel method to test these competing hypotheses through developing a leaf energy balance model capable of predicting leaf temperature as a function of air temperature, radiation load and stomatal conductance. The modelled solution of leaf temperature will help to determine the environmental tolerance of the early angiosperms and whether – given that their low stomatal conductance would limit their transpirational cooling capacity – the earliest angiosperms could have survived the exposed sunny environments of the Aptian when temperatures would have ranged from 38-43 °C. Furthermore, full stomatal closure would likely occur at midday so regardless of baseline conductance, whether the small size of early angiosperms leaves was enough to avoid heating to lethal temperatures is fundamental as to whether the angiosperms could have survived out of the shade.

A remarkable new discoidal fossil from the late Ediacaran of the Long Mynd, Shropshire, UK

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The late Ediacaran (566–555 Ma) biotic assemblage of the Long Mynd, Shropshire, has yielded a previously unrecognised discoidal form that possesses tetraradial symmetry. The new fossils, discovered by an amateur palaeontologist, are 2-5mm in diameter and occur within the Burway Formation. They consist of a central circular depression, preserved in negative epirelief, surrounded by four larger and equally-spaced rounded lobes.

These new tetralobate fossils are substantially more complex than any previously described Longmyndian discoidal structures, and possess both 4-fold radial and mirror symmetry. Tetraradial symmetry is uncommon amongst both the Ediacaran biota and modern macroscopic eukaryotes, with certain plants, and cubozoan and scyphozoan cnidarians, being some of the few extant organisms to possess it. Recognition of such symmetry in late Ediacaran shallow marine to alluvial ecosystems could therefore be useful for determining the biological affinities of these discoidal taxa.

The relationship between the tetralobate forms and the discoidal impressions *Medusinites* aff. *asteroides*, and *Intrites punctatus*, which co-occur in abundance at the same levels, is also intriguing. There is evidence to suggest a possible morphological continuum between these impressions, raising the possibility that the tetra-lobate fossils preserve a stage in the ontogenetic development of those previously described organisms.

Pre-burial preservation potential of land crabs (Decapoda, Brachyura, Gecarcinidae) on San Salvador Island, the Bahamas

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Field surveys were conducted along the northern coast of San Salvador Island to assess the preservation potential of two land crab species, *Gecarcinus lateralis* and *G. ruricola*. Three localities that varied in vegetation, energy and sedimentation rate were investigated. More than 1,400 identifiable remains were found.

Most remains exhibited various levels of disarticulation. Overall, there was a relative over-representation of claws, and the distribution of recovered remains differed significantly from the proportions in the living animal (8 legs, 2 claws and 1 carapace). The impact of fragmentation, surface alteration and colour loss varied significantly across localities. Remains found in direct sunlight and open spaces were consistently more fragmented, and showed more surface alteration and more colour loss than those found within vegetation or on the beach.

The quantity and quality of surficial crab remains found suggests that land crabs, particularly their claws, can survive short term-taphonomic filters, and therefore have the potential to be preserved. Fossil land crabs – known largely from claws – are found in sediments of Pleistocene and Holocene age throughout the Caribbean. Further work focused on the long-term taphonomy of terrestrial crustaceans is needed to fully understand the fossilization potential of fossil land crabs.

Blistering barnacles!

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The Natural History Museum, London (Departments of Earth and Life Science) holds one of the world's largest and finest collections of cirripedes (barnacles), including the specimens famously studied by Charles Darwin for eight years, thought to be central in providing evidence for his theory and before writing "*On the Origin of Species*". Darwin's 1851 and 1855 Palaeontographical Society Monographs have remained standard works in cirripede morphology and systematics, both for fossil and living forms. Visitor and exhibition-related queries often relate to the Darwin specimens but unfortunately Darwin did not catalogue his own material and most specimens remain unidentified.

The authors are engaged in a project to find and document all Darwin's type and figured specimens in order to increase the accessibility and profile of one of the world's most important collections of cirripedes.

Immunohistochemical studies of forebrains across Lophotrochozoa and Ecdysozoa

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The evolution of central nervous systems (CNS) is highly constrained through geological time; therefore, comparative study of neuroanatomy can provide fundamental data for understanding deep phylogeny of major animal groups. In arthropod forebrains, higher order centres are associated with learning and memory, such as the insect mushroom body and malacostracan hemiellipsoid body. A previous immunohistochemical study shows that both structures express the major catalytic subunit of cAMP-dependent protein kinase A (DC0), to the exclusion of the rest of the brain. This evidence, along with corresponding morphological elements, suggests that insect mushroom bodies and crustacean hemiellipsoid bodies are genealogically homologous, but it is unknown whether this organization is part of the ground plan for all arthropods. In this study, we used immunohistochemical methods to localize and compare DC0 expression in arthropods (Insecta, Crustacea, Chelicerata, and Myriapoda) and a polychaete (*Nereis virens*) to determine whether the mushroom body ground plan may have been present in the common ancestor of Ecdysozoa and Lophotrochozoa. Despite superficial differences in morphology of higher order centres between arthropods and polychaetes, we have found DC0 expression localized to these structures in representative taxa, indicating that the mushroom body ground plan might precede the divergence of Lophotrochozoa and Ecdysozoa.

A new species of *Tretaspis* (Trilobita, Trinucleidae) from the Late Ordovician (Katian/Ashgill) Slade and Redhill Mudstones of Carmarthenshire, South Wales

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A new locality near Llanddowror, St. Clears, Carmarthenshire, has yielded a well-preserved trilobite fauna from the Slade and Redhill Mudstones, including many articulated specimens. The conservative fauna includes a new species of *Tretaspis*, which falls outside of Ingham's (1970) division of the genus into a *T. seticornis* group and a *T. moeldenensis* group. It combines the out of phase I1-E1-2 and I2-In radii of the former group, with the anteriorly complete E2 of the latter. The new species is likely conspecific with *T.* sp. indet. B of Price (1977). Species of *Tretaspis* have proved useful biostratigraphic tools, and the new species offers potential for distinguishing an older part of the Slade and Redhill Mudstones from a younger (zone 5-6) part that yields *T. hadelandica brachystichus*. Numerous well-preserved specimens of the odontopleurid *Meadowtownella llandowrorensis* dominate the fauna, and will allow a full redescription of the species. Other trilobite taxa present include *Calyptaulax* cf. *planiformis*, *Toxochasmops marri*, *Sphaerocoryphe* aff. *thomsoni*, *Calymene* cf. *prolata*, *Platylichas* cf. *angulatus*, *Remopleurides* aff. *colbii*, *Hibbertia* sp., *Illaenus* (*Parillaenus*) sp. and *Stenopareia* sp. An unusual cranidium, with a single, continuous eye around the cranidium edge, likely represents a new genus.

posters

Variables contributing to fossilization within concretions

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Fossils are commonly preserved in concretions, yet this process of fossilization is not fully understood. Thus any biases imposed on fossil assemblages within concretions remain to be analysed in detail. The process of exceptional fossilization within concretions can be investigated in two main ways: 1. Detailed analysis of the composition and context of concretions at specific sites; and 2. Statistical analyses of variables of environment, concretion composition and fossilization across a number of concretion sites. Isotope analyses of concretions from the Pennsylvanian Mazon Creek Lagerstätte demonstrate that the carbonate was precipitated due to bacterial activity in the zones of sulphate, iron and manganese reduction, utilizing inorganic carbon, as shown previously for other sites. Preliminary data suggest that two distinct isotope signatures in the precipitated carbonate may reflect bacterial processes in the freshwater and brackish environments at Mazon Creek; more analyses are needed to test this hypothesis. Principal component analyses (PCA) can identify the variables that most influence the distribution of exceptional fossilization among concretion sites. These factors can then be analysed at specific sites to understand their role in concretion formation and exceptional fossilization. PCA also indicates which modern concretion sites are the best analogues for particular ancient concretion sites.

An investigation into the dietary niche of the Port Jackson shark using microtextural analysis

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Determining the dietary preferences and trophic niches of extant and extinct chondrichthyans is problematic. Until recently, the use of quantitative microtextural analysis of tooth wear for dietary discrimination was restricted to terrestrial mammals, but it is now known to be a powerful tool for analysis of trophic niche and dietary change in fish. Can the same approach be applied to chondrichthyans? Microtextural analysis of shark teeth has never been attempted, and the hypothesis that it is correlated with diet, feeding and/or trophic niche thus remains completely untested. Here we present the results of a proof-of-concept study designed to investigate the potential of microwear analysis in chondrichthyans.

Using the Port Jackson shark, *Heterodontus portusjacksoni*, analysis of variation in microtextures between sample sites within a tooth, between teeth within an individual, and between individuals, suggests that a dietary signal is preserved. Comparison of tooth microtextures from *H. portusjacksoni* with data from extant teleost fish with known diets allows the specificity of the dietary signal and the relative importance of differences in tooth morphology and histology, jaw mechanics and organism size to be evaluated.

Taphonomic dynamics of lacustrine ostracodes on San Salvador island, Bahamas

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The taphonomic fidelity of proxy indicators in cores is a critical consideration for using them in paleoclimatic and anthropogenic analyses. This study focuses on the precision and accuracy of a record from seven lakes on San Salvador Island, Bahamas. We tested the record's accuracy by examining the correlations between rank-abundance and taxonomic composition of sixteen living communities and death assemblages; and the precision by comparing the taxonomic composition and species abundances of sixteen death assemblages from each of the same seven lakes. In six of these lakes, the accuracy of the death assemblages is high. In these same six lakes, the within-lake precision of the record is also high since death assemblages recovered from individual lakes are more similar to assemblages from the same lake than to any other lake. In the remaining lake, the accuracy and precision of the record exhibited wide variation at individual sampling sites that are related to its past use as a water resource for a nearby plantation, a steep depth gradient, and tidal fluctuations. This study demonstrates the high fidelity of the ostracode fossil record, but highlights the importance of site-specific taphonomic studies to understand physical and biological processes that may obscure the record.

