The Palaeontology Newsletter

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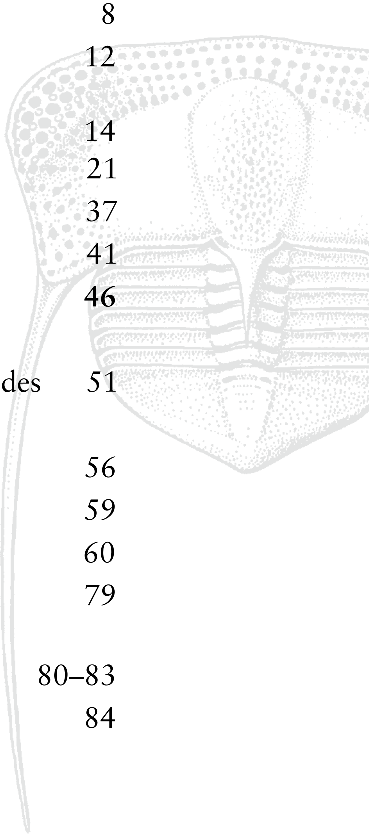
Palaeontology



Reminder: The deadline for copy for Issue no 67 is 18th February 2008.
On the Web: <**http://www.palass.org/**>
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Editorial

Writing this, with the October rain lashing at the windows and a distinct chill in the air, I don't feel particularly festive. By the time you read this, however, the festive season will be almost upon us, kicking off with the Annual Meeting of the Association which this year is to be held – for the first time – in Uppsala. Hopefully as many of you as possible will be able to join us!

Summer was a distinctly busy time for me, with a number of field trips to various far-flung corners of the world, and production of the last *Newsletter* (no. 65) was squeezed into the few days free between trips. As such, I am indebted to Al McGowan for all the extra help in editing, proof-reading and production: thanks Al! Also, I wish to give a belated thank you to Peter Forey for his marvellous course on cladistics, which finished with his article in the last newsletter.

Lastly, the more observant amongst you will have noticed the mysterious disappearance of the 'Mystery Fossil' feature (the last one being published way back in *Newsletter* 63). Cris Little has informed me that this is due to a lack of copy. Apparently, palaeontology has solved all of its mysteries! In the award-winning words of Donald Rumsfeld[1], all the known unknowns have become known knowns and all of those things we knew we didn't know we now know we know! Although Cris is retiring from his post as manager of the Mystery Fossil page – and thanks to him for all his work over the years – the page will be kept open on the off chance that there are still a few mysteries lurking out there – one or two unknown unknowns that we don't know we don't know… If you stumble across any then please send photos in to me at the usual address.

Richard Twitchett
Newsletter Editor
<newsletter@palass.org>

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[1] **http://www.plainenglish.co.uk/footinmouth.htm**

Association Business

NOTIFICATION IS GIVEN OF THE 52ND ANNUAL GENERAL MEETING AND ANNUAL ADDRESS

The AGM followed by the Annual Address will be held at 1600 on Monday 17th December in Uppsala Konsert & Kongress, Stora Salen.

AGENDA

1. Apologies for absence
2. Minutes of the 51st AGM, University of Sheffield
3. Annual Report for 2006 (published in *Newsletter* 65)
4. Accounts and Balance Sheet for 2006 (published in *Newsletter* 65)
5. Election of Council and vote of thanks to retiring members
6. Palaeontological Association Awards
7. Annual address

H. A. Armstrong
Secretary

Draft AGM 2006 Minutes

Minutes of the Annual General Meeting held on Monday, 19th December 2006 at the University of Sheffield.

Apologies for absence: None reported.

1. **Annual Report for 2005.** Agreed, proposed by Prof. Sevastopoulo and seconded by Prof. Edwards.
2. **Accounts and Balance Sheet for 2005**. Agreed, proposed by Dr Cocks and seconded by Dr Hilton.
3. **Changes to Constitution.** The following changes to the Constitution were agreed, proposed Prof. Smith and seconded by Dr Wellman. Restatement of the definition of Student Membership; expansion of the Retired Membership category to include new members (as opposed to previous ordinary Members of 15 years standing) who are over 60 and not in full-time employment; and formal inclusion of the category of Honorary Life Member. A move to permit the Institutional Membership subscription to be decided by Council rather than be referred to the AGM. Inclusion of information required to be consistent with recent changes in Charity Law.

(continued overleaf…)

4. Election of Council and vote of thanks to retiring members

i. Sir P. Crane extended a vote of thanks to the retiring members of Council Dr Loydell (Vice-President), Dr Siveter (co-opted as Annual Meeting organiser), Dr Harper (retires as a Trustee but will remain as handling editor). Dr Palmer (Executive Officer) and Prof. Batten (Editor in Chief) were thanked for their continuing service to the Association. Prof. Bassett extended a vote of thanks to Sir P. Crane, retiring President.

ii. The following members were elected to serve on Council at the AGM on 20th December 2006: *President*: Professor M. G. Bassett; *Vice-Presidents:* Dr P. C. J. Donoghue, Dr C. H. Wellman; *Treasurer*: Prof. J. C. W. Cope; *Secretary*: Dr H. A. Armstrong; *Chairman of the Publications Board*: Prof. D. A. T. Harper; *Newsletter Editor*: Dr R. J. Twitchett; *Book Review Editor*: Dr P. J. Orr; *Newsletter Reporter*: Dr A. McGowan; *Internet Officer*: Dr J. M. Hilton; *Publicity Officer*: Dr P. L. Manning; *Editors who are also Trustees*: Dr L. I. Anderson, Dr C. M. Berry, Prof. E. N. K. Clarkson, Prof. M. P. Smith (Secretary of the Publications Board), Dr P. D. Polly; *Ordinary Members*: Prof. N. Macleod, Dr T. Servais, Dr Jan Auden Rasmusen, Dr M. Sutton and Dr G. Budd.

5. Association Awards

i. Lapworth Medal to Prof. A. Seilacher.

ii. Hodson Fund to Dr Guy Herrington (Univ. of Birmingham) and Dr Paul Barrett (NHM).

iii. Sylvester-Bradley Awards to Herridge, Dunkley-Jones, Donovan, Challands, Joomun, Popov, Muir, Zanno, Allan and Ghobadi pour Mansoureh.

iv. Honorary Life Membership to Prof. Chandler, Prof. Hudson, Prof. Hallam, Prof. Murray, Prof. Whittington and Dr Cocks.

v. Mary Anning Award to Mr Robert Chandler.

vi. A Golden Trilobite Award to Mr Alan Morton.

The Annual Address was presented by Prof. A. Boucot, entitled “What should go into a systematic description.”

H. A. Armstrong
Secretary

Palaeontological Association research grants

Council has agreed that Association funds should be made available to support primary palaeontological research. Awards will be made to assist palaeontological research up to a maximum value of £15,000. Typically grants could support single research projects or 'proof of concept proposals' with an aim of supporting future applications to national research funding bodies. Application guidelines are currently being formalized and will be announced at the AGM. Online guidelines and the application form will be available in good time for the deadline of **1st March 2008**.

Grants in Aid awarded – October 2007

8th International Symposium on the Cretaceous System. Funds have been agreed to support student attendance at the meeting.

Palaeontological Symposia within the 20th International Congress of Zoology, August 2008. Funds have been agreed to support speaker expenses.

IGCP 503. Ordovician Palaeogeography and Palaeoclimate. Funds have been agreed to support student attendance at the meeting.

Paleo-Database course. Funds have been agreed to support student attendance at the short course.

Charles Walcott Conference, Banff 2008. Funds have been agreed to cover the expenses of six research students.

Lapworth Medal 2008

Nominations are now being sought for the Lapworth Medal. This is the premier award of the Association. It is awarded to people who have made a significant contribution to the science by means of a substantial body of research. The medal is not normally awarded on the basis of a few good papers. Council will look for some breadth as well as depth in contributions in choosing suitable candidates. Nominations should include a letter outlining the achievements of the nominee, supporting statements from referees, a CV and portfolio of published work. A new online nomination system is currently being designed and will be available shortly. Nominations should reach the Secretary by **1st March 2008**.

President's Medal

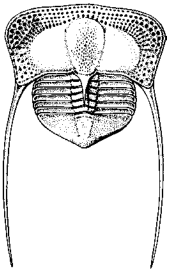
The Association intends to instigate a mid-career award in recognition of outstanding contributions from a scientist in his/her earlier career, coupled with an expectation that they are not too old to contribute significantly to the subject in their further work. Nominations will be invited by 1st March each year. Guidelines and online nomination form will be available shortly.

Grants in Aid

The Palaeontological Association is happy to receive applications for loans or grants from the organisers of scientific meetings that lie conformably with its charitable purpose, which is to promote research in palaeontology and its allied sciences. Application should be made in good time by the scientific organiser(s) of the meeting using the online application form. Such requests will be considered by Council at the March and October Council Meetings each year. Enquiries may be made to <**secretary@palass.org**>; requests should be sent by **1st March**.

Grants-in-Aid: Workshops and short courses

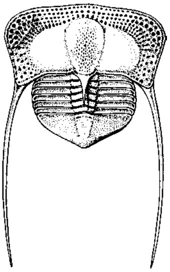
The Palaeontological Association is happy to receive applications for loans or grants from the organisers of scientific workshops or short courses that lie conformably with its charitable purpose, which is to promote research in palaeontology and its allied sciences. Application should be made in good time by the scientific organiser(s) of the meeting using the online application form. Such requests will be considered by Council at the March and October Council Meetings each year. Enquiries may be made to <**secretary@palass.org**>; requests should be sent by **1st March**.

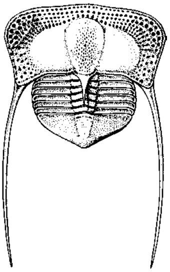


Palaeontology:
CALL FOR SHORT PAPERS!

From January 2005 *Palaeontology* has been published in A4 size with a new layout. In line with this development, space is reserved for rapid publication of short papers on topical issues, exceptional new discoveries and major developments that have important implications for evolution, palaeoclimate, depositional environments and other matters of general interest to palaeontologists. Papers, which should not exceed six printed pages, should be submitted in the normal way, but they will be refereed rapidly and fast tracked, on acceptance, for publication in the next available issue.

Submission of longer review papers is also encouraged, and these too will be given priority for rapid publication. While *Palaeontology* maintains its reputation for scientific quality and presentation, these developments will ensure that the Impact Factor of the journal reflects its status as a leading publication in the field (rising to 1.19 in 2003).





ASSOCIATION MEETINGS

PalAss 2007
51st Annual Meeting of the Palaeontological Association
Uppsala, Sweden *16 – 19 December 2006*

Registration and Call for Abstracts

The year 2007 marks the 300th anniversary of the birth of the favourite son of Uppsala, Carl von Linné. As part of the tercentenary celebrations, Uppsala University is pleased to host the 51st Annual Meeting of the Palaeontological Association. The meeting will be organised by the Palaeobiology Group of the Department of Earth Sciences at Uppsala University, in association with the *Evolutionsmuseet* (Museum of Evolution) of Uppsala University and the *Naturhistoriska riksmuseet* (Swedish Museum of Natural History) in Stockholm. We look forward to welcoming you to Uppsala on 16–19 December 2007.

Registration and abstract submission is now open on the Palass Website (<**http://www.palass.org/**>), where the second circular, which supersedes previous information, can also be downloaded.

Meeting format

The Annual Meeting proper will be preceded by a **symposium** on the **Origin of Major Groups** during the afternoon (**starts 13:00**) of Sunday 16th December. The preliminary schedule of speakers can be found below. All talks will take place at the **Uppsala Concert and Congress Hall**. An icebreaker reception will be held on the evening of Sunday 16th December at the **Museum of Evolution**.

The Annual Meeting will take place on Monday 17th December and Tuesday 18th December, also at the **Uppsala Concert and Congress Hall**. The oral technical sessions will consist of talks scheduled for 15 or 20 minutes inclusive of questions. Parallel sessions may be organised as needed. Posters will be displayed throughout the course of the meeting, but a dedicated poster session will also be scheduled during a reception on Monday 17th sponsored by Blackwell Publishing, followed by the AGM and Annual Address by Dr Adrian Lister (NHM, London) on evolutionary aspects of Quaternary faunas. The annual dinner will take place on the evening of Monday 17th December at **Norrlands Nation**.

In honour of the Linnaeus Tercentenary celebrations, there will be an **excursion** on Wednesday 19th December to several historical sites in Uppsala and Stockholm. The morning will be spent in Uppsala, visiting local points of interest including the Linnaeus Museum, the cathedral, and Linné's summer house (*Linnés Hammarby*) outside Uppsala, followed by lunch in the city. In the afternoon, participants will be transported to the Museum of Natural History in Stockholm. The total cost of this excursion is £30 per person.

Registration and Costs

The cost for early registration for Association members is £35 (ordinary and retired member) and £25 for student members. Non-members pay an added £10, *i.e.* £45 (non-member) and £35 (student non-member), respectively. Early registration ends on **7th September**, after which date all registration fees increase by £15. Abstract submissions will not be considered after this date. Final registration is **14th November**. No refunds will be considered after this date.

The cost of the annual dinner is £35. Registrants also have the option to purchase substantial seated lunches for the two days of the Meeting in advance during online registration, at a total cost of £13 per day. Lunch will take place at the conference locality within the restaurant of the Uppsala Concert and Congress Hall.

The President's Prize will be awarded for the best talk at the Annual Meeting produced by someone under the age of thirty who is a member of the Association. There is a cash prize of £100. The Council Poster Prize will be awarded for the best poster at the Annual Meeting produced by someone under the age of thirty who is a member of the Association. There is a cash prize of £100.

Travel grants to help student members (doctoral and earlier) to attend the Uppsala meeting in order to present a talk or poster

The Palaeontological Association runs a programme of travel grants to assist student members presenting talks and posters at the Annual Meeting. For the Uppsala meeting, grants of up to £100 (or the Euro equivalent) will be available to student presenters who are travelling from outside Sweden. The amount payable is dependent on the number of applicants and the distance travelled. Payment of these awards is given as a disbursement at the meeting, not as an advance payment. Students interested in applying for a PalAss travel grant should contact the Executive Officer, Dr Tim Palmer, by e-mail to <**palass@palass.org**> once the organisers have confirmed that their presentation is accepted, and before 8th December 2007. No awards will be made to those who have not followed this procedure.

Speakers in the Symposium include:

Dr Anthony Poole (Stockholm, Sweden)	Origin of life
Dr Greg Edgecombe (NHM, UK)	Origin of crown-group arthropods
Dr Andrew Smith (NHM, UK)	Origin of echinoderms
Prof. Per Ahlberg (Uppsala, Sweden)	Origin of tetrapods
Prof. Else Marie Friis (NRM, Sweden)	Origin of angiosperms

Meeting organiser

Dr Graham Budd
Palaeobiology Group, Department of Earth Sciences
Uppsala University
Contact: <**Uppsala2007@palass.org**>

Summary of dates and costs

14th November 2007	**Registration Deadline**	
16th December 2007	• Symposium on Origin of Major Groups (13:00) • Icebreaker Reception	Included in registration
17th December 2007	• Technical Sessions • Poster Session and Reception by Blackwell Publishing • Annual General Meeting • Annual Address	Included in registration
17th December 2007	Annual Dinner at *Norrlands Nation*	Annual Dinner: £35
18th December 2007	Technical Sessions	Included in registration
19th December 2007	Linnaeus excursion	Excursion fee: £30

Annual Address: Evolution in the Ice Age

Adrian Lister

Natural History Museum, London

The study of Quaternary mammals has great potential for illustrating patterns and processes of evolution (Lister 2004). The timescales, stratigraphic resolution and dating (10^2–10^6 yr) are suitable for testing among different models of species-level evolution; the well-known climatic and vegetational changes of the glacial/interglacial cycle provide a dramatic backdrop against which to view the responses of the mammals; and the persistence of many of the species (or close living relatives) to the present day provides a fixed point of ecology and adaptation against which to view their fossil precursors. In addition, the recent expansion of research in ancient biomolecules (especially DNA sequence data) is providing a new source of information to complement traditional morphological studies.

In theory there are many reasons why episodes of dramatic environmental change might promote an evolutionary response; but several theorists have proposed that the rapid changes of the Quaternary might, on the contrary, have suppressed it. A brief overview of faunal records is presented, suggesting that in some regions at least, speciation and adaptive change have clearly been driven by Quaternary environmental change. The evolutionary role of range expansions, and contractions into refugia, is a particular topic of current debate.

Individual case histories of Quaternary mammals provide some of the best-documented examples of speciation captured in the fossil record. The origin of dwarfed forms of large mammals on islands is a valuable source of data; red deer on Jersey are shown to have dwarfed in only a few thousand years of the last Interglacial (Lister 1995), and current studies are focusing on elephants in the Mediterranean and hippos on Madagascar.

On the mainland, the evolution of the mammoth lineage has been traced through four million years of Plio–Pleistocene time, from its precursors in Africa to the origin of the woolly mammoth in Eurasia and the Columbian mammoth in North America (Lister *et al.* 2005). An original concept of gradual evolution in Europe has given way, with better dating and broader geographic sampling, to a model of successive allopatric speciation events, the transitions taking place first in China and then in NE Siberia, followed after variable intervals by spread of the new forms into Europe and North America.

In tandem with morphological studies, DNA sequence data is providing further insights into population structure and movements, in mammoth and other species, in the Late Pleistocene (Barnes *et al.* 2007). This includes evidence of significant turnover at a sub-specific level, on relatively short timescales, with implications for the fine structure of species extinctions.

BARNES, I., SHAPIRO, B., LISTER, A., KUZNETSOVA, T., SHER, A., GUTHRIE, D. and THOMAS, M.G. 2007. Genetic structure and extinction of the woolly mammoth, *Mammuthus primigenius*. *Curr. Biol.,* **17**, 1–4.

LISTER, A.M. 1995. Sea levels and the evolution of island endemics: the dwarf red deer of Jersey. *Geol. Soc. Spec. Publ.,* **96**, 151–172.

LISTER, A.M. 2004. The impact of Quaternary ice ages on mammalian evolution. *Phil. Trans. R. Soc. Lond.*, **B359**, 221–241.

LISTER A.M., SHER A.V., VAN ESSEN, H. and WEI, G. 2005. The pattern and process of mammoth evolution in Eurasia. *Quat. Int.,* **126–128**, 49–64.

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Organisers

Dr Daniela Schmidt (University of Bristol,
The Micropalaeontological Society)
Dr Sarah Cornell (University of Bristol,
Challenger Society for Marine Sciences)
Dr Jennifer Pike (Cardiff University)

Themes

Ocean acidification
Temperature
Sea level
Climate active gases
Sea ice
Climate change policy

Confirmed Speakers

Henk Brinkhuis (Utrecht University)
Carol Turley (Plymouth Marine Laboratory)
Caroline Lear (Cardiff University)
Carol Robinson (Plymouth Marine Laboratory)
Robin Edwars (Trinity College Dublin)
Jeremy Young (Natural Histroy Museum)
Peter Liss (University of East Anglia)
Xavier Crosta (Université Bordeaux I)
David Vaughan (British Antarctic Service)

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- Internationally renowned taxonomic and systematic skill base.
- Chemical analysis.
- Molecular and imaging facilities.

SYNTHESYS is able to meet the users' costs for research costs, international travel, local accommodation, and a *per diem* to contribute towards living costs.

Forthcoming deadlines: 28th September 2007
28th March 2008

For more information visit <**http://www.synthesys.info/**> or contact <**synthesys@nhm.ac.uk**>.

From our Correspondents

Hard travelling

It is always a pleasure, tinged with relief if suffused with slightly more exhaustion, when some defined stage of a never-ending task comes to a kind of interim conclusion. So the wholly-knackered parent feels, 'round midnight, as the Baby (who *Wouldn't Go to Bed*[1]) eventually settles to sleep. So it must be, between coats of paint on the Forth Bridge, as the painters go off to celebrate with a pint or two of seventy-shilling, before loading up the brushes once more. So Sisyphus must have felt, on hitching his eternal boulder up against some tree stump on the strictly non-erodable mountain allotted to him by the gods, and lighting up a crafty fag[2]. That feeling has lately settled over me, as the complete draft of the *Second Folio* of the *Atlas of Graptolite Type Specimens* formed a neat pile on the desk, reaching a full centimetre and three-quarters towards the clouds.

The idea of this Sisyphean labour had started so promisingly, as I recall, in the kind of low dive inseparable from Ph.D. studies, where beer was flowing and carrying ideas as flotsam down its considerable current. Full-scale, nation-wide monographs of any major fossil group are no longer possible, it was generally agreed. There are just too many species, and not enough time (or funding, these days) to describe them all. So why not cut to the quick (the idea rose up, like a methane bubble through swamp mud) and simply assemble good new drawings of the type specimens of each species. That's quick and easy, surely?

The road to Hell is, of course, paved with such intentions. Three decades on, we are at least on Folio 2, and that eventually-produced draft. It's a complete draft, mind – though not at all the same as a final draft, given that the legendarily scrupulous eye of my fellow editor (one A.W.A. Rushton; keener eyes have rarely been fashioned) is still to be employed for one final check. And even a final draft is not the same as a perfect draft, as the erratum slip will neatly demonstrate. Pertaining to Folio 1, no. 1 of this opus, no less, it will confirm that Henry Alleyne Nicholson, for all his scholarship and taxonomic acuity, did not foist the concept of the taxon *Acrograptus affinis* upon an unsuspecting world at the tender age of fourteen.

It might represent the lowest and simplest form of palaeontological house-keeping, this simple clarification of morphology in taxonomy, yet it does have its modest rewards. It may, perhaps, be regarded as a small act of kindness to the fossil itself, perhaps akin to helping an errant hedgehog cross the road. For a fossil chosen as a type specimen – to eternally represent[3] its species – has, all too often, an anxious and lonely after-life (the post-excavation part of its after-life, that is), altogether more thankless than those of its myriad and taxonomically unburdened fellow-ghosts.

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[1] Forget anthropomorphised tank engines or dogs named Spot. Lay aside Quiet Crickets, or Hungry Caterpillars, even. For a bedtime story that can be read a thousand times and *still* not scramble parental brains, Helen Cooper's fable[*] simply can't be bettered. Hence, of course, it is scarcely to be seen on the shelves of your friendly local multinational bookstore these days.

[*] Having no discernable palaeontological content, it is present in this column on merit alone.

[2] And ruminating on just what a lucky old so-and-so that Hercules was. The Augean stables got done, after all. And perhaps the cattle could be house-trained.

[3] Or, at least until a suitable plea is placed before the International Commission on Zoological Nomenclature.

Anxious, as it might not prove up to the task. A fossil specimen that is no more than averagely moth-eaten might have been adequate to define one of the broad-brush taxa of the early days of the science; but, amid the forest of more finely-drawn species a century on, it might be effectively unidentifiable. And the loneliness comes in when – no matter how suitable or unsuitable the specimen is as a name-carrier – it lies neglected, unexamined and unloved in a museum drawer for many a decade. The species name can then go off to live a merry life of its own, being applied by palaeontologists to many thousands of other specimens, on the basis of the original published description (written in Latin, perhaps, measured imperially and illustrated with a blunt pencil at times one-and-two-sevenths magnification). Or, worse, on that of subsequent published descriptions of other specimens from elsewhere. And, of course, a fossil and its published description(s) can be two (or more) very different things, and so the concept of a species can itself evolve and mutate down the generations.

So it is agreeable to chase down these original specimens, and then simply draw them just as precisely as one can, with a modern microscope and in a good light and with a properly sharpened 4H pencil[4]; to cut through later baroque excrescences back to the original, as it were. One joins in spirit with those precise and patient Victorian spinsters who so delicately portrayed the flowers of their country gardens in watercolours. But, while country gardens are a haven for the familiar, the fossil world is altogether wilder and more unpredictable. Many a surprise may come to light. It may be as grossly obvious as the original specimen being much bigger or smaller than the concept of the species that has grown (or shrunk) via the Chinese whispers of successive published descriptions. Or it may be quite subtle – a previously undiscovered apertural spine, an extra detail of the fold of a thecal aperture. But one can just, purely and simply, marvel at the new and unfamiliar graptolites that are sent in as contributions.

This folio has a fine crop: some Australian species tracked down by Fons Vandenberg, including the amazing *Pterograptus lyricus*, many-branched and indeed lyre-shaped: sufficiently so, one might imagine, to tempt the shade of Harpo Marx to essay a melody upon it. And half a dozen Chinese graptolites, that are particularly eye-catching to Avalonian eyes. Beautifully drawn by Yuan Dong, these just look so … different. *Didymograptus obesus*, a tuning-fork graptolite sure enough, but a behemoth, more than twice the width of any of the denizens of the Ordovician seas of Wales. And *Sinograptus typicalis*, with its regular high folds making switchbacks severe enough to elicit the envy of any funfair operator.

Why such differences? We are in the realms here, of course, of palaeobiogeographies and faunal provinces, and the controls – through climate, predation, competition, water chemistry – on which species swept across the water column to conquer half a world, and which kept to their own backyard. It is the attempt to peer through the mists of deep time and to divine the multiple constraints – mostly insensible and unpreserved – that determined the course of each day of a long-dead organism's existence and that, through a myriad such increments, would determine whether it would eat or be eaten, feast or starve, and then drift (or swim) a little further into the unknown, or be cut down by any of the perils of a sea that was no less cruel half a billion years ago than it is now.

There are many parallels that can be drawn, and in these pages one is naturally drawn to those

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[4] Pencil sharpener then scalpel blade then emery paper in that order; modern palaeontological technology can at times be nothing less than awesomely sophisticated.

that are as inappropriate as they are misleading. For some years I have been intrigued by the more curious patterns shown by contemporary mass migrations of … well, of fossils, of a sort. Or rather, of things that are both dead and alive, and animated and inanimate, *at the same time*. This makes it sound as if some of Schrödinger's more enigmatic cats are on the prowl. But these particular fossils are far more familiar to us, and may be purchased in your local supermarket for the price of a jar of coffee[5]. Yet, one might posit that they might represent the only truly new and unique class of fossil that – courtesy of the ingenuity of certain members of the human species – has been formed on Earth in the past three billion years or so. The phenomenon is that of recorded words and music, and the unique mode of fossilization is that of the exceptional – indeed, high-fidelity – preservation of sound.

The ability to faithfully recreate elapsed sound! A modern miracle, now made universal and banal in the day of the cut-price CD and the iPod. And yet little more than a century ago it must have seemed a true miracle to hear a voice emerge, more ghostly and more perfect than the Cheshire cat's smile, from the bell mounted on a small mechanical box. No wonder that puzzled dog was listening in, ears cocked. I still have to pinch myself, sometimes, finding that I am in the same room as Callas or Tebaldi, or as the aristocracy (earned, not inherited) of Hines or Basie or Ellington. These recordings seem to me to fulfil most of the qualities of a fossil, albeit of a specific kind of trace fossil. That is, they are the physical preservation of a particular kind of biological activity. It doesn't matter that they are preserved by the same organisms that produced the actions that are being preserved. It is still fossilization. I can think of nothing like it within the strata accumulated over the previous four-and-a-bit billion years of this planet's history.

Wait a minute – you might say – as regards human fossil innovations: what about photographs? Don't these fossilize the appearance of things? They do, but being mere images, though, replications of external shape, they are just not in the same class as regards novelty. They have long been anticipated by everything from Cambrian trilobites to Holocene molluscs. The fidelity of most fossils, then, is not high enough to allow such comparisons? The perfectly replicated *Hallucigenia* and *Anomalocaris* of the Burgess Shale and those finely-coloured Messel insects seem to be answer enough here. But fossils are of organisms only, surely, and do not capture, say, landscapes? Well, only the other day I was helping show our current first years the sub-Triassic unconformity of Charnwood Forest, and that, with its spectacular buried valleys, is as fine a fossilized landscape as one could wish for. What about holograms, though – do they not represent something new in the recording of objects? Perhaps or perhaps not; one might argue that they merely add the third dimension. Graptolites managed that routinely (as did stromatolites, even, way back in the Precambrian), while amber has routinely captured every last joint and eye-lens and hair of a fine range of insects. Moving pictures, then? Well, add those footprints to some dinosaur bones, mix in some sensible interpretive biomechanics, and the saurians will leap from the strata or plod back into the swamp, depending on age, athleticism, demeanour and timing of preservation[6]. Books and writing? Mere code, and fossilized DNA represents a longer epic than *War and Peace*.

No, it is the preservation and replication of sound that seems truly different, a taphonomic innovation without precedent in stratigraphy, a biologically produced signal never previously

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[5] A random Digression is about to unfold, alas. It is not too late to jump ship.

[6] Dinosaurs fossilized on Monday mornings will plod mournfully, for sure.

captured by any preservational mechanism, not even in the most astonishing examples of the current crop of lagerstätten. The only faint analogies that come to mind – and they are emphatically non-biological ones at that – are the shatter-cones to be found around meteorite craters, crude records of the hammer-blow of the impact, or the series of dilatation joints sometimes left in rocks by earthquakes. Here the fidelity, alas, is so low as to reach depths that are quite appropriately subterranean: there is only a muffled echo of the dynamics of the original event preserved in such traces. It is human invention that has triumphed here. Even an MP3 recording of, say, Showaddywaddy, is a miracle by comparison with the crude audio recordings that Mother Earth – no techno-freak, she – has managed to fashion. There are many types of fossil: there are ichnofossils, macrofossils, microfossils, nannofossils, palynofossils, chemofossils, pseudofossils. Thomas Edison scarcely dreamed of the scale of his discovery in producing – now, how can one christen these? Sonofossils, shall we say?