Macroevolutionary trends of the ammonoid family Acanthoceratidae (Late Cretaceous)

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The fossil record displays numerous evolutionary trends, which are persistent changes through time and direction of morphological characters within a monophyletic group. This directionality (*e.g.* increasing body size, greater complexity of life) is a major aspect of evolution. Such macroevolutionary trends have been investigated for a rich clade of ammonoids, the Acanthoceratidae (Late Cretaceous). Adult size, shell coiling, complexity of ornamentation, and complexity of the suture line of an exhaustive compendium with about 150 species (with revised taxonomy, biochronology and phylogeny) have been analyzed. When considered as a whole, the family does not show any sustained trend but displays a diffusive pattern of evolution (ranges of parameters covary with diversity; speciation does not show any preferred direction; no evolutionary attractor can be detected). However, at the subfamily rank, several and different trends are documented. For instance, Mantelliceratinae, Calycoceratinae and Mammitinae do not reveal trends in adult size, while Acanthoceratinae show an initial trend subsequently levelling off, and Euomphaloceratinae show a pervasive trend consistent with Cope's rule and with the effect hypothesis model of species sorting. These differences illustrate that evolutionary trends in ammonoids are not pervasive and homogeneous in time and scale and depend on the taxonomic rank under consideration.

Facies development and death of the Devonian Wülfrath Reef (northern Rhenish Massif, Germany)

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The Rhenish Massif contains numerous Devonian reef complexes. Limestones of the Frasnian Wülfrath Reef Complex crop out on special folds of the NE plunging Velbert Anticline in the northern Bergisches Land. It was situated on the shelf south of the Old Red Continent. New palaeoecological, microfacies and conodont data on the uppermost reefal limestones at Wülfrath were derived from samples taken in the eastern part of the Rohdenhaus-North Quarry and from an adjacent well drillcore. A distinction is made between sediments of a restricted back reef environment and of an open-marine carbonate platform that developed after the reef core had ceased to function as a barrier. The boundary between these two units is an erosional discontinuity. Stromatoporoids of various growth forms dominated the fauna in the back reef, while only tabular/lamellar forms are present in the lower part of the open-marine sediments. These show a deepening trend coinciding with the local disappearance of the last stromatoporoids and blooms of microbial mats. The final demise of the carbonate platform was probably caused by drowning during the Upper Kellwasser Event at the end of the Frasnian.

Habitat specialization controls diversity dynamics in Mesozoic bivalves

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In the face of the current mass extinction it is becoming more and more important to uncover the factors that controlled extinction risk in the geological past. Here we used large taxonomically vetted and sampling-standardized data sets to assess the relative importance of habitat specialization and generalization on diversity dynamics of marine Mesozoic bivalves. Our analysis, which also controlled for the effect of geographical range, showed that mean values of extinction and origination rates are significantly higher for habitat specialists compared to habitat generalists. Moreover, extinction selectivity during times of mass extinction was indistinguishable from background levels, suggesting that the underlying mechanisms do not change in times of global crisis and that broad adaptation buffers against both background and mass extinctions. The temporal patterns in origination differ from those in extinction. In particular, there is no pronounced selective origination throughout much of the studied time interval. However, it appears that when habitable space approaches carrying capacity a further increase in diversity is primarily promoted by elevated origination rates of more specialized forms. As a side effect, the number of species within such ecosystems may be more sensitive to even minor habitat alterations.

A new aglaspidid from the Upper Cambrian Sandu Shale (Guanxi Province, China)

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Aglaspidids are a modestly diverse and relatively obscure group of Lower Palaeozoic arthropods. They are only known from a handful of localities worldwide, and consequently are characterized by a fragmentary palaeobiogeographic distribution. This situation is further exacerbated by the fact that most species of aglaspidids *sensu stricto* are known from the Upper Cambrian of Wisconsin, USA, with only a few monospecific genera having been described from the Upper Cambrian of Tasmania and the Lower Ordovician of Wales and Morocco. Not a single aglaspidid genus is shared between any of these localities, except for a yet undescribed taxon from the Lower Ordovician Fezouata biota, Morocco, which may be referable to Tremaglaspis. Here we report the first unambiguous species of aglaspidids *sensu stricto* from the Upper Cambrian of China. Although fragmentary, the material allows making direct comparisons with the aglaspidid fauna from Wisconsin, resulting in the recognition of a new species within the genus Aglaspella. To date, this represents the only confirmed report of the presence of a previously endemic North-American genus of aglaspidids *sensu stricto* outside Laurentia. This discovery also carries implications for the systematics of the Aglaspidida *sensu stricto*.

Enigmatic life in the Marwar Supergroup, western Rajasthan, India

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Life arose on the Earth during the Early Archean, as indicated by the appearance of fossil bacteria in rocks thought to be 3,500 Ma old. Since then Precambrian life has been undoubtedly one of the greatest unsolved problems although life was microscopic, but mysterious even today. The present study reports peculiar giant life forms from the Sonia Sandstone. Ediacaran Sonia Sandstone shows profuse development of non carbonaceous megaplant-like fossils, which are well-preserved on the bedding surface and deposited under moderate to high energy conditions.

The present study discusses some reasonable answers as well as questions regarding earliest giant life forms for the Precambrian palaeobiologist. If they were plants, why were they of giant size, at this time? Why did they vanish in the Cambrian when animals appeared? Is there any connection with microbial mats which were flourishing during Precambrian times? And can the existence of such life forms contribute to the generation of hydrocarbons within the Precambrian sedimentary basin? These forms show affinities with Voucheriaceae family. Here, it is assumed that the growth of the plant was directly influenced by abundance of microbial mat bound by sediments. Several features are discussed which were responsible for acquiring such large size.

Evolution of the dermal skeleton: Histology of basal actinopterygians

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Despite its vital role in support, protection and morphology of many animals, the early evolution of the dermal skeleton is poorly understood. This is mainly due to a lack of knowledge on the basal actinopterygian condition, crucial to phylogenetically infer conditions in the last common ancestor of osteichthyans, and subsequently all gnathostomes. To resolve this issue, a detailed description of *Moythomasia durgaringa* is presented here. A combination of Scanning Electron Microscopy (SEM) and Synchrotron Radiation X-ray Tomographic Microscopy (SRXTM) analysis reveals many unknown characteristics, remarkable variation and novel insights on the development of the dermal skeleton. The results alter our understanding of timing an order of character acquisition, supporting an early burst of derived characters related to the osteichthyan divergence.

Recognition of pseudoplanktonic bivalve communities in the Upper Sinemurian organic-rich series of the Lusitanian Basin (W Iberia, Portugal)

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Pseudoplanktonic bivalves have been referred as exceedingly rare on the fossil record even when associated with organic-rich sediments. Based on a high-resolution stratigraphic study of the Água de Madeiros Formation at S. Pedro de Moel (SPM) and Peniche outcrops on the Lusitanian Basin (Portugal), an exceptional preservation of optionally pseudoplanktonic communities was recognized. At SPM, across the Polvoeira Member, associated with organic-rich marl-limestone alternations, a faunal change occurs. It is composed of well preserved *Pseudomytiloides* aff. *dubius* (Sowerby) and *Oxytoma* (*O.*) *inequivalvis* (Sowerby). The presence of abundant and varied echioceratid species allows the dating of these records to the Raricostatum Chronozone (Raricostatum to Aplanatum Subchronozones). Some bivalve displayed aspects, such as the alignment of the hinge axis of several specimens along wood remains or at ammonoid shells, indicates a mode-of-life of byssal attachment to floating structures. Notwithstanding the large amount of dispersed shells may be interpreted as facultative true benthos forms. The absence of other epifaunal benthos as well as infaunal elements and brachiopods in those intervals may be related to dysoxic to anoxic bottom conditions. According to the palaeobiology of inoceramid bivalves, it is plausible to regard them as opportunists colonizing the vacant bottom surface.

Sinemurian bivalve diversity within the Lusitanian Basin (W Iberia, Portugal): a hotspot between Tethyean and Boreal Realms?

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The Lusitanian Basin (Portugal) is considered critical to understand fauna exchange between Tethysan and Boreal domains because it is at a palaeogeographic point of confluence. In the Late Sinemurian (Early Jurassic) it should have been an established connection. The mollusc-bivalve record of the Sinemurian Coimbra and Água de Madeiros formations was studied. New specimens were collected in the reference sections of S. Pedro de Moel and Peniche, well-controlled by high-resolution stratigraphy. From the 234 shell beds that contained macrofauna, 2,903 bivalve individuals were sampled. This study was complemented with a re-evaluation of Sinemurian bivalve specimens, housed in Portuguese museum reference collections. This information allowed the recognition of complementary forms previously not recognized in the available outcrops. New records are reported for the Sinemurian of Lusitanian Basin with 55 species and 13 new bivalve genera present. High bivalve diversity is revealed, with 40 of the 54 previously known genera in the NW European Provinces. These correspond to 13 bivalve orders and 28 families, with 11 genera belonging to Pectinida, the more diverse group, and five genera to Ostreida, the more abundant one. All NW European Sinemurian genera assigned to the orders Nuculida, Carditida and Lucinida were recognized.

posters

Pioneer ostracod zooplankton

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Zooplankton are an essential component of the marine ecosystem, consuming phytoplankton and other organic matter, repackaging carbon and delivering this to other parts of the water column, and providing a food source for organisms on higher trophic levels. Colonisation of the water column by zooplankton was therefore a formative step in the evolution of ecosystems, opening the possibility of dispersal and introducing a zooplanktonic element into the food chain. Few studies have attempted to identify the precise environmental or anatomical feedbacks that facilitate a zooplanktonic lifestyle.

Ostracods are an important group of benthic crustaceans, and are the most abundant arthropods in the fossil record. Ostracods form an important component of zooplankton, adapting to this pelagic lifestyle during the Silurian, an ecological shift coincident with oceanographic and zooplankton biodiversity change. The recent discovery of Silurian myodocopes with preserved soft-anatomy has revolutionized understanding of their palaeobiology and for the first time enables a detailed assessment of the morphological adaptations that may have facilitated a zooplanktonic lifestyle. This project seeks to determine the feedbacks that produced an ostracod zooplankton, scrutinizing the extensive Silurian fossil record of myodocopes, determining their ancient environmental distribution, biodiversity and morphology, and identifying the drivers of the ecological transition.

A revision of the chimaeroid fishes (Chimaeroidei) from the Lower Oxford Clay (Middle Jurassic, Callovian) of Cambridgeshire, England

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Prior to revision, the chimaeroid fishes from the Lower Oxford Clay (mainly middle Callovian) of Cambridgeshire consisted of four nominal tooth-based species (*Brachymylus altidens* [Woodward, 1892]; *Pachymylus leedsi* [Woodward, 1892]; *Ischyodus egertoni* [Buckland, 1835]; *I. beaumonti* [Egerton, 1843]). During the revision, all available specimens at the NHM, London [all types]; Sedgwick Museum, Cambridge; Oxford University Museum; as well as tooth plates recently collected from the pits near Peterborough, were examined – a total of 50+ specimens.

As a result of the study, the Lower Oxford Clay chimaeroid assemblage has been increased to nine genera and nine species. It consists of callorhinchids: *Callorhinchus* sp., *Brachymylus altidens*, "*Br. altidents*" (a new genus with Edaphodon-type dentition), "*Brachymylus minor*" (a new genus and species), "edaphodontids", *Ischyodus egertoni* (= *I. beaumonti*), *Elasmodectes* sp., *Elasmodus* sp. (a new species), "*Stoilodon*" sp. (a new species) and a rhinochimaerid *Harriotta* sp.

Both *Elasmodus* sp. and "*Stoilodon*" sp. represent the first Jurassic records for these genera, while *Harriotta* sp. is a first mid-Jurassic record for the genus. These chimaeroids are characterized by different types of crushing, breaking and cutting dentitions and constitute an ecologically divergent assemblage, the most diverse currently known anywhere from the Jurassic.

Infaunal moulting in calmoniids trilobites: the polyphyletic origin of a defensive character in the context of the Middle Paleozoic Marine Revolution

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Infaunalism for moulting in trilobites was initially recognized based on a striking three-dimensional moult pattern of the phacopid *Paciphacops*, from the Silurian–Devonian of Argentina (Rustan *et al.* 2011). Later, the same moult pattern was identified in several *Viaphacops* species from the Devonian of Bolivia (Rustan *et al.* 2012). In turn, a thorough taxonomic revision indicated that one Argentinean species should be considered as *Echidnops*.

Here we report the diagnostic moult pattern in several specimens of the calmoniid *Pennaia verneuili* from the Middle Devonian of the Sica Sica Formation, La Paz, Bolivia (AMNH collection, USA).

Concerning a phylogenetical context, these evidences definitively confirm that the infaunal moult behaviour, as ethological defensive character, appeared more than once in different trilobite families (*i.e.* phacopids and calmoniids), thus being clearly polyphyletic.

This finding provides new insights for the understanding of the evolutionary-ecological context of the "Middle Paleozoic Marine Revolution" (Signor and Brett, 1984), a major

bioevent related to an arms-race triggered by the sudden appearance of several groups of durophagous predators in Silurian–Devonian marine ecosystems.

Colour Patterns of Devonian Trilobites

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In several specimens of Middle Devonian scutelluid trilobites from the Rheinische Schiefergebirge colour patterns have been observed, especially on the pygidia. Two patterns have been distinguished. In the first type (*Scutellum flabelliferum* [Goldfuss, 1839]) a dark area around the end of the rachis on the plateau of the pygidium shows a black semicircular region, broadly corresponding to the area outlined by the inner margin of the doublure; while there is secondly a pale coloured broad band round the periphery of the pygidium. In the second form (*Scutellum geesense* Rud and E. Richter, 1956) there is a single curving brown band along the median steepest part of the pygidial surface. These markings are shown in several specimens of each species, illustrated here. Both patterns may enable some degree of carmouflage in sunlit shallow water with a wave rippled surface. There seem to be some dark dappled splotches on the glabella of *Eldredgeops rana* var. *milleri* (STEWART, 1927) from New York state. All forms are suggestive of camouflage.

Malformed (teratological) acritarchs at the beginning of Early Palaeozoic $\delta^{13}C$ isotope excursions: indication of global palaeoenvironmental perturbations?

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The Ordovician and Silurian periods show several strong, global positive $\delta^{13}C$ excursions, some of them representing the strongest perturbations of the carbon cycle in the Phanerozoic. The onset of the excursions is characterised by extinction and/or turnover events of several groups of marine invertebrates. The causal mechanisms of the carbon cycle perturbations, however, are still unknown and currently a matter of scientific debate. Our investigations in the Hirnantian (latest Ordovician) and a literature review show very high abundances of abnormal, teratological forms of acritarchs at the onsets of these major $\delta^{13}C$ excursions. Other fossil groups, including chitinozoa, graptolites and bryozoans, are also affected. Today, high abundances of teratological forms in modern marine protists are commonly observed in environments with a high degree of environmental stress. In the fossil record, the challenge is to attribute these abnormal forms of organisms to specific environmental circumstances. Our study implies that they are somehow related to oceanographic/climatologic events that also affected the global carbon cycle, and that they are harbingers of contemporaneous extinction and/or turnover events in other fossil groups with which they share a common extrinsic cause.

The preservation potential of articulated chitons is better than expected: So why are there so few fossil chitons?

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Polyplacophoran molluscs (chitons *sensu lato*) are known from the late Cambrian to Recent, and possess a distinctive scleritome of eight overlapping calcareous valves. The vast majority of fossil chitons are preserved as single valves; few exhibit body preservation or even an articulated shell series. Despite a superficially similar morphology between fossil and living forms, the modern fauna includes more than 900 living species, with other disparate Palaeozoic forms. An experimental taphonomic programme was conducted using the polyplacophorans *Lepidochitona* and *Tonicella* (suborder Chitonina) and *Acanthochitona* (Acanthochitonina) to study the fossilisation potential of chitons. Acanthochitonina is more robust to disarticulation than Chitonina; some individual specimens of the former remained largely intact after 120 days' decay followed by tumbler experiments simulating transport. Experiments in a rock tumbler on disarticulated valves also revealed variation; in one experiment, 53.8–61.5% of *Lepidochitona* valves were recovered but 92% of those from *Tonicella* and 100% of *Acanthochitona* elements. Different species of living chitons have distinctly different preservation potential. This, problematically, does not correlate with obvious differences in gross valve morphology; some, but not all, differences correlate with phylogeny. Chiton valves and even partly decayed carcasses are far more robust to transportation than their limited fossil record implies.

Shale facies microfossils from the Proterozoic Chhattisgarh Supergroup, India

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For many years the fossil microorganisms – including colonies of prokaryotes, single-celled eukaryotes and fossil seaweeds – have played a key role in reconstructing the history of Life on Earth before the dawn of the Cambrian. Large numbers of Proterozoic microfossil assemblages have been globally recorded and studied to understand the nature of the Precambrian biosphere. In the present study, rich and diversified assemblages of organic-walled microfossils (OWMs) comprising both prokaryotes and eukaryotes are recorded from the black carbonaceous shale belonging to the lower Chhaporadih Formation, Chandarpur Group of Chhattisgarh Supergroup. The OWMs assemblage is dominated by both ornamented/unornamented sphaeromorphic and acanthomorphic acritarchs (size ranges 40 µm – 100 µm) followed by moderately abundant filaments (>100 µm long), low numbers of coccoid microfossils (size ranges 10µm – 30µm), and vase-shaped microfossils. The assemblage also includes numerous forms showing complex morphologies. Acritarchs belonging to Sphaeromorphida, Sphaerohystrichomorphida and Fusomorphida subgroups are known. Associated cyanobacterial microfossils are a solitary group of sphaeroidal cells (loose/compact), aseptate-septate and coiled trichome with/without mucilaginous sheath comparable to the extant algal group Chroococcales, Eoentophysales and Nostocales, suggesting moderate deep water conditions during the deposition. The overall assemblage is comparable to the biota of Staenian–Tonian successions recorded from other regions.