They are extraordinary things, these sonofossils. They capture, arguably better than any other means of fossilization, a simulacrum of life itself, virtually cheating Death itself in the process. In my youth I was, for a few hours, in the same room as Duke Ellington and his orchestra. I saw them live, being taken by a father who much preferred classical music but who had sufficient tact to make neither the ferrying nor the sitting through the concert seem like a chore. Indeed, he noted aloud (for my benefit, I now realise) the musicianship on show – simultaneously a tacit encouragement for my juvenile enthusiasms and a signpost to the fact that the inherent worth of anything does not depend on appearances, reputation, prejudice, schooling or background.

The memories remain vivid, but, funnily, are not especially reinforced either by pictures or by film. An audio recording, though – particularly a concert recording – hits the memory button instantly and powerfully, as the great man’s piano introductions to the pieces, and spoken introductions to the soloists (he chose chords and words with equal care) unfold. The frozen patterns of vibrating air somehow preserve the essence of the man himself and bring back the awestruck teenager listening to him. This seems beyond fossilization, and more akin to the suspension of both animation and belief. It is harmonic DNA, in which both ancestors and descendents co-exist.

Sonofossils, combining thus the qualities of life and death (your local CD store therefore being biocoenosis and taphocoenosis and modern community rolled into one, as it were) and also items of cultural significance to the human species, show their own patterns of migration, related to and driven by – but by no means identical with – the patterns of migration of the humans themselves.

Let’s take an example, just one of many impressions made on travelling to Poland in the 1980s, in those uncertain and isolated days of martial law. It was an anxious time, and difficult, and most goods (including food) were in short supply, but – at least for visitors – it didn’t present an aspect of completely unrelieved grimness. Standard Slavic rules of hospitality applied, and perhaps were reinforced by the sociopolitical context. One met people, made friends, conversed over plates of whatever food could be gathered, over glasses of smuggled beer and home-made wine and hooch, and listened to music.

There, I discovered the popularity of jazz in the country. That wasn’t hard to understand: the forbidden fruit of the decadent west has long been a driving force for the eastwards migration of this form of sonofossil. More surprising, though, was an enthusiasm for sound-replicates that had come from the east, from Russia, many preserving the voices of a handful of post-war ballad-singers. Remember, this was emphatically the era, still, of the intensely unpopular Soviet domination ('hegemony' gets it about right), and of, say, the forced (and strongly resented) imposition of the Russian language as a compulsory subject in schools. Most of my newly-made friends were active Solidarity members, often at considerable risk of imprisonment. And here they were listening to the enemy. What was happening? Were these balladeers among the fabled dissidents?

Well, no, not really. They did not sing protest songs or hymn agendas for the counter-revolution. But they did sing of the reality of everyday life in Russia, of normal hopes and fears and likes and dislikes, and sometimes of the experiences (mostly grim) of 'The Great Patriotic War'; on occasion they were not afraid to mention the labour camps, matter-of-factly, as places where people sometimes went to, and often never came back from. Hence, these singers were not liked much by the authorities and life was not made easy for them (very hard to get those Melodiya recording contracts, for example). But they were revered by ordinary Russian people, who circulated their songs in samizdat tapes in their millions, until, grudgingly, Melodiya gave in and made some recordings. And because these singers sang of hardships and pleasures common to both ordinary Russian and Polish people, these recordings made their way across to Poland, and were also absorbed into a popular culture in which (as a novelty to me) the fine distinction between a system and the people of that system could be made.

I didn't know much of this, then, and I didn't understand Russian (and still don't, by more than a few words). It simply struck me as some of the world's indispensible music, with a sense of melody and rhythm and articulated emotion as fine as (and often finer than, to my ears) anything by Brassens or Greco, as universal as anything I've heard.

Who were these balladeers? Let's take one example. Vladimir Vysotsky, aka Vyssotsky, aka Wlodzimierz Wysocki (the latter's the Polish version I first grew familiar with; translation from the Cyrillic can play merry hell with cross-cultural understanding, but at least it does produce a long synonymy list). Not heard of him? Join the crowd. Neither had I. Yet he is regarded, still, in Russia as among the most important Russian cultural figures of the 20th century. Some say he is *the* most important. This, in the land that produced Stravinsky and Shostakovitch, Bulgakov and Diaghilev, is saying something. An actor by profession, Vysotsky had a genius for composing ballads that got under the skin of life and death; too young to have known the war, his songs moved veterans to tears – and to disbelief that his words were based on imagination, not experience. He wasn't a criminal – but his songs about the Russian underworld made listeners think that he was. There was little of this that I could catch, but the intensity of interpretation and melodic invention were sufficient in themselves to mark out something very special. Yet, the sonofossils of Stravinsky *et al.* had crossed to British shores, and so I knew them. His hadn't.

They still haven't. Browse through the Russian section of the world music section of British music stores, big and small, and you will find a peculiarly skewed sample of the indigenous music. I used to search hopefully through the racks, whenever I went into one of the bigger music shops. It was a small but perfectly formed musical wasteland. There was any amount of stuff by the Red Army choir. There was a variety of unlikely-looking be-moustachio'd ethnic folk bands, clutching balalaikas in their massive fists and threatening discord. There was a sprinkling of pretty Slavic waifs, who could probably be accused of possessing flute-like voices. But of Vysotsky or of his genuinely popular and musically substantial ilk, not a trace. There was a reason for my searches. Democracy had come to Poland, and ushered in a minor extinction event. It was the day that particular music died, a casualty of an unequal cultural contest. Vysotky's music disappeared from Polish shelves.

This was freedom, political and economic, and in flooded the supermarkets and burger bars. Musically, there was MacDonaldization, too. There was now limitless western pop music (mostly as bootleg tape versions in the early years), from Abba to Led Zeppelin and with everything in between. But indigenous music became much harder to find, while Vysotsky's music had simply vanished. I asked hopefully on every visit, for years, always with the same answer, and a shrug of the shoulders: the stuff simply wasn't available. Until one splendid, exceptional day. Another music shop, the same question, the same answer … and then a sudden change of mind as a memory struck. The man frowned, reached under the counter and pulled out a dusty packet, wrapped in brown paper and tied with string. It was a stack of 15 LPs (they were fossils in themselves; CDs had conquered the world some years ago): the entire original Melodiya set of Vysotsky concerts. Somebody had brought them in. Did I want any? I didn't hesitate, or ask the price, but just bought the lot. They are treasured possessions, still.

Why so treasured? Well, it seemed like a lost world, one suddenly become distant and inaccessible. It was as if one could no longer have access to the Schubert lieder or the Beethoven sonatas, or to the songs of Leonard Cohen or the Beatles, because of some mysterious and arbitrary controls on their sale and distribution. Vysotsky's ballads had disappeared from Poland, but they had never even migrated to Britain, a land where everything, seemingly, was accessible and available and moreover one where world music had, in recent years, grown into an industry with festivals and prizes and dedicated radio programmes.

There's the thinnest of analogies buried in this history, or at least an association that occasionally crossed my mind when considering this unequal and arbitrary contest of competing cultures[7], thrown together by the sudden disappearance of a physical barrier. It's an example that has stayed, cartoon-like, in my head from some pedagogical encounter of the distant past: the formation of the Panama isthmus.

Now here was a real land bridge, unlike the mythical ones that transported dinosaurs around the world in the days before continents were free to drift in both imagination and reality. In rising above the waves it conjured up the Americas, and the meeting of the two, long-isolated faunas of the northern and southern continents. In the simple pedagogical parables of my youth this slender segment of crust allowed the muscular and well-adapted proto-imperialist mammals of the North to flood into the South and take over the joint, the indigenous species of which promptly died like flies around them. In these stories there were but a few heroic animals, such as the giant sloth, that withstood the south-moving tide and shouldered their way north, to finally succumb in the caves of the south-west US.

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[7] Vysotsky's music has, over the past few years, come back into Polish shops, mainly as compilation CDs. They're not a patch on the Melodiya LPs that, simply and unfussily, record entire concerts, thus capturing both organism and environment. It's a classy piece of sonofossilization. Say what you like about the Soviet cultural establishment, there were people there who knew their stuff.

Education's a wonderful thing, sort of, but the reality was more complex, as a quick visit to the burgeoning Wikipedia archives demonstrates. The Great American Biotic Interchange, it is now called, and the traffic was, if not quite symmetrical, much more two-way than either my memory of its retelling or (say) the melancholy history of trans-European post-Iron Curtain sonofossil assemblage dynamics. The giant sloth in reality eventually made it all the way to Alaska, and it was joined by some hefty friends: those avian plug-uglies the phorusrhacid terror-birds, and the glyptodonts. And a few of the invaders – albeit the smaller ones, such as the porcupines – settled happily and abundantly and made hay[8] in those northern forests and prairies. It is true that some extinctions in the south may have been the result of direct competition: the big sabre-tooth cats arriving from the north may have been leaner and meaner and faster and nastier than *Thylacosmilus*, the analogous sabre-toothed marsupial of the south. But both perished, along with many others, as climate started its rhythmic Quaternary quadrille and then as humans joined in for the last dance, newly-minted Clovis spear-points at the ready.

Just what governs which routes organisms migrate along, and where they settle, seems to be just as mysterious, and as quasi-random, as the factors that govern the spread of musical memes from country to country. It adds another layer of mystery, too, when considering the wanderings of the graptolites. These enigmatic and emphatically non-uniformitarian creatures spread through oceans that seem more akin to the alien seas viewed through the scanner of the good ship Tardis than they resemble any modern ocean.

These oceans, we suppose, formed as today some two-thirds of the globe's surface, assuming an Earth of equal size[9] and continents a little less accreted and so perhaps just fractionally smaller, in total, than today. And, of course, we are well past the 200-million-year cut-off point beyond which subduction has taken ocean crust and oozes and entombed graptolites deep into the mantle, and that has by now converted, almost certainly, some of those graptolites into diamond (now *there's* a preservational mode that demands further research). Early Palaeozoic stratigraphy is almost all of the ocean's edge; it is the ancestors of the North Sea and its like that we mostly examine, not those of the deep Atlantic.

There do seem to be some putative fragments that have survived the wholesale tectonic recycling. The Moffat Shales of the Southern Uplands of Scotland, for instance, plastered in that uncannily regular fashion against the side of the Laurentian palaeocontinent. Or the rafts of 'lydite' floating within the maelstrom of the Sudetan accretionary prism (none of those precisely sculpted Scottish patterns there). Are they really true ocean-remains? And if so, how representative are they? They had the capacity to be preserved. Are they therefore – in a Heisenbergish and uncertain fashion – oddballs, quite untypical of standard Early Palaeozoic ocean floor?

The mists of time here swirl like billy-o in front of the poor researcher's bemused eyes. But if the rocks are to be believed, they, as the familiar graptolite shales, conjure up a vision of widespread anoxic ocean floors. Does this mean, then, a surface skin of oxygenated water resting atop a mostly anoxic water column in the deep oceans, a globe-encircling kilometres-thick dead zone for metazoa? This is a vision from Bosch or – as Alex Page disinterred from a near century-old

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[8] Not *literally*, you understand.

[9] Another memory of those years is the intense discussions with proponents of an expanding Earth. It's an idea that is ingenious but almost certainly wrong, though trying to prove this certainly puts one on one's tectonic mettle.

edition of the *Quarterly Journal* – from the pen of a prescient J.E. Marr, that pioneer of Lake District geology, who imagined 'poisoned water below the 100 fathom-line'. Or perhaps the anoxia was present as patches, drifting just above the sea floor, over zones of upwelling and around expanded oxygen minimum zones, while the oceans were for the most part reasonably ventilated? The distribution and migration of graptolites, and of their taphonomically invisible co-macrozooplankton and rivals for resources – the ctenophores, arrow-worms, jellyfish and such – must have been quite different in each case.

It's invigorating, if more than somewhat unsettling, to be still at the dawn of the science, posing fundamental questions about the basic constraints on communities of sea creatures that haven't a prayer of being answered, this decade or next. What lies behind the perceived strangeness of unfamiliar graptolites? Painting any reasonable depiction of such a deep time canvas seems light years away, still, beyond the merely perplexing question of how more modern taxa migrated, and in the latter one might lump together trans-Panamanian mammals and obscure Slavic minstrels within one category. So much to do, so little time. Best simply to get one's head down and get on with the work. Time to put a favourite sonofossil on the decoder and to draw that next type specimen. It would be nice to finish Folio 3 before the year 2017.

Jan Zalasiewicz

PalaeoMath 101
Groups III: Cluster Analysis

Over the last two essays we've discussed strategies for undertaking the analysis of multivariate datasets that are known to be characterized by a group-level substructure. This covers a lot of what we might need to do in terms of the evaluation of *a priori* group-based hypotheses. But what do we do if we suspect groups may be present in our data, but don't have a very good idea who belongs to which group? If the groups are very obvious we can, of course, run the data through a procedure that assumes the presence of a single group (*e.g.*, PCA, PCoord, Correspondence Analysis) and check the ordination plots. In such cases obvious clusters of data points that account for a high proportion of the sample variance should show up as distinct clouds of points in the space created by the first few eigenvectors of the similarity matrix. But this will not always be the case, especially if the group-level structure is diffuse and/or swamped by other sources of variation. In such instances the standard approach would be to employ a formal 'cluster analysis'.

Cluster analysis is one of the oldest approaches to multivariate data analysis, tracing its origins back at least to the 1930s and 40s. It really came into its own, though, in the 1950s and 1960s when taxonomists began using numerical algorithms coded for processing on (the then new) computers to make the process of creating a classification more objective. This led to creation of the school of numerical taxonomy. Cluster analysis was the data analysis method of choice for most numerical taxonomists (see Sokal and Sneath 1963; Sneath and Sokal 1973). It is also one of the most widely used of all multivariate data analysis procedures, with a solid literature of applications in fields ranging throughout the natural and social sciences and even on to areas such as market research, advertising and bioinformatics. On the face of it then, cluster analysis has an impressive history. Nevertheless, I must admit to finding the entire subject very *ad hoc*, lacking in organized development, and frustrating. So, with that personal caveat, and with a firm commitment to try not to let my own biases show through (too much), let's begin.

The best way to begin, of course, is with an example. Let's return to our old friends the trilobites and select a small subset of the previous data to illustrate some basic principles (Table 1).

Table 1. Trilobite data

Genus	Body Length (mm)	Glabella Length (mm)	Glabella Width (mm)
Acaste	23.14	3.50	3.77
Cheirurus	31.74	9.33	12.11
Phacops	27.23	5.30	8.19
Rhenops	55.94	19.00	13.10
Trimerus	89.43	23.18	21.52
Minimum	23.14	3.50	3.77
Maximum	89.43	23.18	21.52
Range	66.29	19.68	17.75
Mean	45.50	12.06	11.47
Variance	765.45	74.56	43.44

Since we wish to combine these taxa into groups based on the data we have collected (in this case distances between corresponding features of the body), our first task is to decide on a quantitative index we can use to summarize similarities and differences among these genera. These distances are represented by real numbers, so we'll need to use an index designed to take advantage of fractional units. Since we are interested in relations between objects (= the *Q*-mode problem), the most obvious choice would be to calculate a 'straight-line' or Euclidean distance between genera in the space formed by the three measured variables. Either of the standard formulations of the Euclidean distance are the typical choices, the standard Euclidean distance …

$$d_{ij} = \sqrt{\sum_{k=1}^{p} \left(x_{ik} - x_{jk}\right)^2} \qquad (12.1)$$

… or the squared Euclidean distance:

$$d_{ij} = \sum_{k=1}^{p} \left(x_{ik} - x_{jk}\right)^2 \qquad (12.2)$$

In both equations i represents the i^{th} specimen, j represents the j^{th} specimen, and p represents the total number of variables measured on each specimen. The only difference between these two indices is that the former produces a result whose units are the same as those of the original variables whereas the latter produces a result in squared units. Obviously this assumes all variables have been measured in the same units, which is the case for our data.

But there is a further decision we must make. Note the range of the body length variable is many times the magnitude of the lengths of the glabellar variables. This difference means that a greater proportion of the distance between genera will be due to differences in the body length than between glabellar length or width. Accordingly, the body length variable will 'count' more in expressing differences between genera than the glabellar variables.

As we've seen before, this forces us to decide whether differences between variables are part of the signal we're trying to assess, or a nuisance factor. While most texts would recommend standardizing the variables to remove between-variable magnitude differences, my recommendation is to think more closely about this. If all variables are measured in the same units (in this case mm) differences between variables cannot always be regarded as artificial. In such cases the differences—and so the variables—should be maintained in their original form unless there is a good reason not to do so. If the variable set includes mixed types some of which are intrinsically different in terms of their magnitude than others, or if the difference between variables is not part of the hypothesis you wish to test (*e.g.*, you're interested in a size-free analysis of similarity), it's best to standardize the variables as this operation forces them to account for the same proportion of overall sample variance. For our example we'll leave the variables in their raw form and use the Euclidean distance index (eqn. 12.1). Table 2 shows these distances for the Table 1 data.

Table 2. Euclidean distance matrix.

	Acaste	*Cheirurus*	*Phacops*	*Rhenops*	*Trimerus*
Acaste	0.00	13.32	6.29	37.46	71.39
Cheirurus	13.32	0.00	7.20	26.08	60.07
Phacops	6.29	7.20	0.00	32.18	66.07
Rhenops	37.46	26.08	32.18	0.00	34.78
Trimerus	71.39	60.07	66.07	34.78	0.00

By now the concepts behind, and overall form of, a *Q*-mode distance matrix should seem familiar. If not, go back and read the previous columns on *r*-mode and *Q*-mode analyses. There are other distance measures we could have used. The raw Euclidean distance ignores the between-variables covariance structure. If the covariance structure can be estimated to a reasonable degree of certainty, the Mahalanobis distance might be a better choice (see the Groups I column). Similarly, L. W. Penrose (1953) proposed a distance measure that could be used if multiple specimens from each genus were available. If we assume for a moment that Table 1 represents a matrix of means rather than individual measurements, the Penrose and Mahalanobis distance matrices for the example data are shown in tables 3 and 4.

Table 3. Mahalanobis distance matrix.

	Acaste	*Cheirurus*	*Phacops*	*Rhenops*	*Trimerus*
Acaste	0.00	2.83	1.51	2.56	2.74
Cheirurus	2.83	0.00	1.47	2.55	2.73
Phacops	1.51	1.47	0.00	2.56	2.27
Rhenops	2.56	2.55	2.56	0.00	2.78
Trimerus	2.74	2.73	2.27	2.78	0.00

Table 4. Penrose distance matrix.

	Acaste	*Cheirurus*	*Phacops*	*Rhenops*	*Trimerus*
Acaste	0.00	0.72	0.17	2.21	6.06
Cheirurus	0.72	0.00	0.20	0.68	2.99
Phacops	0.17	0.20	0.00	1.38	4.48
Rhenops	2.21	0.68	1.38	0.00	1.11
Trimerus	6.06	2.99	4.48	1.11	0.00

A careful inspection of tables 2–4 will show that the various estimates of between-genus similarity are quite different. Which distance index is best? That tends to be a matter of opinion. For this very simple dataset I'd argue the original Euclidean distance matrix makes the fewest assumptions about the data. But if we were analyzing a larger dataset, the choice might not be so clear. Moreover, these are the only three alternative indices. We don't have the space to go into all of the various distance measures that have been devised, but exotica such as the Bhattacharya distance, Bray and Curtis distance, Canberra distance, Gower distance, Chebychev distance, Chi-square distance, squared-chord distance, geodesic distance, Manhattan distance, *etc*. would all be potential alternatives. And that's just for the distance indices. If we were looking for an index that represented similarity as an angle between the vectors representing specimens in the variable space[1] we'd have another range of choices. By the same token, if we had a data matrix composed of binary, state codes (*e.g.*, present/absent, large/small, simple/complex) we'd have another very extensive set of association indices that could be used to express similarity based on the proportion of shared presences and, in some cases, shared absences (*e.g.*, Jaccard Index, Dice Index, Otsuka Index). There are also probability-based indices, indices for use with proportions, the list is virtually endless. To be honest, any of these similarity measures could also be used as the basis of a principal coordinates or *Q*-mode factor analysis (see the columns covering those methods). But in practice you simply don't see as much variation in the manner in which inter-object or inter-variable similarity is expressed in the theoretical development, or practical application, of these approaches compared to cluster analysis.

Once you've settled on an index you feel is appropriate to gauging similarity among your specimens, your next decision involves a choice of overall clustering strategy. Almost every textbook treatment offers a different taxonomy of clustering approaches. I'm going to restrict my discussion to the two most frequently used approaches: hierarchical agglomerative clustering, and partition-based clustering.

Hierarchical agglomerative clustering is a classic top-down approach. At the beginning of the process each specimen is regarded as its own unique group. Then, as the level of similarity is progressively lowered, the separate groups are allowed to merge and the agglomeration history tracked. The procedure ends when all specimens have been collected into a single group.

The simplest hierarchical agglomerative clustering method is called *single linkage* or *nearest neighbour* analysis. The single linkage agglomeration history for the matrix in Table 2 is shown in Table 5.

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[1] This is the approach we'd use if we had mixed variable types in our data matrix.

Table 5. Cluster formation sequence.
Abbreviations: ***A – Acaste, C – Cheirurus, P – Phacops, R – Rhenops, T – Trimerus***

Distance	Grouping History
0.00	*A,C,P,R.T*
6.29	*(A,P),C,R,T*
7.20	*(A,P,C),R,T*
13.32	–
26.08	*(A,P,C,R), T*
32.18	–
34.78	*(A,P,C,R,T)*
60.07	–
66.07	–
71.39	–

Under single-linkage cluster analysis the values in the similarity/dissimilarity matrix are placed into rank order either from greatest to least (similarity) or least to greatest (dissimilarity, left column) and the objects or specimens joined into groups based on the greatest similarities between them (right column).

Stepping through this analysis, after 0.00 level, at which level all genera exist as discrete groups, the next greatest similarity value is 6.29. This is the distance between *Acaste* and *Phacops* (Table 2). So, at this level these two genera are joined to form a single group symbolized by the parentheses in the right-hand column of Table 5. Moving down the similarity value list we find 7.20, which is the level of distance-based similarity between *Cheirurus* and *Phacops*. Since *Phacops* is part of the *Acaste–Phacops* group, *Cheirurus* joins that group at the 7.20 level. The fourth smallest distance value is 13.32, which links *Acaste* and *Cheirurus*. However, since these two genera were already linked into the same group in the previous step the group structure is maintained through this level. Next there is a big decrease in the set of similarity values to 26.08 where *Rhenops* joins the *Acaste–Phacops–Cheirurus* group by virtue of its similarity with *Cheirurus*. This structure is also maintained through the 32.18 similarity mark that links *Rhenops* with *Phacops*. Lastly, *Trimerus* joins the main cluster at a distance level of 34.78 through its similarity with *Rhenops*. At this point all genera have joined the same group, so the analysis is complete. Graphically the structure of the Euclidean distance matrix under single linkage cluster analysis can be summarized by a tree-like diagram called a *dendrogram* (Fig. 1).

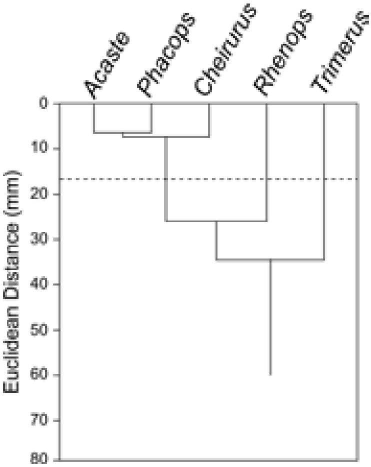

Figure 1. Single linkage dendrogram for the five-genus example trilobite data (see tables 1 and 2).

While dendrograms summarize the structure of similarity matrices, by themselves they don't tell you where the cluster or group boundaries are. What they do tell you is that, at a distance-similarity value 0.00, there are five groups and at 34.78 there is only one. A dashed line has been drawn in the middle of the greatest step between distance-similarity values that resulted in consolidation of the structure. This gap forms a natural subdivision in the distance data. With respect to these data this level corresponds to a 'morphological gap' of some type. Thus, it would make sense to set our grouping criterion at this level, in which case three clusters would be recognized: *Acaste–Phacops–Cheirurus, Rhenops,* and *Trimerus*. This level-based approach to interpreting dendrograms is used throughout agglomerative, hierarchical clustering procedures, with the level itself being referred to as the *phenon line* by numerical taxonomists and the *cut line* by statisticians. The problem, of course, is that the number of groups identified depends on where the phenon line is drawn, but there are no widely applied rules to guide this choice. The gap approach used above is one way to approach the issue of phenon line location. There are others (see below).

Generally speaking this result accords well with our data (see Table 1). *Acaste*, *Phacops* and *Cheirurus* are all small individuals—in our dataset, at least—with the former two being noticeably smaller than the latter. *Rhenops* is over twice as long as these three taxa, though it has a proportionately smaller and decidedly elliptical glabella. *Trimerus* is larger still in overall body length, with a still smaller (proportionately) and circular glabella. Unfortunately, none of these geometric interpretations are evident from the dendrogram itself or from the information output by a cluster analysis (*e.g.*, Table 5). Unlike eigenanalysis-based methods, the results of a traditional cluster analysis usually don't facilitate interpretation of the original data by any means other than *post hoc* comparison.

Of even more concern, however, is the issue of distortion of the data represented by the cluster analysis result—the dendrogram. Because of the rules used to create the clustering history and dendrogram, important information about the structure of similarities among taxa is lost. Figure 1 implies that the distance between *Cheirurus* and *Acaste* is the same as the distance between *Cheirurus* and *Phacops*. This is not the case (see Table 2). Indeed, *Cheirurus* is almost twice as close (= similar) to *Phacops* as to *Acaste*. By the same token, *Rhenops* appears to be just as similar to *Cheirurus* as to *Acaste* and *Phacops*. This is also incorrect.

A measure of the amount of distortion present in the cluster analysis result can be derived by comparing the actual similarities to those implied by the dendrogram. For the trilobite data this comparison is illustrated in Table 6.

Table 6. Cophenetic distance matrix (see text for discussion).

	Acaste	*Cheirurus*	*Phacops*	*Rhenops*	*Trimerus*
Acaste		7.20	6.29	26.08	34.78
Cheirurus	13.32		7.20	26.08	34.78
Phacops	6.29	7.20		26.08	34.78
Rhenops	37.46	26.08	32.18		34.78
Trimerus	71.39	60.07	66.07	34.78	

Here the matrix's lower diagonal contains the Euclidean distance values (Table 2) observed in the raw data of Table 1. The upper diagonal contains those distances implied on the basis of the single-linkage dendrogram (Fig. 1). Numerical taxonomists refer to these implied values as the cophenetic values. This relation can also be expressed as a scatter diagram (Fig. 2) and summarized by calculating the correlation between the observed and implied distance values.

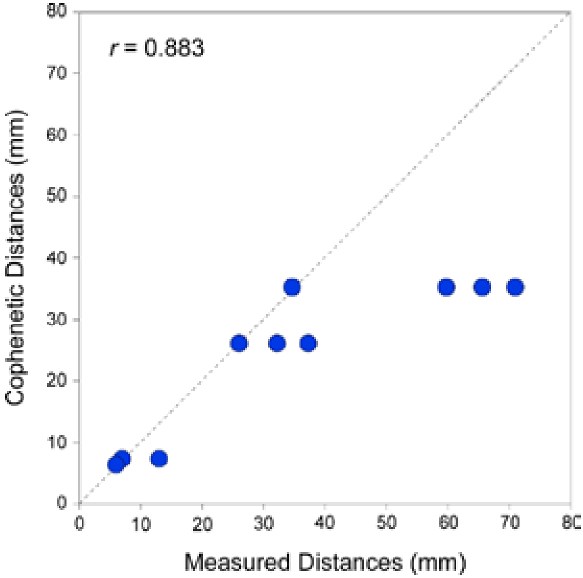

Figure 2. Distortion induced by a single-linkage cluster analysis of the five-genus example trilobite data. Dashed line represents model of perfect correlation.

In the context of a taxonomic cluster analysis this correlation is usually—and misleadingly—termed the 'cophenetic correlation coefficient' despite the fact that it is calculated using the standard Pearson product-moment formula. For our example analysis the level of distortion is substantial and most pronounced at the higher end of the distance scale—differentially affecting those data that are most important for inferring the deep structure of similarity relations.

Fortunately (or not as we shall see), single linkage isn't the only clustering game in town. The logical complement to single linkage is *complete linkage* or *furthest neighbour* linkage in which links are set at the level of the furthest or most dissimilar comparisons. Table 7 shows the linkage history for a furthest neighbour analysis of the example trilobite data. Note that the first two genera (*Acaste* and *Phacops*) join together at the same distance as before (6.29). This is because there is only one similarity value involved. After this, though, the order and level of group joining is set by the largest (instead of the smallest) similarity value (*e.g.*, *Cheirurus* joins the *Acaste–Phacops* group at a distance of 13.32 instead of 7.20 (see Table 2).

Table 7. Cluster formation sequence using the complete-linkage approach. Abbreviations as in Table 5.

Distance	Grouping History
0.00	*A,C,P,R.T*
6.29	*(A,P),C,R,T*
13.32	*(A,P,C),R,T*
34.78	*(A,P,C),(R,T)*
71.39	*(A,P,C,R,T)*

The corresponding dendrogram and cophenetic correlation analysis are provided in Figure 3.