The *Glossopteris* component community: Permian silicified peats of the Prince Charles Mountains, Antarctica

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A Middle Permian silicified peat capping a coal seam in the Bainmedart Coal Measures of the Prince Charles Mountains, East Antarctica, accumulated from the remains of a community of mire plants dominated by *Glossopteris*. Observations of the peat blocks in thin-section and scanning electron microscopy of materials extracted from the silicified peats through bulk maceration reveal several cryptic elements of the peat-forming community and demonstrate a range of biological interactions centred around the *Glossopteris* plant. Evidence for a range of invertebrate feeding strategies that target all parts of the *Glossopteris* plant is found in the peats. In addition, an assortment of fungal groups and microorganisms are present which exploit the *Vertebraria* roots and decaying tissues of the *Glossopteris* plant in a variety of relationships. Additional elements of the peat mire include diminutive herbaceous lycophytes (and their dispersed megaspores), a diversity of fern sporangia, an array of seed morphotypes, and small fragments of arthropod exoskeleton.

Morphology and wall ultrastructure of the megaspore *Reticuspinosporites ravenscarensis* gen. et sp. nov. from the Middle Jurassic of Yorkshire, UK

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Palynomorphs from Middle Jurassic terrestrial deposits of the Ravenscar Group from the Cleveland Basin in northeast Yorkshire are described. Assemblages of abundant, diverse and well-preserved spores/pollen have been recovered throughout the sequence. Megaspores are described from the Bathonian Long Nab member of the Scalby Formation. Preservation of megaspores is outstanding and in three dimensions. Light microscopy reveals the presence of at least three species (*Paxillitriletes phyllicus*, *Minerisporites institus* and *Reticuspinosporites ravenscarensis* gen. et sp. nov.) of lycopsid affinity. *R. ravenscarensis* gen. et sp. nov. is described using combined light microscopy, scanning electron microscopy (SEM) and transmission electron microscopy (TEM). The lycopsid affinity of *R. ravenscarensis* gen. et sp. nov. is based on the wall ultrastructure and distinctive surface ornamentation. TEM analysis of *R. ravenscarensis* gen. et sp. nov. shows the presence of three wall layers: an outer layer covering the ornaments (outer exospore); a thick spongy layer (middle exospore); and a thin inner layer comprised of numerous lamellae (inner exospore). Abundant and well preserved plant macrofossils are present in the famous plant beds scattered throughout the sequence. Future work aims to integrate palynological and palaeobotanical data with published dinosaur footprint data in order to deduce floral and faunal interactions.

Body size during the rise of archosauromorphs: weak support for Cope's rule, and biological not environmental limits on maximum size

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Two major evolutionary questions are whether natural selection has driven trends of size increase ('Cope's rule'), and whether environment has affected long-term patterns in body size evolution. We addressed these questions by examining trends during the Triassic replacement of therapsids by archosauromorphs as predominant large-bodied terrestrial vertebrates. We fit phylogenetic and non-phylogenetic models of body size evolution to *c*. 400 taxa from the Late Permian to Middle Jurassic. Results do not support a widespread 'Cope's rule', despite sustained increase in archosauromorph maximum size. Instead, non-directional evolution (*i.e.* 'passive expansion') is common in taxonomically large clades, and stasis/constraint in small clades. Non-phylogenetic patterns of maximum body size were also compared to environmental models. No correlation was found between three abiotic factors – atmospheric oxygen, carbon dioxide (*i.e.* temperature) and land area – with body size. Growth curve fitting favours a (Gompertz) model of exponentially decreasing size increase at larger sizes. This indicates that biological limits (*e.g.* energetics, reproductive rates), not environmental factors, controlled archosauromorph and therapsid maximum body size. Middle–early Late Triassic archosauromorph predators exceeded the size of contemporaneous therapsid herbivores, again indicating that limits to body size are clade-dependent.

Mollusc life and death assemblages on a tropical rocky shore as proxies for the taphonomic loss in a fossil counterpart

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Modern rocky shores and their faunas are well-studied, but little is known about their ancient counterparts since well-preserved rocky shores are relatively rare in the geological record. Comparison of a living rocky shore mollusc fauna from Thailand with the associated death assemblage is used to investigate the fossilization potential and determine the fidelity of a palaeoecological reconstruction of a Late Cretaceous rocky shore fauna from Ivö, Sweden. The death assemblage shows high ecological fidelity to the life assemblage and only a few exotic species are present, but the taxonomic similarity is lower than reported in previously published studies. A hypothetical fossil assemblage is constructed from the death assemblage by inferring the taphonomic features which will act on the shells of the death assemblage. The study shows that the hypothetical fossil rocky shore assemblage has a low taxonomic similarity to an original life assemblage, but a rocky shore environment can be inferred from the faunal composition. The mollusc life assemblage changes from an epifaunal, herbivorous gastropod-dominated fauna in terms of species richness to an infaunal, suspension-feeding bivalve-dominated hypothetical fossil community. The results are used in a comparative study of the modern fauna and the Late Cretaceous rocky shore fauna.

Modelling the impact of phylogeny on interpretations of extinction in deep time

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Palaeontologists and biologists have previously used different methods when analysing comparative datasets. This is problematic because it has meant that results from the two communities are not directly comparable. To achieve synthesis of results, palaeontological data must be analysed within a comparative framework that corrects for species non-independence by integration of an explicit phylogenetic hypothesis. However, there are important differences between fossil phylogenies and phylogenies of extant taxa that must be considered before results are interpreted. Through simulating fossil phylogenies I am investigating the impact of incorporating palaeontological trees into analyses, focusing on the phylogenetic clustering of extinction. Further to this I have used simulation modelling to investigate whether taxonomy can be used as a reasonable substitute for the most recently available phylogenetic reconstructions when performing comparative analyses. Results suggest that missing data and reconstruction of ancestral taxa as sister groups to their descendants impedes accurate recovery of phylogenetic signal, except in instances of extreme phylogenetic clustering. Further to this, the lack of a systematic offset between "fossil" and "real" test statistics suggests that correction may be highly problematic.

The role of the Teleost specific Whole Genome Duplication Event in the evolution of novel microRNAs

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Whole Genome Duplication Events (WGDE) are believed to play a fundamental role in the processes that have shaped vertebrate evolution. The three WGDE (1R, 2R and 3R) which occur in vertebrates correspond to both increases in morphological complexity and/or adaptive radiations, with some workers arguing causality between the two. Furthermore WGDE have been argued to play a fundamental role in the evolution of novel microRNAs (miRNAs). miRNAs are small, *c*. 22 nucleotide non-coding genes, which regulate the translation of protein-coding gene(s) by binding with imperfect complementarity to sites in the 3' untranslated regions of messenger RNAs – thus subjecting the transcript to cleavage or to blockage of its translation, and thereby playing a key role in the gene regulatory network.

Previous work has suggested that the role of 1R and 2R at the origin of vertebrates had little effect on the evolution of novel miRNAs. Here 3R, the Teleost-specific WGDE, is investigated. Deep sequencing data for miRNAs was collected from all non-Teleost Actinopterygian lineages (*Polypterus*, Gar, Bowfin, Sturgeon and Paddlefish) as well as several Teleost lineages including Osteoglossum, which allows the tight bracketing of 3R, and its role in the evolution of novel miRNAs, to be fully assessed.

Taphonomy and palaeoecology of the green pentamerid Devonian brachiopods from the Aferdou el Mrakib, eastern Anti-Atlas, Morocco

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On the large reef mound Aferdou El Mrakib in the Maïder Basin (Anti-Atlas, Morocco), thick-shelled pentamerids (*Devonogypa* and *Ivdelinia*) occur in a locally high abundance. Like *Stringocephalus* from shallow water limestones of Germany, these Moroccan brachiopods often display greenish shells. By EDX analyses of the shells, it turned out that the colour was caused by impurities of Fe^{2+}-ions – their concentration indicating that the colour is less dependent on the iron-concentration than on shell thickness. There is also some indication that the Fe-content increases towards a deeper shell layer (further away from the surface).

Additionally, we examined the quality and spatial distribution of sublethal injuries in over 200 specimens of *Devonogypa* and *Ivdelinia* in order to find indications for their origin. The results support the hypotheses that (1) the injuries had several causes, (2) some of which were inflicted by predators, probably cephalopods, and (3) many fractures might have been caused by the brachiopod shells hitting each other in dense populations in agitated water. Numerous such dense clusters consisted of the association of members of both brachiopod genera or of only one taxon, occasionally accompanied by other brachiopods, some trilobites, corals and a few other groups.

Paleocene forests and climates of Antarctica: signals from fossil wood

*** Laura J. Tilley, Jane E. Francis[1], Vanessa C. Bowman[1] and J. Alistair Crame[2]**

[1]*School of Earth and Environment, University of Leeds, Leeds, UK*

[2]*British Antarctic Survey, Cambridge, UK*

During the greenhouse world of the Paleocene, Antarctica was covered in forests, even though the continent was situated over the South Pole. Fossil wood is abundant in Paleocene marine sequences of Seymour Island, Antarctica. The wood originated from forests that once grew on the volcanic arc now represented by the Antarctic Peninsula, and then floated as driftwood on the ocean before eventually sinking into the ocean sediments and becoming permineralised. Fossil wood has been systematically collected from Paleocene marine sequences of Seymour Island and has been studied in order to reconstruct the forest composition and evolution of the vegetation throughout the Paleocene. Initial results indicate that trees of southern beech (*Nothofagus*), monkey puzzle trees (*Araucaria*) and podocarp conifers lived in the forests. These tree types can be found in cool temperate forests in Chile and New Zealand today. Tree rings in the fossil wood will also be analysed to reconstruct the climate in which the forests grew in the Paleocene.