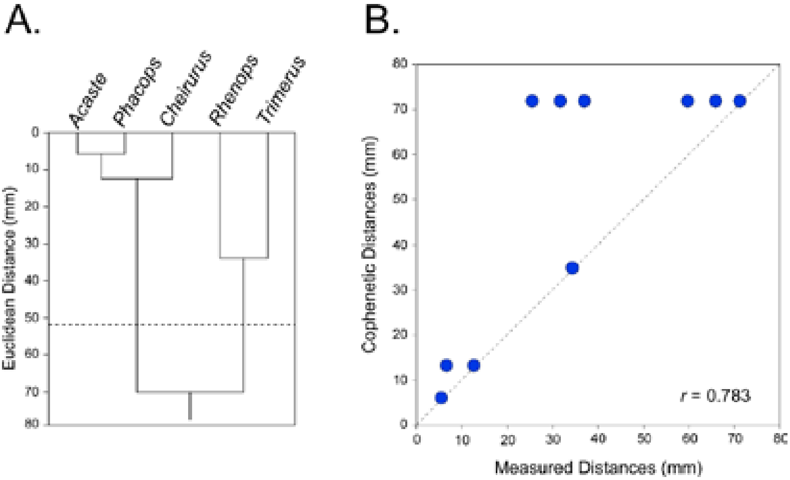

Figure 3. Results of a complete-linkage cluster analysis of the example trilobite data. A. Complete-linkage dendrogram. B. Associated cophenetic correlation scatterplot. Compare with figures 1 and 2.

Note the change in the structure of apparent distance relations among these taxa. Under complete linkage, *Rhenops* and *Trimerus* are seen as forming a locus of similarity of their own, though as before, whether this substructure becomes part of the interpretation depends on where the phenon line for group recognition is located. If we use the same criterion as for the single-linkage analysis, the *Rhenops–Trimerus* cluster would be recognized. Unfortunately, the level of distortion for this analysis is even higher than for the single linkage example, with the greatest distortions, once again, occurring at the deeper levels of the hierarchy.

In order to overcome the obvious limitations of single-linkage and complete-linkage cluster analysis approaches a variety of alternative agglomerative procedures have been developed. One of the most popular among numerical taxonomists (and palaeontologists) has been unweighted pair-group mean averaging (UPGMA). In most instances UPGMA maximizes the cophenetic correlation coefficient of a cluster analysis and so produces results with minimum levels of distortion (Farris 1969; Sokal and Rohlf 1970). The UPGMA approach does this by attempting to use a greater proportion of the information present in the similarity matrix. Let's work through the procedure as applied to the five-genus trilobite example.

Table 8 shows the linkage history for a UPGMA analysis.

Table 8. Cluster formation sequence using the UPGMA approach. Abbreviations as in Table 5.

Distance	Grouping History
0.00	A,C,P,R.T
6.29	(A,P),C,R,T
10.26	(A,P,C),R,T
31.91	(A,P,C,R),T
58.08	(A,P,C,R,T)

As before, five groups exist at the 0.00 distance level. Also as before, the shortest distance (greatest similarity) exists between *Acaste* and *Phacops* at the 6.29 level. Thus, during the first round of analysis these two genera join to form a group. *Cheirurus* exhibits the next smallest differences, both with *Acaste* and *Phacops* (both now members of the same group). However, the level at which *Cheirurus* joins this group is now set to the average of its distances-based similarity with both members of the group (= [7.20+13.32]/2, or 10.26). In other words, the UMPGA procedure attempts to 'split the difference' between these discrepant levels of similarity and so estimate the level of similarity between *Cheirurus* and the *Acaste–Phacops* group in as unbiased a manner as possible. *Rhenops* is next up, exhibiting a distance of 32.18 with *Phacops*. But in order to estimate its level of similarity with the *Acaste–Phacops–Cheirurus* group we average its similarity with all three of these taxa (=[37.46+26.08+32.18]/3, or 31.91). Finally, *Trimerus* is added to the group at its average distance to the other four genera (=[71.39+60.07+66.07+34.78]/4, or 58.08). The dendrogram determined from the UPGMA clustering history and associated cophenetic correlation plot are shown in Figure 4.

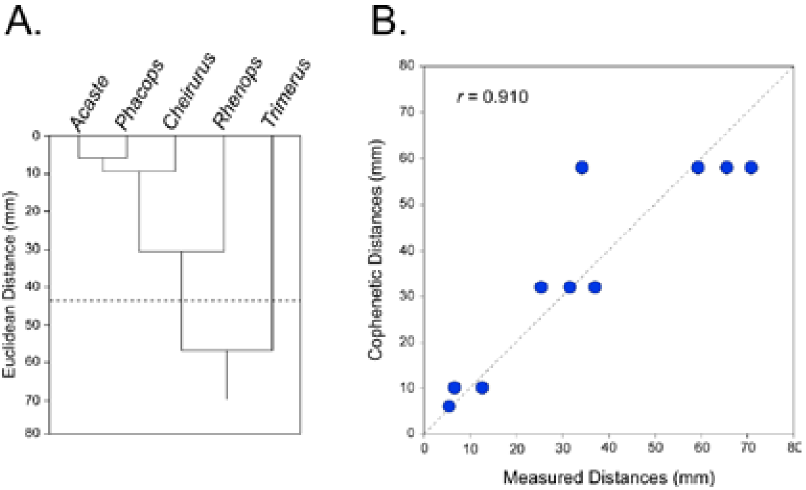

Figure 4. Results of a UPGMA cluster analysis of the example trilobite data. A. UPGMA dendrogram. B. Associated cophenetic correlation scatterplot. Compare with figures 1, 2 and 3.

The distortion resulting from the analysis is still on the large side (*r* = 0.910), but has been improved. Perhaps more importantly in terms of estimating the overall structure of the matrix and the deep structure of the cluster hierarchy, this distortion is now spread evenly across the entire range of distance values. Again, we can locate the phenon line at the level of the greatest morphological gap, in which case two groups are identified. But note even though the pattern of relations between the single-linkage and UPGMA dendrograms (figs 1 and 4A respectively) are identical, placement of the phenon line according to the morphological gap criterion yields different answers. If we changed the phenon-line location rule (*e.g.*, first long branch) the group-recognition result would be identical. Which of these rules is 'best'? Both have their advantages and disadvantages. It is not clear which location rule should be used in this case.

A UPGMA analysis of the entire trilobite dataset (Table 9) is presented in Figure 5. This problem is a bit more realistic in size, though still not too large to trace detailed links between the dendrogram and original data.

Table 9. Trilobite data.

Genus	Body Length (mm)	Glabella Length (mm)	Glabella Width (mm)
Acaste	23.14	3.50	3.77
Balizoma	14.32	3.97	4.08
Calymene	51.69	10.91	10.72
Ceraurus	21.15	4.90	4.69
Cheirurus	31.74	9.33	12.11
Cybantyx	36.81	11.35	10.10
Cybeloides	25.13	6.39	6.81
Dalmanites	32.93	8.46	6.08
Deiphon	21.81	6.92	9.01
Ormathops	13.88	5.03	4.34
Phacopidina	21.43	7.03	6.79
Phacops	27.23	5.30	8.19
Placoparia	38.15	9.40	8.71
Pricyclopyge	40.11	14.98	12.98
Ptychoparia	62.17	12.25	8.71
Rhenops	55.94	19.00	13.10
Sphaerexochus	23.31	3.84	4.60
Toxochasmops	46.12	8.15	11.42
Trimerus	89.43	23.18	21.52
Zacanthoides	47.89	13.56	11.78
Minimum	13.88	3.50	3.77
Maximum	89.43	23.18	21.52
Range	75.55	19.68	17.75
Mean	36.22	9.37	8.98
Variance	346.89	27.33	18.27

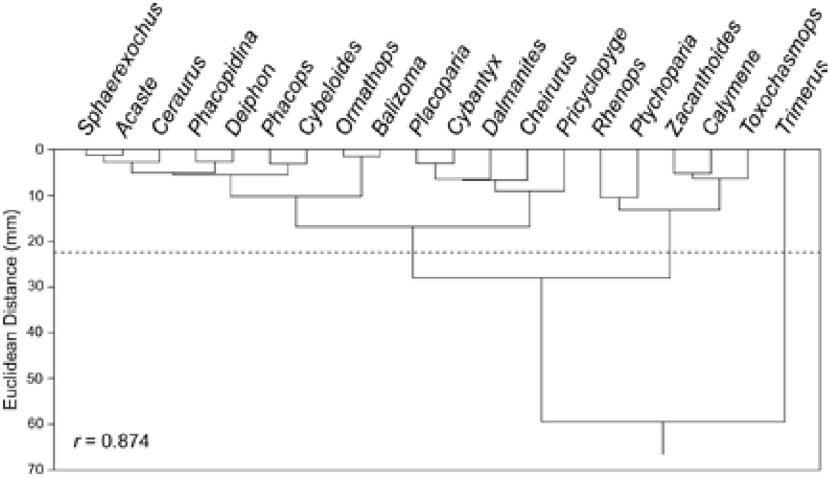

Figure 5. UPGMA dendrogram for the trilobite dataset.

The UPGMA dendrogram for these data shows a profound difference between *Trimerus* and the rest of the genera. This is clearly a reflection of the larger size of the *Trimerus* specimen. If the data had been standardized this difference would not have been as apparent.

Again the number of groups recognized is determined by where we set the phenon line. If we look for natural breaks in the dendrogram (= morphological gaps), and ignore the profound size-related gap between *Trimerus* and the other genera, we could most objectively identify two additional groups (see dashed line on Fig. 5). This distinguishes *Calymeme*, *Zacanthoides, Toxochasmops, Rhenops* and *Ptychoparia* from the remaining genera. But note how I've changed the location rule again. If I apply either the greatest morphological gap rule or first long gap rules (see above) only two groups are identified.

Inspection of Table 9 shows these genera are united in having body lengths in the range of 45–65 mm. The *Trimerus* specimen has a much greater body length and all the rest exhibit body lengths much less than 45 mm. So, the deep structure of the UPGMA dendrogram appears primarily to reflect body length, whereas the higher-level structure reflects differences between relative glabella size and glabella shape. As you can see, for small numbers of taxa and/or small numbers of variables, dendrograms can be interpreted in ways that tell us something meaningful about the data used in their construction. This inspection-based approach becomes much less practical for dendrograms containing large numbers of objects and/or large numbers of variables. For those datasets such clean and compelling interpretations are rare.

Since there are so many different agglomerative hierarchical clustering methods—not to mention similarity–dissimilarity–association indices—it is natural to ask how stable any particular result is. The most straightforward way of approaching this issue is to compare the results yielded by different cluster analysis approaches. Biologists have tended to prefer averaging approaches because these address the issue of similarity matrix distortion. Statisticians have largely focused on other issues, notably 'continuity', which is a shorthand way of saying that 'small changes in the data should result in small changes in the dendrogram'. Under this criterion single-linkage approaches usually perform better than averaging approaches. Figure 6 shows the result of the single-linkage analysis of the Table 9 data.

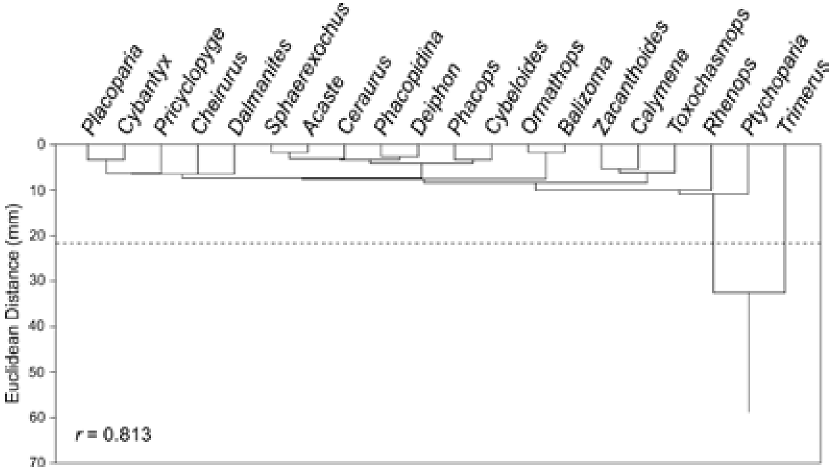

Figure 6. Single-linkage dendrogram for the trilobite dataset.

Obviously this is quite a different and more complex answer than was obtained by UPGMA analysis. Or is it? In many cases the top-level groups are the same, they've just been reordered. *Acaste* still links to *Sphaerexochus* and these two link to *Ceraurus*. But now this group is located in the centre of the dendrogram instead of on the left side. Since the order in which groups are presented has no significance, both the single-linkage and UPGMA patterns are equivalent for these taxa, though the UPGMA analysis links these taxa together at a lower level. This is the expected effect of averaging. The same can be said for the *Placoparia–Dalamanties*, *Ormathops–Balizoma*, and *Zacanthoides–Toxochasmops* groups.

Where these two dendrograms differ is in the manner in which the top-level groups are linked together. In the UPGMA analysis *Rhenops* and *Ptychoparia* are joined with the *Zacanthoides* group before this group joins the combined *Acaste–Placoparia* group. In the single-linkage dendrogram *Rhenops* and *Ptychoparia* chain together to link *Trimerus* to the other genera. *Trimerus*, of course, is the odd genus out in both analyses because of its large body length. What it all boils down to is a difference in the placement *Rhenops* and *Ptychoparia*. But this difference matters in terms of the interpretation. The UPGMA solution indicates that, if we accept *Trimerus* as a 'group', at least two other groups—possibly three—are present in the data. The single-linkage result suggests there is only one.

Which solution is correct? Strictly speaking, they both are in the sense that both are accurate and internally consistent representations of the structure of the distance matrix. They differ in the aspects of that structure they emphasize. Given the radical difference between the deep structure of the two dendrograms, the most well-supported generalized conclusion is that, for these trilobite data, which aspect of the distance matrix structure the analyst ends up emphasizing via their choice of approach makes quite a large difference to the answer obtained. Also recall, our trilobite data are very simple. For datasets containing more variables and/or more objects, the differences between alternative clustering patterns would be expected to increase.

There is another approach to cluster analysis that I need to mention briefly: **partitioning approaches** (sometimes referred to as **divisive** or **arbitrary origin** methods). These are effectively the opposite of agglomerative methods. Instead of beginning with all objects as different groups and tracking the history of their agglomeration as the similarity threshold is decreased, divisive approaches begin with all objects as constituting a single group and track the history of their subdivision as the similarity threshold is increased. Whereas agglomerative approaches are 'top-down', partitioning approaches are 'bottom-up'.

The most popular partition clustering approach is the *k*-means method. Here the user is required to specify the number of clusters known or expected to exist at the outset of the analysis. These are regarded as cluster seeds, and are usually initialized using random numbers scaled so that the seeds fall within the range of the observed data. During the first iteration the similarity between all objects and the seeds is calculated and the object most similar to each seed associated with it to form an initial group. The centroid between each seed group is then calculated and these centroids designated as new seeds. The process then repeats, with the next most similar objects joining the seed groups and so on until all objects have joined a group. At higher levels in the analysis, group joining is controlled by minimization of a group-level descriptor such as the trace of the group's similarity matrix, that matrix's determinant, or the Wilk's λ statistic. Over the course of the iterations the seeds rapidly shift to the true centres of the emerging group clusters since the biasing effect of the artificial seeds diminishes with each iteration. A table of the three-group *k*-means solution for the entire trilobite dataset using the Wilk's λ criterion as the clustering statistic is presented in Table 10.

Table 10: Three-group *k*-means solution (Wilks' λ criterion).

Group 1	Group 2	Group 3
Acaste	*Calymene*	*Ptychoparia*
Balizoma	*Cheirurus*	*Rhenops*
Ceraurus	*Cybantyx*	*Trimerus*
Cybeloides	*Dalmanites*	
Deiphon	*Placoparia*	
Ormathops	*Pricyclopyge*	
Phacopidina	*Toxochasmops*	
Phacops	*Zacanthoides*	
Sphaerexochus		

Once again, note how different this result is from the UPGMA and single linkage dendrograms. The advantage of the *k*-means approach is that more specific grouping hypotheses can be evaluated and that the overall procedure can be performed much more quickly than agglomerative approaches, though given the speed of modern desktop computers this feature only matters for very large clustering problems. The primary disadvantage is that the *k*-means approach tends to produce suboptimal results owing to idiosyncrasies in the random placement of the original seeds. This can be overcome to some extent by using actual objects as seeds, enhancing the specificity of the original hypothesis, but also requiring more be known about the problem at hand than is often the case. Another strategy is to test the result's stability by performing the analysis multiple times using different starting seed values and comparing those results to the original for consistency, though this compromises the time-saving advantage.

So, what can we say about cluster analysis? Some degree of procedural variation exists for all the methods we've discussed to date. Usually these variants have focused on the manner in which the data are prepared (*e.g.*, unstandardized, standardized, transformed) and type of similarity matrix used to quantify relations between variables and/or objects. However, once these decisions have been made, regression analysis, principal components/coordinates analysis, factor analysis, correspondence analysis, partial least squares analysis, and discriminant analysis all settle down to the application of standardized procedures (*e.g.*, mostly forms of least squares analysis) whose statistical characteristics are well known. Cluster analysis differs because, in addition to the data type and similarity index variants, broad variation exists in the procedures used for undertaking the data analysis.

In addition, the statistical characteristics of these procedural variants are, by and large, not well known. This makes selection of the appropriate procedure for any particular dataset and data analysis situation much more difficult. Once a result is obtained, its interpretation is also complicated by the fact that there is no widely agreed method whereby the phenon/cut line can be placed in agglomerative dendrograms, and by the instability of partition approach results. Moreover, the results of a cluster analysis do not lend themselves to efficient and nuanced interpretation in terms of the original variables in the manner in which eigenvector-based methods do.

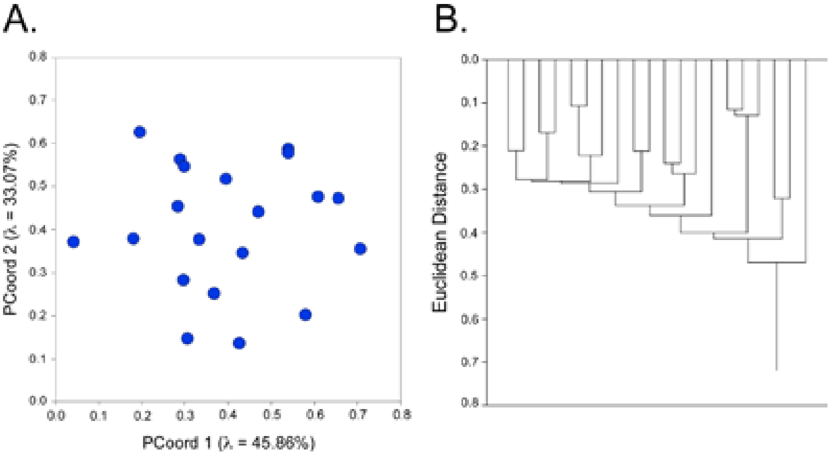

Figure 7. Quantitative analysis of a 20 x 3 table of random numbers. A. principal coordinates analysis result. B. Single-linkage cluster analysis result (distance matrix). Note that by forcing these random data to be represented by a hierarchical model the cluster analysis dendrogram displays much more apparent structure than the non-hierarchical PCoord ordination plot. While this random dendrogram differs from previous data-based patterns in the number of long terminal branches, this will not always be the case, especially for small datasets. Also, because of the statistical properties of eigenanalysis it is easier to test the PCoord result for the null hypothesis of random variation than it is to test the cluster analysis result.

Last, but by no means least, most cluster analysis methods fit a hierarchical model of inter-object similarity to the data even though there is nothing inherent in the structure of most similarity matrices that implies such a structure. Eigenvector-based methods also represent the structure of similarity matrices, but do not express that structure in terms of a hierarchy. Cluster analysis methods tend to adopt this approach because it prevents objects from being assigned to more than a single group. The upside of this is that, provided your data adequately capture the hierarchical structure you suspect is present, and provided the hierarchical structure is a clear and dominant feature of those data, cluster analysis will likely find it. The downside is that cluster analysis will find a visually compelling hierarchy in any dataset regardless of whether the hierarchical signal is actually there—even in random data (Fig. 7).

I hope I haven't been *too* hard on cluster analysis. Like all data analysis methods, it has its place and can be very helpful when applied intelligently and with due caution. In this context the reader is well advised to remember that Cormack's (1971) observation about cluster analysis—that it is not a satisfactory alternative to clear thinking—actually extends to all numerical data analysis procedures.

There was a time when it was hard to page through an issue of the top half dozen systematics and/or palaeontology journals and not see a dendrogram. Not true now. Indeed, I'd say eigenvector-based methods are now more widely used by palaeontologists for routine data analysis than clustering methods. Regardless, cluster analysis lives on in the phylogenetics literature in the guise of numerical cladistics, which was derived directly from the cluster analysis procedures developed by the phenetic school of numerical taxonomy (see Sokal and Sneath 1963; Sneath and Sokal 1973). Indeed, these books remain two of the most comprehensive treatments of cluster analysis, especially for biologists and palaeontologists. Other, more recent references that focus on statistical issues, but are readable by non-mathematicians, include Kauffman and Rousseeuw (2005) and Fielding (2007).

In terms of computer programs, cluster analysis is such a long-standing and popular technique that it is rare to find a commercial multivariate statistical package that doesn't include it in some form. These range from inexpensive plug-ins for MS-Excel (*e.g.*, UNISTAT, XL-STAT, StatistiXL) to sophisticated stand-alone packages. A variety of older books on statistical analysis also come with cluster analysis software (*e.g.*,Davis,1981; Backer 1995; usually for DOS operating systems). As a last—or maybe as a first—resort, there are a large number of freeware and shareware cluster analysis applications available for download over the Internet.

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<http://www.palass.org/modules.php?name=palaeo_math&page=1>

Meeting REPORTS

Computer Aided Visualisation in Palaeontology

Imperial College, London *13 September 2007*

On a bright September morning, after the last minute frenzy of poster placement (to help guide attendees through the muddle of refurbishments taking place within Imperial's Earth Science and Engineering department), I sat with conference organisers Imran Rahman and Mark Sutton in nervous anticipation of the arrival of the first delegates for the inaugural meeting on Computer Aided Visualisation in Palaeontology. Since formal registration was not a requirement for the day's proceedings and we had only an estimate of expected numbers (though it must be said – this was much higher than was originally envisaged), the sight of over fifty delegates (many still slightly ruffled by their battles with our capital's rush-hour mayhem) filing into the lecture room that was to accommodate the symposium was a very welcome one. The inflated numbers not only marked an organisational and marketing triumph but also the importance of this meeting as a new found and very much needed forum for the discussion of recent developments in computational methods assisting the three-dimensional visualisation and analysis of fossil material. This theme is clearly of increasing importance to the process of analysing various palaeontological problems, as evidenced by the growing frequency with which beautifully reconstructed three-dimensional fossil models are now encountered at various palaeontological conferences.

After a welcoming address from Prof. Martin Blunt (Head of Imperial College's Earth Science and Engineering Department), who emphasised his delight that Imperial should play host to this meeting – the first of its kind – in a field of growing relevance not only within the palaeontological community but also in an ever expanding number of geological arenas, the main body of the meeting got under way.

Things were kicked off by conference co-organiser **Imran Rahman** (Imperial College), who introduced an enigmatic group of marine fossils (the mitrates) that are undergoing an anatomical re-analysis utilising X-ray microtomography in order to resolve more clearly the group's morphological characters and subsequently their phylogenetic affinities. The case in point not only beautifully illustrates the importance of three-dimensional visualisation in affording considerably more detailed morphological descriptions, but also provided one of the most entertaining photo opportunities of the symposium, whereby to fully appreciate the spectacular images of mitrate anatomy (produced from manual editing of the X-ray data) the obliging audience simultaneously donned 3D glasses (sadly this moment was missed, in part due to the lack of a camera but also in reluctance to blind the completely transfixed audience).

Next up was **Martin Dawson** (University of Leeds), who drew our attention to the virtues of neutrons for three-dimensional imaging in palaeontology, with several noteworthy demonstrations of the technique, both from the results of imaging fossil material (including the reconstruction of an ancestor of the Monkey Puzzle tree family) and material of a more eclectic nature, including a bullet, a BMW engine and a coffee machine. After a momentary technical glitch (which was remedied almost instantly, as would be expected in a room filled with palaeontology's computer whizzes) **Norm MacLeod** (NHM) rounded off the first session of the day with his musings on what can be done with the three-dimensional information after you have enjoyed the "pretty pictures" in order to extract the optimal level of detail from the data. Norm showed that via the employment of eigensurface analysis, a rigorous and systematic approach to the scrutiny of morphological disparity within three-dimensional datasets may be permitted.

After a short break in which delegates, especially those who had arrived on early trains, were furnished with a much needed caffeine hit, the enthusiastic crowd was ready and eager to begin the start of the day's second session. **Neil Gostling** (University of Bristol) began this session with the first of a number of talks highlighting the benefits and versatility of synchrotron radiation for palaeontological imaging. **Mehran Moazen** (University of Hull) followed with a presentation on musculoskeletal modelling, whereby an anatomically accurate three-dimensional computational model of a *Uromastyx* skull was developed. Reasonable mechanical properties were assigned to this dataset in order to predict skull loading and musculature movements via finite element analysis of the jaw structures.

Sue Rigby (University of Edinburgh) considered the use of three-dimensionally accurate morphological models (produced using X-ray microtomography) to help in the analysis of computational fluid dynamics. In this case Sue was interested in the hydrodynamic properties of several graptolite species as a proxy for their environmental tolerances. Although she had previously tried to develop experimental models using "cling film and string", placing these models in wind tunnels to simulate hydrostatic flow, this method was far too simplistic to warrant any viable findings. As such X-ray microtomographic datasets were produced that could be fed into computational fluid dynamic programs in order to accurately image the hydrodynamic flow tolerances around three-dimensional spatial volumes representing various graptolite forms. In her findings from this work Sue uncovered a trend that bucked the ideas of all previous graptolite workers, in that those species with simple triangular spines (theca) produce a greater perturbation of the hydrodynamic flow than those with more complex hooked theca, therefore negating the one supposed theory that those species with hocked theca had become specialised for high flow turbidity.

Mark Sutton (Imperial College) took up the pre-lunchtime slot to extol the virtues of POT (physical-optical tomography) to the transient bemusement of the attentive audience. Unlike the techniques used to assess three-dimensional morphology up to this point, Mark's POT procedure was inherently destructive in nature, thus ruling out this method for some rare fossil specimens and rendering it seemingly less favourable than non-destructive alternatives. However, as was rightly pointed out in this presentation, in many circumstances POT provides far greater contrast optically than any form of X-ray data, and has the added advantage of allowing reconstructions to be made from any kind of serial slice data found in the historical record, making it in some situations the preferred method from which to render three-dimensional anatomical models.

After lunch the symposium reconvened to hear **Jonathan Antcliffe** (University of Oxford) demonstrate how high resolution laser scanning methods are being utilised in conjunction with serial montage techniques to image the often problematic low relief morphologies of the Ediacara biota (a technique that doubles as a means of conservation). This allowed the identification of various ontogenetic growth stages within specimens, ultimately contributing to a renewed understanding of the evolution of generative zones and the means by which the

Ediacara are thought to grow, *i.e.* by the addition of new modules rather than the inflation of existing ones. **Karl Bates** (University of Manchester) enlightened us with his insights into the various palaeontological applications of the Light Detection and Range (LiDAR) imaging technique, including its use in exploring the three-dimensional geometry of fossil dinosaur track-ways (from which kinematic models of locomotive foot movement can be rendered) and the digitisation of *in situ* museum-based theropod skeletal mounts, from which three-dimensional scale models can be constructed that may serve as a base to be integrated into various studies of theropod anatomy. Karl also included some truly impressive examples of digital outcrop models (yet a further user of the LiDAR technology), from which virtual field studies and learning aids can be manufactured.

As the afternoon progressed steadily onwards, **Emily Rayfield** (University of Bristol) was next up to the mark with a critical analysis of the reliability of the results of finite element analysis (FEA) when examining stresses and strains within fossilised skeletal remains. Through her work on validating finite element models on extant ostrich jaws, Emily was confident to surmise that although various assumptions must be made when undertaking FEA (*e.g.* the mechanical properties given to each individual area, or voxel, of the three-dimensional model), the patterns of strain orientation predicted seem to hold up to rigorous scrutiny; however the actual values forecast in the most part remain somewhat unrealistic.

Paddy Orr (University College Dublin) closed the day's penultimate session with a further example of the use of synchrotron-radiation X-ray tomography and its value as a tool from which to render three-dimensional models. Aoife Braiden's work on rare, non-bio-mineralised, Triassic arthropods of south-west England formed the basis of this talk, which served to highlight the importance of synchrotron radiation not only as a means by which to assess and reconstruct three-dimensional models of the shrimp's internal and external anatomy, but also as a tool from which important compositional information can be gleaned, based on the distribution of recognisable authigenic mineral phases preserved within the synchrotron-radiation data.

Following the afternoon break, which afforded many the opportunity for a perusal of the several excellent poster presentations on display, the meeting continued with a European flavour, due to the unfortunate cancellation of Phil Manning's talk scheduled to take place in this session (Phil was by now stuck somewhere on a flight that had been severely delayed). **Christian Neumann** (Humboldt University of Berlin) initiated our continental double-header with his comparison of neutron-, micro- and synchrotron-computed tomography in the visualisation of echinoderm symbiosis. Since this type of interaction is rarely preserved in the fossil record, Christian required a means by which to attain the maximum morphological data from these endosymbiont fossils, so all three of the non-destructive methods of rendering fossil data into three-dimensional models had been used and compared. Christian's findings indicate that each method has various drawbacks and advantages, but in general neutron-tomography offered the least resolution and highest level of artefacts in each of the endosymbiont fossils examined. However, since each of the methods of visualisation can be considered complementary, the greatest level of detail was found where all three methods were used simultaneously.