Waptia: a forgotten Burgess Shale arthropod revisited

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[3]*Department of Earth Science and Engineering, Royal School of Mines, Imperial College London, London SW7 2AZ, UK*

Waptia is an iconic arthropod from the Burgess Shale that has never been described in detail since its discovery by Charles Walcott one century ago. Its familiar shrimp-like appearance had led scientists to consider *Waptia* a possible crustacean, although major uncertainties remain concerning its relationships to other arthropods. The anatomy of *Waptia fieldensis* Walcott, 1912 is reconstructed in details here based on the USNM collection specimens, and comparisons are made with other Cambrian waptiids including taxa from the Chengjiang biota. *Waptia fieldensis* has: 1) a short head with prominent stalked eyes, long multisegmented antennae and a pair of short frontal lobes; 2) five uniramous appendages, four of them ending with spines and claws; 3) six pairs of biramous gill-bearing appendages; 4) five limbless telescopic segments and a tail fan formed by the telson, and two three-segmented lateral flaps. *Waptia* clearly differs from both crown-group and stem-group crustaceans by its tagmosis and appendage structure. The gut consists of a J-shaped esophagus, a crop, and a long, narrow, tube-like intestine. A comprehensive cladistic analysis including a large number of other arthropod groups is used to determine the position of *Waptia* within Arthropoda. *Waptia* was probably a nektobenthic animal and may have used its appendages for clinging on to submarine reliefs or sessile organisms rather than for ambulatory purposes.

posters

The nature of the Cretaceous–Paleogene mass extinction in Antarctica and its relationship to global sulphur and carbon cycle perturbations

*** James D. Witts[1], Paul B. Wignall[1], Jane E. Francis[1], Rob J. Newton[1] and J. Alistair Crame[2]**

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[2]*British Antarctic Survey, Cambridge, UK*

The environmental catastrophe at the end of the Cretaceous is well studied in the northern hemisphere, but effects on the southern hemisphere are relatively poorly understood. The highest southern latitude site for studying this interval is Seymour Island, Antarctica (65°S). The Cretaceous–Paleogene (K/Pg) section is preserved within a sequence of marine siltstones and sandstones deposited in a back-arc basin.

We have produced new stratigraphic range data for major macrofossil groups based on detailed sedimentary sections from the shallow marine Maastrichtian López de Bertodano Formation on Seymour Island. Initial results show an increase in diversity up-section prior to the K/Pg boundary, before turnover in the molluscan fauna coincident with the boundary as defined by dinoflagellate cysts.

Several of the hypothesised events around the K/Pg such as bolide impact, flood basalt volcanism, anoxia, and increased weathering all have implications for the global carbon and sulphur cycles. We have generated new high-resolution organic carbon records from bulk sediment and hand-picked plant fragments through the latest Maastrichtian–earliest Paleocene sequence. We have also extracted carbonate-associated-sulphate (CAS: a proxy for marine sulphate isotope composition) from apparently well-preserved shell material to produce the first record of seawater sulphate across the K/Pg transition.

Palaeogeographic and evolutionary implications of new Furongian (Cambrian) echinoderms from China

Samuel Zamora[1], Xuejian Zhu[2,3] and Bertrand Lefebvre[4]

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[4]*UMR CNRS 5276, Université Lyon 1, Villeurbanne, France*

A new Furongian (Cambrian) Echinoderm-Lagerstätte from South China has yielded one of the most diverse and well preserved echinoderm faunas from this poorly known time interval. Eight different taxa were identified and belong to four major groups of echinoderms: edrioasteroids, rhombiferans, solutans, and stylophorans. Glyptocystitid rhombiferans are morphologically intermediate between Cambrian eocrinoids and typical rhombiferans. The finding of a solutan in this assemblage is also important because it is the single complete representative of this group known from this time interval. The edrioblastoid also provides new information on the morphology and palaeoecology of this very rare grade of echinoderms. It is the first edrioblastoid preserving a complete stem with a distal holdfast attached to a trilobite fragment. Stylophorans are more diverse here than elsewhere. They include two possibly endemic cornutes (hanusiid and spineless chauvelicystid), as well as two other taxa suggesting affinities with both coeval (Furongian of Korea) and slightly younger (Tremadocian of France, Morocco, UK) peri-Gondwanan assemblages (*Flabellicarpus*-like cornute and basal mitrocystitid). This assemblage shows strong palaeobiogeographic affinities with other, previously described, Gondwanan faunas from Australia, France and Korea. In terms of faunal evolution, it is intermediate between the "Cambrian Evolutionary Fauna" and the "Palaeozoic Evolutionary Fauna".

Devonian tabulate corals from the Southern Region of the Holy Cross Mountains, Poland

*** Mikołaj K. Zapalski**

Faculty of Geology, University of Warsaw, Warsaw, Poland

The Holy Cross Mountains (central Poland) occupy a key position among Devonian outcrops in Europe because of their intermediate position between the Variscan belt and the Russian Platform. Devonian (Givetian to Frasnian) reefal carbonates of the Southern (Kielce) Region of the Holy Cross Mountains contain 52 species of tabulate corals (Favositida: 40 species, Syringoporida: six species, Auloporida: six species). A single favositid, *Yavorskia paszkowskii*, the first Famennian tabulate coral described from the Holy Cross Mountains, was found in beds representing deeper environments. Givetian and Frasnian tabulates share many species in common with the Ardennes and the European part of Russia, but some species (*Roseoporella heuvelmansi*, *Sapounofouskilites minimus*, *Aulopora slosarskii*) are apparently endemic. Givetian tabulate faunas from the study region are dominated by the Alveolitidae; this is in contrast to the Devonian of Ardennes, where Givetian faunas are dominated by the Pachyporidae. The Frasnian faunas in both regions are dominated by the Alveolitidae. Famennian tabulates in the Holy Cross Mountains are restricted to one species, compared to four in the Ardennes. The overall α-biodiversity in the Devonian of the Kielce Region is high (53 species) but smaller than that of the Devonian in Ardennes (113 species).

The Palaeontological Association

Annual General Meeting

17.40

Monday

17th December

Papers

Annual Meeting 2012

Notification is given of the 56th Annual General Meeting and Annual Address.

The Annual Meeting will be held at University College Dublin on Monday 17th December 2012, following the scientific sessions.

AGENDA

1. Apologies for absence
2. Minutes of the 55th AGM, Plymouth University
3. Trustees Annual Report for 2011
4. Accounts and Balance Sheet for 2011
5. Election of Council and vote of thanks to retiring members
6. Report on Council Awards
7. Annual address

DRAFT AGM MINUTES 2011

Minutes of the Annual General Meeting held on Sunday 18th December 2011 at Plymouth University.

1. **Apologies for absence:** Prof. D. Batten.
2. **Minutes:** Agreed a correct record.
3. **Trustees Annual Report for 2010.** Proposed by Mr D. Ward and seconded by Dr T. Servais, the report was agreed by unanimous vote of the meeting.
4. **Accounts and Balance Sheet for 2010.** Proposed by Prof. G. D. Sevastopoulo and seconded by Mr W. Fone, the accounts were agreed by unanimous vote of the meeting.
5. **Election of Council and vote of thanks to retiring members**

   Prof. J. E. Francis extended a vote of thanks to the following members of Council who were retiring from their positions this year: Dr P. Orr, Dr H. Armstrong, Prof. M. P. Smith, Dr R. J. Twitchett, Dr D. Schmidt, Dr C. Underwood, Dr C. Buttler.

   The following members of Council were elected to serve on Council. President: Prof. J. Francis; President elect: Prof. M. J. Benton; Vice Presidents: Dr H. A. Armstrong and Prof. J. W. Cope; Treasurer: Mr P. Winrow; Secretary: Dr R. J. Twitchett; Chair of Publications Board: Dr P. Orr; Editor Trustee: Dr P. C. J. Donoghue, Dr H. A. Armstrong; Book Review Editor: Dr C. Jeffrey-Abt; Publicity: Dr E. Rayfield and Prof. M. A. Purnell; Newsletter Reporter: Dr L. Herringshaw; Newsletter Editor: Dr A. McGowan; Web Officer: Dr M. Sutton; Meeting Coordinator: Dr T. Vandenbroucke; Ordinary Members: Prof. M. P. Smith, Dr C. Klug, Dr R. Owens, Dr P. Upchurch, Dr W. Renema and Mr D. Ward. Dr F. Gill and Dr C. Buttler were co-opted to assist with outreach. Dr Orr will organise the Annual Meeting in 2012 at the University College Dublin.

6. **Association Awards**

The following awards were made: Lapworth Medal to Prof. R. A. Aldridge; President's Medal to Dr G. Edgecombe (Natural History Museum); Hodson Award to Dr R. Butler (Ludwig Maximilian University, Munich); and the Mary Anning award to Mr C. Duffin and Mr D. Brockhurst. Honorary Life membership was awarded to Prof D. J. Batten, Dr P. Lane. Under the Small Grants Scheme, the following awards were announced: Sylvester-Bradley Awards to P. Andreev, S. Brusatte, B. Henrick, M. Hoffmeister, P. Hull and O. Reyes; Callomon Award to J. Ortega-Hernández; and Whittington Award to A. Otero. Research Grants were awarded to Dr D. Loydell (University of Portsmouth), Dr H. Hughes (Plymouth University), and Dr A. Daley (Natural History Museum). The President's Award was made to Alexander Liu (University of Cambridge) and the Council Poster Prize was presented to Samantha Giles (University of Bristol).

The Annual Address entitled "Climate and Evolution in the Cenozoic Oceans" was given by Prof. P. N. Pearson (University of Cardiff).