The final talk of the day was given by **Daniel Mietchen** (Friedrich Schiller University Jena), a physicist at heart, and seemingly somewhat reluctant to present his findings to a palaeontological crowd for fear of making an omission symptomatic of an "outsider". Nevertheless, Daniel delivered an astute account of a further method that may be used to generate three-dimensional reconstructions of fossil material: Magnetic Resonance Imaging (MRI). This method is dependent on a hydrogen signal from water trapped within the crystal matrix of the sample, and has been found effective in imaging a range of fossil specimens including belemnite guards, crinoids and silicified conifer cones. Since both X-ray CT scanning techniques and MRI techniques image different components, Daniel – much like Christian – sees the various non-destructive three-dimensional imaging techniques as complementary and mutually reinforcing, providing the most detailed morphological models when used conjunctively.

Mark Sutton closed the symposium by thanking the speakers for a day of excellent talks and asked for an indication as to whether the meeting should become an annual affair; the response was a unanimous yes and there were even tentative offers from Bristol and Manchester to host the event in 2008 and 2009 respectively.

Finally, the action moved on to the Queens Arms, where delegates mused over the day's proceedings. Seemingly, it was thought by all a thoroughly enjoyable meeting with excellent and stimulating presentations throughout. The newly instituted one-day symposium clearly achieved its initial aim of bringing together those working on all aspects of the three-dimensional reconstruction of fossil material, from researchers interested in the applications of new techniques for 'virtual palaeontology' to those involved in their development, with a major emphasis placed on the presentation of new results and innovative methods.

On behalf of the attendees I would like to thank all those who made the meeting successful, in particular Imran Rahman and Mark Sutton for their excellent efforts in co-ordinating and establishing this new symposium. Thanks must also go to The Palaeontological Association for their sponsorship of the event, enabling the subsidy of transport costs for students, making the attendance by so many young researchers possible.

Zoe Wickens
Imperial College, London

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Please find below a list of known meetings from other bodies. Help us to help you! *Send announcements of forthcoming meetings to:* Meetings co-ordinator (<**meetings@palass.org**>). The Palaeontological Association Future Meetings website is updated regularly; it is at <**http://www.palass.org/modules.php?name=palaeo&sec=meetings&page=55**>.

International Conference on Geology: Indian Scenario and Global Context

Kolkata, India *January 7 – 11 2008*

The conference is a part of the Platinum Jubilee celebration of the Indian Statistical Institute to be held during 2007–2008, which is also the 50th year of the establishment of the Geological Studies Unit in this Institute. The conference aims to provide a platform for interaction between Indian geologists and the global geological fraternity.

The conference will be focused around Precambrian geology of cratons and orogenic belts, Proterozoic and Gondwana basin studies, Gondwana and related vertebrate faunas, alluvial depositional systems, and quantitative analysis of geological data and numerical simulation. The conference will be held at the Indian Statistical Institute, Kolkata, India.

Session I: Quantitative Analysis and Numerical Simulation in Earth Science
Session II: Precambrian Terranes and Tectonics
Session III: Evolution and Diversity of Late Palaeozoic and Mesozoic Terrestrial Vertebrates
Session IV: Evolution and Diversity of Late Palaeozoic and Mesozoic Terrestrial Vertebrates
Field workshop 1:
Geo-traverse across the Eastern Ghats Belt, adjoining terranes and the South Indian craton
Field workshop 2:
Sedimentology and vertebrate palaeontology of the Satpura Gondwana succession, central India

Meeting Contact

Prof. S. Bhattacharya, Geological Studies Unit, Indian Statistical Institute, 203, B. T. Road, Kolkata-700108, India
E-mail: <**gsu2008@isical.ac.in**> or <**dgsu50.isi75@gmail.com**>
Telephone: +91-33-25753150, +91-33-25753157
Fax: +91-33-2577-3026
Meeting website <**http://www.isical.ac.in/~gsu2008**>.

8th International Congress on Rudists (IRC 8)

Izmir, Turkey *23 – 25 June 2008*

The meeting will be held at the Dokuz Eylul University-Izmir, and dedicated to Turkish rudist specialist Necdet Karacabey-Öztemür who made very valuable palaeontological studies on the rudists of Turkey. The theme of the congress is “Cretaceous Rudists and Carbonate Platforms”.

The congress includes major sessions and field trips as follows:

A Major sessions

1 Palaeogeography and Depositional Environments of Cretaceous Carbonate Platforms

2 Origins, Events and Demise of Rudist Palaeocommunities

3 MacGillavry session: Taxonomic and Phylogenetic Studies in Preparation for the Revision of Rudist Section in the Bivalvia Treatise (organization by P.W.Skelton)

B Field Trips

- Pre-meeting field trip (1): Campanian–Maastrichtian rudist-bearing mixed siliciclastic–carbonate transgressive–regressive system tracts of the eastern and southeastern Anatolia: Faunal correlation, depositional facies and palaeobiogeographic significance.
- Post-meeting field trip (2): Rudist-bearing marbles of the metamorphic Menderes Massif and the Upper Cretaceous rudistid limestones of the Bey Da_lar? (western Taurides) carbonate platforms.
- Post-meeting field trip (3): Lower Cretaceous rudist faunas from the Zonguldak region, western Pontides (northern Anatolia).

The presentation and examination of the rich rudist material collected by Dr Sacit Özer (DEU-Izmir) from the Pontide belt (northern Anatolia), the Anatolian and Arabian platforms (central-eastern and southeastern Anatolia), metamorphic Menderes Massif and western and central Tauride platform will be available during the meeting at the congress centre.

The congress will also contain effective social events such as selected historical and touristic regions and Turkish folkloric activities.

For more information, please consult the meeting's web site at <**http://web.deu.edu.tr/irc8/**>, or contact the chairman of the organizing committee at <**sacit.ozer@deu.edu.tr**> or the secretary at <**bilal.sari@deu.edu.tr**>.

International Federation of Palynological Societies

Bonn, Germany *August 2008*

The next International Palynological Congress will be in August 2008, in Bonn (Germany). For further details refer to <**http://www.geo.arizona.edu/palynology//ifps.html**>.

The Second International Congress on Ichnology

Cracow, Poland *1 – 5 September 2008*

Following the successful First ICI, held at Trelew, Argentina in 2004, number 2 is being organized in Europe. Papers are invited on all subjects ichnological, including bioturbation, bioerosion, ichnofacies and ichnofabrics, leaf mines, coprolites, ichnotaxonomy and fringe areas. Field trips to the Carpathian and Holy Cross Mountains will be included. Intending participants are asked to visit the web page and to pre-register at <**http://www.uj.edu.pl/ING/ichnia08/**>.

For further information, please contact Alfred Uchman at <**alfred.uchman@uj.edu.pl**>.

Cluj-Napoca, Romania, e-mail <**sorin@bioge.ubbcluj.ro**>.

Mike Kaminski, UCL, e-mail <**m.kaminski@ucl.ac.uk**>.

8th International Workshop on Agglutinated Foraminifera

Cluj-Napoca, Romania *September 7 – 13 2008*

The Grzybowski Foundation and the Department of Geology, Babes-Bolyai University are pleased to announce the dates of the next International Workshop on Agglutinated Foraminifera. The workshop is open to all participants interested in the taxonomy, ecology, evolution and stratigraphy of the Agglutinated Foraminifera, and follows workshops previously held in Amsterdam, Vienna, Tübingen, Kraków, Plymouth, Prague, and Urbino over the last 27 years. The workshop will consist of three days of technical sessions, followed by a field excursion in the spectacular Transylvanian Basin and Southern Carpathians.

The meeting will be held in the Department of Geology, Babes-Bolyai University, situated in the former Roman town of Cluj-Napoca, Romania. The conference room offers modern projection facilities, and lunchtime meals will be taken in the University Restaurant opposite the Geology Department. Microscopes will be available for working groups and demonstration purposes.

Costs:
The registration fee for the conference is estimated to be approx. €120 euros, and a discount will be given to student participants. The fee will cover conference materials, refreshments at the meeting, and the welcoming reception. Field trip costs will be calculated separately. The Grzybowski Foundation will make available a limited number of travel grants for participants from eastern European countries. Accommodation will be at local hotels near the central square, at the discount rate of approximately €50 a night. Full details of costs will be made available in the second circular.

Preliminary Programme:
Sunday 7th September: arrival and welcoming reception
Monday 8th September to Wednesday 10th: Technical Sessions
Wednesday 10th September: Conference Dinner
Thursday 11th September to Saturday 13th: Field Excursion (Transylvania, Carpathians).

Information and Registration:

Sorin Filipescu, Department of Geology, Babes-Bolyai University, str. Kogalniceanu 1, 400084 Cluj-Napoca, Romania, e-mail <**sorin@bioge.ubbcluj.ro**> or Mike Kaminski, UCL, e-mail <**m.kaminski@ucl.ac.uk**.>.

An International Conference on the Cambrian Explosion

Banff, Alberta *August 3 – 7 2009*

We invite you to attend a special Conference on the **Cambrian Explosion** to commemorate the **100th anniversary of the discovery of the Burgess Shale by Charles Doolittle Walcott**. We cordially extend this invitation to all geologists, palaeontologists, geochemists and biologists interested in the profound organismal, ecological and environmental changes that occurred during the Precambrian–Cambrian transition. Moreover, we think that this meeting would be of great interest to historians of geology and anyone curious about the origins of animals.

For further details visit the meeting website at <**http://www.geology.utoronto.ca/facultycaron/Walcott2009.htm**>.

International Scientific and Organizing Committee (as of April 2007)

Co-Chairs:

Dr Jean Bernard Caron (Royal Ontario Museum, Toronto), <**jcaron@rom.on.ca**>
Dr Doug Erwin (Smithsonian Institution, Washington), <**ERWIND@si.edu**>
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Dr Jean Vannier (Université Claude Bernard Lyon 1), <**jean.vannier@univ-lyon1.fr**>
Dr Xingliang Zhang (Department of Geology, Northwest University,Xian), <**xlzhang@pub.xaonline.com**>
Dr Maoyan Zhu (Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences), <**myzhu@nigpas.ac.cn**>

International Symposium on the Cretaceous System

Plymouth, UK *6 – 12 September 2009*

The International Symposium on the Cretaceous System will be held at the University of Plymouth, on 6–12 September 2009. The conference will be followed by a number of field excursions visiting Cretaceous locations in the UK. Themes for the meeting may include: 200th Anniversary of the birth of Charles Darwin, sequence stratigraphy and sea level change, Cretaceous oil and gas exploration in the N.W. European Continental Shelf, Cretaceous stratigraphy, palaeontology, isotope stratigraphy, biotic and other events, regional geology and palaeoclimates. Papers will be solicited for peer-reviewed publication with submission of manuscripts *at the meeting*.

For more information contact Prof Malcolm Hart, School of Earth, Ocean & Environmental Sciences, University of Plymouth, Drake Circus, Plymouth PL4 8AA, e-mail <**mhart@plymouth.ac.uk**>.

Please help us to help you! Send announcements of forthcoming meetings to <**newsletter@palass.org**>.

Outside The Box

Fossil Trade

Since 1998 I've been the manager, and more lately owner, of a small fossil shop in Edinburgh. On leaving university I knew that I enjoyed the palaeontological side of geology far more than the rest, but that it was not a field of study given to an obvious career path. After a few years working in Glasgow museums, I was looking for work in Edinburgh. My brother called me after seeing an ad in a shop window. It wasn't something I'd previously thought about, and it was more of a stumble into an unexpected new life than the purposeful stride into gainful employment most recent graduates hope for.

I had a background that assured a reasonable knowledge of the stock-in-trade, but virtually no experience of retailing or management, so I came into the job with a lot to learn. I was fortunate in having the previous manager on hand for a year or so after starting and was able to ease into this side of the business relatively gently. It was important to get to spot a good price, recognize quality and be able to determine the retail value of a fossil or mineral. Aside from the day-to-day work of basic shop-keeping, there is also a small component of financial and personnel management. Being a small shop, there has never been a staff of more than three, and staff turnover is not particularly quick, so this latter aspect is not a mammoth task. Paperwork such as PAYE forms, VAT returns and tax returns are not a great delight, but do not demand a great deal of time. For me, the fun part is buying the stock. There is a degree of pleasure to be taken in discovering a potential new line, finding a bargain, or seeing new stock sell well.

The fossil trade is a strange business – it's a small world and it doesn't take long to get to know the majority of the bigger players involved. As one might imagine there are a number of interesting characters from diverse backgrounds within the UK and internationally. There isn't a huge market in Britain – it's a bigger market elsewhere in the world – but a fairly steady background trade exists within the UK.

There is a broad customer base – from six-year-old boys delighted to get their hands on their own dinosaur tooth to the seasoned collector looking for some obscure Peruvian blastoid. Fossil enthusiasts and knowledgeable palaeontologists do not form a large section of the market though, and far more fossils are sold for aesthetic reasons than scientific. The vast majority of a fossil shop's stock will be from

sites rich in one or two types of fossil, and are unlikely to be of any real interest to a museum, except perhaps as educational handling material or for temporary exhibition.

There has been a commercial side to fossil collecting from even before the origins of palaeontology. Mary Anning, she of the sea shore, is a notable example. She was finding material on the beaches of Lyme Regis in the early 1800s which was of great importance to the academic world. What is less well known, however, is that her parents had collected fossils before her and there is no reason to doubt commercial collecting had been going on for some time before Anning gained her belated fame.

The development of the science was beginning to find its feet by Mary's time, and many of the early leaders in the field were more than happy to pay others for their finds in order to supplement their own collecting and allow more time to study what they had accumulated. When word spread that money could be made, others began to collect fossils actively, and this fuelled a rapid development of the discipline.

When I left a very brief career in museums to work in Stan Wood's fossil shop, I faced a couple of light-hearted 'gamekeeper turned poacher' jibes. There exists, for some, an uneasy relationship between the academic and commercial worlds, but the ties are vital and the two sides are once again beginning to work together more closely.

The importance of a symbiotic bond between the commercial trade in fossils and the academic world cannot be overstated. The reliance on provision of material in one direction and the establishment of appropriate collecting guidelines in the other can only be mutually beneficial. Many museums struggle to find the time and money to mount exploratory digs, and it makes financial sense to buy the pick of the material from those already engaged in the activity – amateur and professional fossil hunters.

In a great deal of cases, quite possibly the majority, collectors will donate scientifically important specimens to academic bodies. This is prompted by law in some countries, and in the interest of good relations in others. Obviously, there are examples where significant items and data are lost to science by unscrupulous or uninformed collectors – infamously the Lanarkshire fossils in German museums chased to no avail by the Scottish authorities. Establishment of informed guidelines for fossil collecting has become more of an issue, and Scottish Natural Heritage is currently in the process of consulting a range of concerned parties to create a simple set of rules. This will help preserve important information, simplify the tracing of potentially significant sites and start beginner collectors off on the right foot.