Trustees Annual Report 2011

Nature of the Association. The Palaeontological Association is a Charity registered in England and Wales, Charity Number 276369. Its Governing Instrument is the Constitution adopted on 27th February 1957, amended on subsequent occasions as recorded in the Council Minutes. The aim of the Association is to promote research in Palaeontology and its allied sciences by (a) holding public meetings for the reading of original papers and the delivery of lectures, (b) demonstration and publication, and (c) by such other means as the Council may determine. Trustees (Council Members) are elected by vote of the Membership at the Annual General Meeting. The contact address of the Association is c/o The Executive Officer, Dr T. J. Palmer, Institute of Geography and Earth Sciences, University of Aberystwyth, Aberystwyth, SY23 3DB, Wales, UK.

Trustees. The following members were elected to serve as trustees at the AGM on 18th December 2010: President: Prof. J. E. Francis; Vice Presidents: Prof. J.C.W. Cope and Dr P. Orr; Treasurer: Mr P. Winrow; Secretary: Dr H.A. Armstrong; Chair of Publications Board: Prof. M.P. Smith; Editor Trustee: Dr P. Orr and Dr P.C.J. Donoghue; Book Review Editor: Dr C. Jeffrey-Abt; Publicity: Dr E. Rayfield; Newsletter Reporter: Dr L. Herringshaw; Newsletter Editor: Dr R.J. Twitchett; Web Officer: Dr M. Sutton; Meetings Coordinator: Dr D. Schmidt; Ordinary Members: Dr C. Underwood, Dr E. Rayfield, Dr P. Upchurch, Dr C. Klug, Dr W. Renema, Dr C. Buttler and Dr T. Vandenbroucke. The Executive Officer: Dr T. J. Palmer and Editor-in-Chief: Dr S. Stouge continued to serve Council but are not Trustees.

Membership. Membership on 31st December 2011 totalled 1,167 (1,197 at the end 2010). Of these 707 were Ordinary Members, 182 Retired and Honorary Members and 278 Student Members. There were 62 Institutional Members and 83 institutional subscribers to *Special Papers in Palaeontology*. Wiley Blackwell also separately manage further Institutional subscribers and distribute publications to these Institutional Members on behalf of the Association.

Professional Services. The Association's Bankers are NatWest Bank, 42 High Street, Sheffield S1 1QF. The Association's Independent Examiner is G. R. Powell BSc FCA, Nether House, Great Bowden,

Market Harborough, Leicestershire LE16 7HF. The Association's investment portfolio was managed by Quilter, St Helen's, 1 Undershaft, London EC3A 8BB.

Reserves. The Association holds reserves of £662,101 in General Funds, which enable the Association to generate additional revenue through investments, and thus to keep subscriptions to individuals at a low level, whilst still permitting a full programme of meetings to be held, publications produced and the award of research grants and grants-in-aid. They also act as a buffer to enable the normal programme to be followed in years in which expenditure exceeds income, and new initiatives to be pursued. The Association holds £80,990 in Designated Funds which contribute interest towards the funding of the Sylvester-Bradley, Hodson Fund and Jones Fenleigh awards, and which will contribute interest towards the funding of the Callomon and Whittington awards. Funds carried forward to 2012 totalled £743,091.

Finance. Total income in 2011 was £305,204. Total charitable expenditure, through grants to support research, scientific meetings and workshops in 2011 was £266,982. Governance costs were £16,481. Total resources expended were £310,318.

Risk. Despite the small operating deficit in 2011, the Association is in a sound financial position. Succession planning for executive officers remains a concern and will be considered as part of the Annual Review of Officers in 2012.

Charitable Activities. The Association continues to increase its range and investment in charitable activities. We have continued to provide funds to support student and speaker attendance at our own and international meetings.

Grants. Palaeontological Association Research Grants were awarded to Dr D. Loydell (University of Portsmouth), "Integrated biostratigraphy of the Trannon River section, Wales"; Dr H. Hughes (University of Plymouth), "Biotic responses to Silurian global environmental change"; and Dr A. Daley (Natural History Museum), "Early evolution and ontogeny of the anomalocarids".

Grants–in-aid. The Association provided funds to support the following meetings: Bivalve Chemosynthetic molluscs (NHM); Rockwatch meeting to support events at reopening of Fossil Grove, Victoria Park (Glasgow); World Conference on Marine Diversity (Aberdeen); Geobiology and Environments of silica biomineralizers (Lille); Rotting fish and fossils (University of Leicester); and Late Carboniferous terrestrial environments, Ukraine (IGCP 575). A grant was made to Prof. N. Hughes (Riverside, University of California) to support publication of a book for children in India on the origin of silicified wood.

Small Grants Scheme. The new Callomon Award and Whittington Award were managed alongside the Sylvester-Bradley Award as part of an integrated Small Grants Scheme. The scheme received sixteen applications. Eight were recommended for funding in 2012. Sylvester-Bradley Awards will be made to P. Andreev, S. Brusatte, B. Henrick, M. Hoffmeister, P. Hull and O. Reyes. The Callomon Award will be made to J. Ortega Hernandez, and the Whittington Award to A. Otero.

Online activities. The online activities of the Association continue to expand. Funding was provided to develop palaeontological outreach through the website. The Association continues to host mirror sites for *Palaeontologia Electronica*, the EDNA fossil insect database, the Palaeontographical Society website, and a database of fossils from Kent produced by the Kent RIGS Group. Payments in the Online Shop are now made via Worldpay.

Public meetings. Four public meetings were held in 2011, and the Association extends its thanks to the organisers and host institutions of these meetings.

55th Annual Meeting. This was held on 17–20 December at Plymouth University. Dr R. J. Twitchett with local support from colleagues and PhD students organised the meeting, which included a symposium on "Ancient and modern biotic crises" and comprised a programme of internationally recognised speakers. There were 257 attendees. The Annual Address entitled "Climate and Evolution in the Cenozoic Oceans" was given by Prof. P. N. Pearson (University of Cardiff) and attendance included non-academics and local sixth form students. The President's Award for best oral presentation from a member under 35 was made to Alexander Liu (University of Cambridge). The Council Poster Prize was presented to Samantha Giles (University of Bristol). The post-conference field trip was to the English Riviera Global Geopark and Kents Cavern.

British Science Festival, Palaeontological Association Symposium. This is an annual forum for presentations to the public and general scientists. The Symposium "Paradise Lost? Strange environments and major events from the geological past" was organised by Dr C. T. S. Little (University of Leeds) and funds were provided in support of four internationally renowned speakers.

Progressive Palaeontology. The annual open meeting for presentations by research students was organised by Laurent Darras, David Riley and Alison Tasker, and was held at the University of Leicester.

Lyell Meeting. The Association hosted the Lyell Meeting in 2011 on the topic of "Island faunas, migration and evolution", organised by Prof S. Donovan.

Publications. Publication of *Palaeontology* and *Special Papers in Palaeontology* is managed by Wiley Blackwell. Volume 54 of *Palaeontology*, comprising six issues, was published. *Special Papers in Palaeontology* 85, "The Phylogeny of Post-Palaeozoic Asteroidea (Neoasteroidea, Echinodermata)," by Andrew S. Gale; and *Special Papers in Palaeontology* 86, "Studies on Fossil tetrapods," edited by Paul M. Barrett and Andrew R. Milner, were also published during the year. One *Field Guide to Fossils*, on "English Wealden Fossils", edited by D. J. Batten, was published. The Association is grateful to the National Museum of Wales and the Lapworth Museum (University of Birmingham) for providing storage facilities for publication back-stock and archives. Council is indebted to Meg and Nick Stroud for assistance with the publication of *Palaeontology Newsletter*. The Association remains a Tier 1 sponsor of *Palaeontologia Electronica*, and the *Treatise on Invertebrate Paleontology*.

Publicity. The Association continues to promote palaeontology and its allied sciences through press releases to the national media, radio and television. The Association continues its membership of the International Palaeontological Association.

Awards. The Lapworth Medal, awarded to people who have made a significant contribution to the science by means of a substantial body of research, was presented to Prof. R. A. Aldridge (University of Leicester). The President's Medal for a palaeontologist in recognition of outstanding contributions in his/her earlier career, coupled with an expectation that they will continue to contribute significantly to the subject in their further work, was awarded to Dr G. Edgecombe (Natural History Museum). The Hodson Award, for a palaeontologist under the age of 35 who has made an outstanding achievement in contributing to the science through a portfolio of original published research, was awarded to Dr R. Butler (Ludwig Maximilian University, Munich). The Mary

Anning awards, for an outstanding contribution by an amateur palaeontologist, were made to Mr C. Duffin and Mr D. Brockhurst. Council also awards an undergraduate prize to each university department in which palaeontology is taught beyond Level 1. Honorary Life membership was awarded to Prof. D. J. Batten and Dr P. Lane. Golden Trilobite Awards were made to the following websites: <**www.ultimateungulate.com**>; Links for Palaeobotanists (<**www.equisetites.de/palbot1.html**>); Burgess Shale Online Exhibition (Royal Ontario Museum; <**www.burgess-shale.rom.on.ca/**>); and <**www.ammonites.fr**>.

Governance. The Association continues to improve its administration with further improvements to the *Newsletter* and website. Trustees were members of the Joint Committee for Palaeontology; Prof. Francis (Chair) and Dr Servais represented the Association. Dr Armstrong acted as the Association representative on the International Palaeontological Association. During the year the Association responded to requests for information from the HEFCE consultation on the Research Excellence Framework, NERC and the BGS.

Forthcoming plans. Council will continue to make substantial donations, from both General and Designated funds, to permit individuals to promote the charitable aims of the Association. A total of £10,797 will be allocated from the Small Grants Scheme to fund the eight individuals who were successful in the 2011 application round. Resources will be made available from General Funds to support the Association Research Grant, Grants-in-Aid, provided to carry out research into palaeontological subjects, to disseminate findings in print and at conferences, and support the provision of palaeontological workshops. The Association will continue to recognise the contribution individuals have made to palaeontology and associated sciences through its awards. In 2012, a similar programme of public meetings and publications will be carried out. Funds will be made available to further develop the website, aimed at encouraging outreach, and to fund a new Outreach Officer position. The 56th Annual meeting will be held at University College Dublin. Progressive Palaeontology will be held at the University of Cambridge. The Association will sponsor a symposium at the British Science Festival, "Our fossil-fuelled future," and provide travel grants for the Congress of the European Geosciences Union.

Richard J. Twitchett
Secretary

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No. 276369

STATEMENT OF FINANCIAL ACTIVITIES FOR THE YEAR ENDED 31st DECEMBER 2011

			General Funds £	Designated Funds £	TOTAL 2011 £	TOTAL 2010 £
Incoming Resources						
Generated Funds						
Voluntary income	Subscriptions	61,916			61,916	66,913
	Legacies	0			0	30,000
	Donations	0		1,250	1,250	1,589
			61,916	1,250	63,166	98,502
Charitable activities						
Sales	Palaeontology	202,710				
	Special Papers	11,314				
	Offprints	728				
	Field Guides	12,283				
	Distribution	1,680				
			228,715		228,715	226,874
Investment income			13,238	85	13,323	12,163
TOTAL INCOMING RESOURCES			303,869	1,335	305,204	337,539
Resources expended						
Costs of generating funds						
For voluntary income	Administration	23,640				21,029
Investment management	Stockbroker fees	3,215				2,845
			26,855	0	26,855	23,874
Charitable activities						
Publications	Palaeontology	82,360				
	Special Papers	9,899				
	Offprints	1,317				
	Field Guides	14,174				
	Newsletters	13,655				
	Distribution	2,215				
	Marketing	2,238				
	Editorial costs	58,168				
	Total Publications	184,026			184,026	178,403
Scientific Meetings & Costs		29,060			29,060	70,931
Grants and Awards		3,091		6,896	9,987	14,785
Research Grants		14,358			14,358	5,619
Administration of charitable activities		29,551			29,551	26,286
			260,086		266,982	296,024
Governance costs	Examiner's fee	400				
	Trustee expenses	10,171				
	Administration	5,910				
			16,481	0	16,481	13,107
TOTAL RESOURCES EXPENDED			303,422	6,896	310,318	333,005
NET INCOMING RESOURCES			447	-5,561	-5,114	4,534
INVESTMENT GAINS/LOSSES						
Realised gain/(loss)		-1,665				
Unrealised gain/(loss)		-10,552				
			-12,217		-12,217	46,249
NET MOVEMENT IN FUNDS			-11,770	-5,561	-17,331	50,783
TRANSFERS BETWEEN FUNDS			0	0	0	0
SURPLUS/DEFICIT FOR THE YEAR			-11,770	-5,561	-17,331	50,783
FUNDS BROUGHT FORWARD			673,871	86,551	760,422	709,639
FUNDS CARRIED FORWARD			662,101	80,990	743,091	760,422

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No. 276369

BALANCE SHEET as at 31st DECEMBER 2011

2010			Note			2011
£						£
		INVESTMENTS				
	534,720	At market value	**9**			520,606
		CURRENT ASSETS				
138,151		Cash at Banks		199,212		
126,690		Sundry Debtors	**6**	111,900		
264,841		Total Current Assets			311,112	
		CURRENT LIABILITIES				
20,795		Subscriptions in Advance		23,500		
18,344		Sundry Creditors	**7**	65,127		
39,139		Total Current Liabilities			88,627	
	225,702	NET CURRENT ASSETS				222,485
	760,422	TOTAL ASSETS				743,091
		Represented by:				
	673,871	GENERAL FUNDS				662,101
		DESIGNATED FUNDS	**8**			
20,325		Sylvester Bradley Fund			17,218	
22,805		Jones-Fenleigh Fund			21,914	
13,421		Hodson Fund			11,828	
10,000		Callomon Fund			10,010	
20,000		Whittington Fund			20,020	
	86,551					80,990
	760,422					743,091

Notes to the Financial Statements for the year ended 31st December 2011

1. Accounting Policies

The principal accounting policies adopted in the preparation of the financial statements are set out below and have remained unchanged from the previous year and also have been consistently applied within the same financial statements.

1.1 Basis of preparation of financial statements

The accounts have been prepared in accordance with the Statement of Recommended Practice issued by the Charity Commission in March 2005 and cover all the charity's operations, all of which are continuing.

The effect of events relating to the year ended 2011 which occurred before the date of approval of the statements by Council have been included to the extent required to show a true and fair state of affairs at 31st December 2011 and the results for the year ended on that date.

1.2 Fund Accounting

General Funds are unrestricted funds which are available for use at the discretion of the Council in furtherance of the general objectives of the charity and which have not been designated for other purposes.

Designated funds comprise unrestricted funds that have been set aside by Council for particular purposes. The aim of each designated fund is as follows:

Sylvester-Bradley Fund: Grants made to permit palaeontological research.

Jones-Fenleigh Fund: Grants to permit one or more students annually to attend the meeting of the Society of Vertebrate Palaeontology and Comparative Anatomy (SVPCA).

Hodson Fund: Awards made in recognition of the palaeontological achievements of a worker under the age of 35.

Callomon Fund: Grants made to permit palaeontological research with a fieldwork element.

Whittington Fund: Grants made to permit palaeontological research with an element of study in museum collections.

1.3 Incoming Resources

The charity's income principally comprises subscriptions from individuals and institutions which relate to the period under review, and sales of scientific publications which are brought into account when due.

1.4 Resources Expended

All expenditure is accounted for on an accruals basis and has been classified under the appropriate headings.

Charitable expenditure is that which is incurred in furtherance of the charity's objectives.

Administrative costs have been allocated to the various cost headings based on estimates of the time and costs spent thereon.

1.5 Investments

Investments are stated at market value at the balance sheet date. The statement of financial activities includes net gains and losses arising on revaluations and disposals throughout the year.

All investment gains and losses, both realised and unrealised, are allocated to General Funds; designated funds are held as cash.

2. Analysis of Financial Resources Expended

	Staff costs £	Other costs £	Total 2011 £	Total 2010 £
Generating Funds	17,059	9,796	26,855	23,874
Charitable activities	60,449	206,533	266,982	296,024
Governance	4,265	12,216	16,481	13,107
	81,773	228,545	310,318	333,005

3. Staff Costs

	Salary £	National Insurance £	Pension Contributions £	Total 2011 £	Total 2010 £
Publications: 1 employee (2010: 1)	34,378	0	4,747	39,125	34,112
Administration: 1 employee (2010: 1)	32,167	3,444	7,037	42,648	39,130
	66,545	3,444	11,784	81,773	73,242

4. Trustees Remuneration and Expenses

Members of Council neither received nor waived any emoluments during the year (2010: nil)

The total travelling expenses reimbursed to 12 Members of Council was £10,086 (2010: £7,450)

5. Costs of Independent Examiner

	2011 (£)	2010 (£)
Examination of the accounts	400	400
Accountancy and payroll services	1,450	1,400
	1,850	1,800

6. Debtors

	2011 (£)	2010 (£)
Accrued income – receivable within one year	111,900	126,690

7. Creditors – falling due within one year

	2011 (£)	2010 (£)
Social Services costs	3,303	3,182
Accrued expenditure	61,824	10,462
	65,127	13,644

8. Designated Fund

(See page 106.)

9. Schedule of Investments

(See pages 108–109.)

THE PALAEONTOLOGICAL ASSOCIATION Registered Charity No. 276369

STATEMENT OF FINANCIAL ACTIVITIES FOR THE YEAR ENDED 31st DECEMBER 2011

DESIGNATED FUNDS Note 8 to the Accounts

	Sylvester-Bradley £	Jones-Fenleigh £	Hodson £	Callomon £	Whittington £	TOTAL 2011 £	TOTAL 2010 £
Donations	764	487	0	0	0	1,250	1,589
Interest Received	20	22	13	10	20	85	94
TOTAL INCOMING RESOURCES	784	509	13	10	20	1,335	1,683
Grants made	3,890	1,400	1,606	0	0	6,896	7,261
NET SURPLUS/(DEFICIT)	-3,106	-891	-1,593	10	20	-5,561	-5,578
TRANSFERS BETWEEN FUNDS	0	0	0	0	0	0	50,000
SURPLUS/(DEFICIT) FOR THE YEAR	-3,106	-891	-1,593	10	20	-5,561	44,422
FUNDS BROUGHT FORWARD	20,325	22,805	13,421	10,000	20,000	86,551	42,128
FUNDS CARRIED FORWARD	17,218	21,914	11,828	10,010	20,020	80,990	86,550

Independent Examiner's Report on the Accounts of The Palaeontological Association for the year ended 31st December 2011

Respective responsibilities of trustees and examiner

The charity's trustees consider that an audit is not required for this year (under section 43(2) of the Charities Act 1993 (the Act), as amended by s.28 of the Charities Act 2006) and that an independent examination is needed.

It is my responsibility to:

examine the accounts (under section 43 of the Act as amended)

follow the procedures laid down in the General Directions given by the Charity Commissioners (under section 43(7) of the Act as amended), and

to state whether particular matters have come to my attention.

Basis of independent examiner's statement

My examination was carried out in accordance with the General Directions given by the Charity Commissioners. An examination includes a review of the accounting records kept by the charity and a comparison of the accounts presented with those records. It also includes consideration of any unusual items or disclosures in the accounts and seeking explanations from the trustees concerning such matters. The procedures undertaken do not provide all the evidence that would be required in an audit and consequently I do not express an audit opinion on the accounts.

Independent examiner's statement

In connection with my examination, no matter has come to my attention:

(1) which gives me reasonable cause to believe that in any material respect the trustees have not met the requirements to ensure that:

proper accounting records are kept (in accordance with section 41 of the Act) and

accounts are prepared which agree with the accounting records and comply with the accounting requirements of the Act.

(2) to which, in my opinion, attention should be drawn in order to enable a proper understanding of the accounts to be reached.

Dated: 25th April 2012

G R Powell F.C.A.

Nether House, Great Bowden,
Market Harborough
Leicestershire LE16 7HF

Note 9 to the Accounts

Nominal	Holding	Cost (pre 2011)	Value (end 2010)	Proceeds (in 2011)
£18,000	UK 4.75% Stock 07/03/20 GBP 100	18,145.87	20,072.00	
£20,000	UK 4.5% Gilt 07/03/19 GBP 0.01	20,092.99	22,030.00	
£64,176.46	COIF Charities Fixed Interest Fund	85,000.00	81,523.36	
804	Royal Dutch Shell B shares	12,432.00	17,005.00	
1,425	BP Ord 25c shares	5,047.35	6,634.00	
600	BHP Billiton $0.5 shares	4,341.48	15,306.00	
500	BG Group Ordinary 10p shares	3,977.95	6,480.00	
1,825	HSBC Holdings Ordinary 0.5 US Dollar shares	5,512.91	11,883.00	
6,800	Lloyds TSB Ordinary 25p shares	10,169.91	4,468.00	
875	BAE Systems Ord 2.5 P shares	3,542.00	2,888.00	
1,000	3I Group Ordinary £0.738636 shares	3,058.76	3,285.00	
1,150	Tesco Ord GBP 0.05	4,583.22	4,888.00	
1,550	Kingfisher Ord GBP 0.157142857	3,554.45	4,083.00	
175	Carnival Plc Ord USD 1.66	3,996.49	5,219.00	
650	Glaxo Smithkline Ordinary 25p shares	10,232.42	8,060.00	
2,499	Bluecrest Allblue Ord Npv GBP shares	3,020.28	4,248.00	
1,100	Wood Group (John) Ordinary 3.33p shares	2,975.36	6,149.00	6,874.01
550	Amec ord 50P			
7,000	Ing Global Real Estate Securities Ord NVP shares	7,084.00	6,003.00	
4,175	Vodaphone Group Ord USD 0.11428571	6,034.20	6,922.00	
2,150	BT Group Ordinary 5p shares	7,787.53	3,887.00	
225	Brit Amer Tobacco Ord GBP 0.25	4,991.81	5,543.00	
300	Unilever PLC Ord GBP 0.031111	4,326.21	5,889.00	
460	Pearson Ordinary 25p shares	8,069.00	4,637.00	
490	Serco Group Ord 2P	3,005.01	2,722.00	
700	National Grid Ord GBP 0.113953	3,648.26	3,871.00	
420	Experian Ord 10C	3,444.95	3,352.00	
670	Blackrock World Mi Ord 5P	4,019.09	5,434.00	
315	Standard Chartered Ord USD 0.50	5,514.48	5,435.00	
650	RIT Capital Partners Ordinary £1 shares	4,903.90	7,794.00	
1,000	Balfour Beatty 50P	2,913.17	3,129.00	
20	Schroder Alt Solut Agriculture C GBP Dis Hdg	2,987.22	2,790.00	
1,500	British Empire Sec & Gen Trust Ordinary 10p shares	5,005.61	7,290.00	
425	Findlay Park Partners US Smaller Companies	6,158.47	13,130.00	
2,825	Ishares S&P 500 GBP	20,319.63	22,819.00	
900	JPMorgan Am UK Ltd Emerging Markets I Instl	5,043.10	5,620.00	
8,000	Bny Mellon Glb Fds Erg Mkts Debt Loc Crr C			
1,750	Cazenove Inv Fd Mt European Fund X Acc Nav	6,107.82	7,948.00	6,835.08
425	Fidelity EUR Value Ordinary 25P shares	4,059.07	4,730.00	
3,900	Edinburgh Dragon Trust Ordinary £0.20 shares	4,478.10	9,965.00	
3,100	Capita Morant Wright Japan B Inc Nav	5,170.11	6,423.00	5,687.62
160	GLG Japan Corealpha Equity IT Acc			
5,200	Scottish Widows Property Trust B	4,669.49	4,678.00	
100	Bluebay Funds SA LI.FD-D GBP Base	11,581.33	11,252.00	10,707.94
26	Veritas Asset Mgmt Veritas Asian A GBP	8,182.27	8,462.00	
1,320	Goldman Sachs Fund US Equity I GBP Inc Nav	14,640.81	14,559.00	
65	Roche Hldgs Ag Genusscheine Nvp	7,226.55	6,104.00	
6,600	Henderson Gbl Invs European Special Sits I Inc	7,037.91	8,336.00	
55	Shd Umbrella Funds Paragon Capp App Ire B	9,894.52	9,927.00	
1,283.80	COIF Charities Investment Fund Acc Units	75,000.00	101,847.58	
	Total	462,987.06	534,719.94	30,104.65

Cost (in 2011)	Gain realised (in 2011)	Value (end 2011)	Gain unrealised (at end 2011)	
		22,469.00	2,397.00	UK 4.75% Stock 07/03/20 GBP 100
		24,370.00	2,340.00	UK 4.5% Gilt 07/03/19 GBP 0.01
		85,669.16	4,145.80	COIF Charities Fixed Interest Fund
		19,730.00	2,725.00	Royal Dutch Shell B shares
		6,562.00	-72.00	BP Ord 25c shares
		11,265.00	-4,041.00	BHP Billiton $0.5 shares
		6,883.00	403.00	BG Group Ordinary 10p shares
		8,962.00	-2,921.00	HSBC Holdings Ordinary 0.5 US Dollar shares
		1,762.00	-2,706.00	Lloyds TSB Ordinary 25p shares
		2,495.00	-393.00	BAE Systems Ord 2.5 P shares
		1,810.00	-1,475.00	3I Group Ordinary £0.738636 shares
		4,640.00	-248.00	Tesco Ord GBP 0.05
		3,886.00	-197.00	Kingfisher Ord GBP 0.157142857
		3,721.00	-1,498.00	Carnival Plc Ord USD 1.66
		9,565.00	1,505.00	Glaxo Smithkline Ordinary 25p shares
		4,176.00	-72.00	Bluecrest Allblue Ord Npv GBP shares
	725.01			Wood Group (John) Ordinary 3.33p shares
6,133.62		4,991.00	-1,142.62	Amec ord 50P
		5,705.00	-298.00	Ing Global Real Estate Securities Ord NVP shares
		7,469.00	547.00	Vodaphone Group Ord USD 0.11428571
		4,104.00	217.00	BT Group Ordinary 5p shares
		6,875.00	1,332.00	Brit Amer Tobacco Ord GBP 0.25
		6,489.00	600.00	Unilever PLC Ord GBP 0.031111
		5,566.00	929.00	Pearson Ordinary 25p shares
		2,323.00	-399.00	Serco Group Ord 2P
		4,375.00	504.00	National Grid Ord GBP 0.113953
		3,677.00	325.00	Experian Ord 10C
		4,231.00	-1,203.00	Blackrock World Mi Ord 5P
		4,438.00	-997.00	Standard Chartered Ord USD 0.50
		7,956.00	162.00	RIT Capital Partners Ordinary £1 shares
		2,648.00	-481.00	Balfour Beatty 50P
		2,338.00	-452.00	Schroder Alt Solut Agriculture C GBP Dis Hdg
		6,211.00	-1,079.00	British Empire Sec & Gen Trust Ordinary 10p shares
		12,891.00	-239.00	Findlay Park Partners US Smaller Companies
		23,031.00	212.00	Ishares S&P 500 GBP
		4,649.00	-971.00	JPMorgan Am UK Ltd Emerging Markets I Instl
10,745.39		9,957.00	-788.39	Bny Mellon Glb Fds Erg Mkts Debt Loc Crr C
	-1,112.92			Cazenove Inv Fd Mt European Fund X Acc Nav
		4,263.00	-467.00	Fidelity EUR Value Ordinary 25P shares
		8,463.00	-1,502.00	Edinburgh Dragon Trust Ordinary £0.20 shares
	-735.38			Capita Morant Wright Japan B Inc Nav
11,330.79		10,569.00	-761.79	GLG Japan Corealpha Equity IT Acc
		4,673.00	-5.00	Scottish Widows Property Trust B
	-544.06			Bluebay Funds SA LI.FD-D GBP Base
		6,663.00	-1,799.00	Veritas Asset Mgmt Veritas Asian A GBP
		14,045.00	-514.00	Goldman Sachs Fund US Equity I GBP Inc Nav
		7,119.00	1,015.00	Roche Hldgs Ag Genusscheine Nvp
		6,917.00	-1,419.00	Henderson Gbl Invs European Special Sits I Inc
		9,510.00	-417.00	Shd Umbrella Funds Paragon Capp App Ire B
		100,494.71	-1,352.87	COIF Charities Investment Fund Acc Units
28,209.80	-1,667.35	520,605.87	-10,551.87	