For the most part – one way or another – fossils of scientific consequence usually end up within the academic world, or at least made available for study on request.

The fossil trade at the retail end should play a small educational role, at the very least furthering awareness of the subject amongst customers. I take care to supply relevant information – at least the basics of name, age, locality – with every sale. This is generally much appreciated but also serves to encourage interest. A number of questions arise time and again from interested customers. How do you know how old it is? Where do you get all this stuff? I didn't know there were fossil shops – shouldn't they all be in museums? I think there is a psychological barrier to cross for some in entering the shop – a slight apprehension that they are surrounded by things they know little about. I am keen to make sure people leave feeling they know a bit more than when they arrived.

Mr Wood's Fossils has always had a policy of hiring staff with more than just a background knowledge of geology, enabling informed answers to the customers' queries. As well as offering a basic level of geological education, this also acts as a level of customer service that can aid loyalty and ensure beneficial word-of-mouth. It is very much in my interest to know about the fossils I am selling, and the same applies at the wholesale stage. I feel more confident buying from someone who knows his stuff.

There are relatively few fossil shops in Britain; most are clustered around the fossil-rich coastlines of Yorkshire and the South of England. Local interest in collecting, the draw of the sites for collectors from further afield and the ready availability of stock are all factors in this clustering. There are also a few shops in towns and cities with a customer base big enough to support them. The rise in the interest in new-age crystal healing has led to a growing number of businesses selling minerals, often carrying a limited range of fossil lines. The market occasionally sees a short-term boost from external influences such as a trend in interior or garden design, or a blockbuster movie. The BBC series *Walking With Dinosaurs* and the *Jurassic Park* films stirred up an interest in dinosaur material and insects in amber.

There are a good number of UK-based wholesalers providing fossils for the retail market, some more specialist than others. Aside from these, trade fairs scattered around the globe allow good opportunities to find new suppliers and a wider range of commercial material. The biggest of these is held annually in Tucson, Arizona, a sprawling affair consuming a sizeable chunk of the city and spread over three weeks. Many hotels are filled with dealers from around the world, laying out their wares on beds, temporary shelving and trestle tables. There are also market places, warehouses, exhibition centres and a few permanent showrooms. To take

it all in properly would take the whole three weeks, and with hotels raising their room rates through the roof for the duration of the show, it can be an expensive trip.

I get a great deal of stock from two annual trips to fossil fairs. It's nice to be able to meet the source of material if possible; learn about how they are collected and prepared. I get to meet people from all over – for many it is their sole occupation, others operate on a more amateur level. They all have stories to tell about their collecting, of their favourite finds, the things they'll never part with. Of course, from a more businesslike point of view, it also allows careful stock selection and better prices.

There is, as with everything else, a burgeoning trade in fossils on the Internet. A great many commercial fossil sites are now very well established and many display a thorough understanding of their wares. Prices vary considerably, though. There are some reasonable valuations to be found, but often at the collector end of the scale prices rise exponentially over small degrees of preservation quality. Web-based auction sites certainly provide entry level prices, but have less in the way of unusual material and there are many associated pitfalls. The level of expertise is not necessarily too high, and a great many fakes make it into this market.

The faking of fossils is a continual blight on the fossil trade, with a great deal of material from Morocco, Brazil and China needing close scrutiny before purchase. There are very few cases of entirely fake fossils; mostly you see embellishments such as exaggeration of fins, replacement of missing parts, the extension of broken genal spines and so on. Once you know what to look for, there are few difficulties in spotting any 'enhancements' and avoiding those examples outside of acceptable restoration. Broadly, Brazilian fakes are very poor and easy to spot, even for the layman; Moroccan stuff needs a closer look and the Chinese can be very convincing.

The Brazilian fakes tend to be limited to fish nodules with crudely carved tails and dorsal fins, though there are many mesosaur specimens with tell-tale fractures across the rear of the slabs. Moroccan material is more diverse – the clever carving of the centre of ammonites, application of resin to damaged trilobites, and insetting of shark and mosasaur teeth into matrix are all very common. Some Chinese preparators have taken their skills to a fine art. While the elaborate painted fins on the two fish species familiar to the market are clear to anyone looking for artifice, the faking of nothosaurs and keichousaurs has developed to the point where it can be difficult to spot unless familiar with the techniques used.

Aside from the artifice, there is a black market within the fossil trade. More and more countries are laying down rules to control the collection and export of their palaeontological resources, and this has led to a fairly confusing web of legislature. China has tinkered with their exportation rules over the past couple of decades, and has settled on a blanket ban of vertebrate fossil material leaving the country. This is mostly to protect the scientifically important feathered dinosaur finds from the Liaoning sites, but also has affected the trade in relatively insignificant fish, dinosaur eggs and shell, *etc*. Some countries allow export under licence, allowing a degree of control by the authorities, and this has proved fairly effective. While there has been some policy in place for a considerable time allowing export under licence, Argentina has recently changed its rules again, and now prohibits fossil ownership and export; the authorities there have gone as far as repatriating material that left the country before the rule change, and seven tons of a dealer's stock was confiscated by the US in Tucson in 2006.

While a fossil shop is never going to fund an extravagant lifestyle, it's an enjoyable place to work. I get to handle beautiful examples of fossils from all over the world, and talk to people who are at least slightly interested in them. For the most part, people who come into the shop are there because they want to be there. It's not like they are simply buying a pint of milk – they usually want to browse, take their time, take pleasure in their experience. So even if I'm not feeling particularly excited on a given day, seeing a kid's face as he realizes just what that dinosaur coprolite in his hand *is* brightens things a little.

Growing up, I always wanted to be a zookeeper. I suppose I am now, though all my charges are long dead. No need for mucking out, at least.

Matt Dale
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Palaeontological field guides for the 21st Century

In last year's flurry of natural history wall chart giveaways by national newspapers, fossils were conspicuous by their absence (I await email from aggrieved taxonomists of extant groups that were also neglected). As far as I know, not even the charismatic megafauna of palaeontology that is the non-avian dinosaurs was represented (yes, yes, there were plenty of bird charts and guides). However, this article isn't a litany of complaint about the choice of taxa selected by the editors of newspapers. I'd like to reflect on the role of field guides in palaeontology, relative to those available for extant taxa, with the intention of stimulating discussion on the topic and identifying the particular challenges involved in producing palaeontological field guides.

First, I would like to consider the use of field guides that relate to extant groups and how their use has changed. Having considered field guides for extant taxa, I will then discuss the peculiarities of fossils and the difficulties that the inherent links between geology and palaeontology introduce into compiling field guides for users with limited geological knowledge. Finally I will make some suggestions about some approaches that might provide solutions to the problems involved in producing field guides that will appeal to the widest possible audience.

Field guides for extant taxa

Field guides exist to answer the question "What am I am looking at?" Most field guides will illustrate the taxon, provide some text relating to its key morphological features, a distribution map of the taxa, and sometimes an indication of how common the species is. All of the information is there. Like all stores of information, the key is how to access the information you want.

Many field guides apply a taxonomic organizational scheme. While this is useful to users with some familiarity with a group, it can raise difficulties for more casual users. Another approach is to use a habitat-by-habitat basis, as some of the Wildlife Trusts guides do. The habitat-by-habitat basis tends to work reasonably well with organisms that have predictable occurrences in certain environments, but this approach can be rather unhelpful with mobile or generalist taxa. Another problem with this approach is that once you become familiar with the taxonomic approach to laying out a field guide, a habitat-based approach is infuriating to use.

A third approach is to use general body shapes, or distinctive morphological features, as the key to the guide. Having used all three types of guide for birdwatching, I prefer to use a taxonomic guide in the UK and northern Europe, where I have a reasonable idea of the general group of birds I am looking at, but found body-shape-based guides much more useful in the US and Canada. Such guides can still rely on quite a bit of specific anatomical knowledge about the organisms you are looking at, but it does overcome many of the problems when confronted with unfamiliar organisms that nonetheless look somewhat familiar.

Another major divergence in field guides tends to be between the relatively large and fast-moving animals, and the smaller and more sedentary organisms. Guides that deal with mammals and birds tend to focus on giving descriptions, particular 'field recognition signs' which are distinctive markings or behaviours that can allow the user, in theory, to identify the taxon as it flees towards nearest cover.

Guides that deal with invertebrates and fish often tend towards a taxonomic key approach. As these taxa tend not to move very quickly, relative to humans, or in the case of fish are temporarily out of the water, the observer can key out the taxon at leisure. Botanical guides are nearly always based on keys and I would argue that research botanists have access to the most reliable general data sets supplied because of the uniformity of methods used by all botanists to recognize taxa.

How the use of field guides has changed over time

Collection of species occurrence data has changed somewhat over the past 200 years. Darwin was apparently handy with a fowling piece, the preferred method of bringing specimens close enough for examination and identification before the widespread use of binoculars, and the vast collections of beetles and butterflies pinned and labelled reflects the methods of the time. It also reflects how 'field guides' were used. Books were expensive, and would tend not to have been carried about in the field. Typically specimens were collected in the field or detailed field sketches were made and books consulted upon the return from the field. This pattern persisted until the 1950s, when the first mass-produced field guides, such as the 'Observer Guides' series, made it feasible to take field guides into the field. Some natural historians have bemoaned the decline in field sketching and note-taking skills, but I think that field guides have served to interest far more people in natural history.

The availability of well-illustrated field guides has driven a tendency to want to identify taxa in the field. With unfamiliar taxa or in a new area this is often a rather ambitious hope. With digital cameras we now have the ability to take hundreds of photos in a day, and it will be interesting to observe whether there is a reversion towards taking quick field records and identifying taxa back at base using reference materials. I have seen a few PDA-based field guides, but unless your PDA is pretty rugged and well-insured I don't think these will catch on widely.

Fossils as natural history: the challenge facing palaeontological field guides

Palaeontological field guides have to deal with the summed biodiversity of a country/area/formation over millions of years. Even seasoned palaeontologists will gather specimens they cannot identify beyond 'gastropod' or 'fish tooth'. Specimens often need further preparation work, but photographs can be useful. Usually if fieldwork has been planned with specific targets in mind a search of the literature can allow a 'cheat sheet' of the common fossils to be put together from previous publications, but it will rarely cover all taxa found, even in a single day of collecting.

The sheer diversity of fossils from even a single formation is a significant hurdle to compiling palaeontological field guides. The Palaeontological Association field guides tend towards providing complete information on the taxa from a particular geological unit or geographic area, which makes the scope of their applicability very clear. Such detailed guides take a great deal of effort to compile, usually from a number of specialist contributors. For instance there are around 450 species listed in the Palaeontological Association *Oxford Clay Field Guide*, split among 23 major invertebrate and vertebrate groups. To put this in context, there about 650 species of spiders in the UK at present. This comparison of a diverse group of extant taxa and a geological unit with a diverse fossil list illustrates an important difference. A UK spider field guide could reasonably cover all species, while for a single geological unit a similar-sized field guide is needed to cover one formation. A comprehensive guide to every formation in the UK that is reasonably fossiliferous would run to over 100 guidebooks.

However, palaeontologists shouldn't despair; instead we should take a pragmatic view. In general, it appears that when using natural history guides people do actually want to be able to identify and name plants and animals to the species-level, or their common name. In the case of fossils, due to their more obscure nature, from my experience of doing roadshows and public enquiries many people are pleased to be told that what they have found is indeed a fossil and be told that it is a fossil snail or clam and what age (preferably in millions of years, as well as the geological period/epoch/stage). Having sent an email round my colleagues in the Department of Palaeontology, many of whom have far more experience in handling enquiries, most people who replied agreed that this minimal information will often satisfy casual enquiries. Some additional important points did emerge. Field guides do need to be uneven in their coverage. When dealing with unfamiliar taxa such as stalked crinoids or sponges, full reconstructions and information on their relationships to extant taxa are important, while in the case of more familiar taxa such as snails, clams and fish, less information is needed on the type of animal they are but other background information may be more welcome.

We are confronted with the problem of fragmented preservation, or cross-sections at unusual angles through 'familiar' taxa. Someone who has taken a palaeontological course may be able to mentally reconstruct or rotate the fossil, but this is probably the most frustrating aspect of guides for non-specialists. The material in front of them doesn't look like *any* of the pictures in the book. This issue may be the critical difference between the specialist and non-specialist in assessing the usefulness and usability of field guides. A novice has only one or two 'search images', usually the pictures of good, prepared specimens, in the guide they have bought. An experienced collector has many images and clues from collecting trips, museum trips and background reading. This may be why 'entry-level' guides, especially the fold-out sorts that are often sold in areas where people encounter fossils for the first time such as the Yorkshire coast, or along the Jurassic Coast, appear to be useful and reasonable guides to experienced palaeontologists; but when it comes to use by novices the problem is that the guides do not cover the full range of variation and preservation. This is not a problem that is confined to fossils. Picture atlases of minerals and rocks in thin section, which many of us bought so eagerly as geology students, are often little help with particular specimens. For exams most people learn that they have to remember the general description and properties of the mineral or rock, rather than rely on the pictures, but people on holiday or a day trip aren't taking exams. They do like to come away with the sense that they know more after buying a guide than they did before.

This leads me to the nature of the 'habitat' of fossils. Habitats can be of great use in most areas of natural history, because of their simplicity and relatively intuitive nature. If an organism is listed as occurring in woodland or coastal environments, this is a concept that nearly anyone can grasp. Most fossils are intimately linked with the rocks they occur in, but the identification of the rock type can be an additional hurdle to the inexperienced user. As far as possible, field guides should provide a geological map or other information that removes uncertainty about the geological context.

What does work in a palaeontological field guide?

After spending a considerable portion of this article discussing other areas of natural history, it is notable that, in my opinion, the best general palaeontological field guide I have used is the *Field Guide to North American Fossils*, published by the National Audubon Society. The

Audubon Society is similar to the RSPB, but has diversified its conservation efforts. It has transferred its approach to other areas of natural history to the fossil record. The guide contains a potted history of life on earth, notes on geological time, and geological maps broken up into important fossiliferous regions of North America. To make identifications, the user of the guide combines the maps with the general shape of the fossil at hand. This combination then leads to more detailed descriptions and taxonomic information in the back of the guide. Thus it strikes a difficult balance of being useful across the range from complete novice to experienced palaeontologist. On reflection, the broad usefulness of the guide arises from the fact that there are multiple pathways into the taxonomic information section. An experienced palaeontologist could skip through the higher-level taxonomy based on shape to get straight to information about the likely fossils, but the novice investing in the guide does have a reasonable hope of identifying taxa to Superfamily level, as well as getting a set of geological maps, colour fossil photos and general background information. The Audubon guide uses a key-based approach, which is sensible as fossils aren't going anywhere fast. However producing such high-quality guides is not cheap.

What more can we do as a community?

Field guides are utilitarian. You don't buy field guides to grace your coffee table. They should help to open up the identification of taxa in the field. Other works with more detail can be consulted in the office or armchair. Most modern field guides pack in as many illustrations as possible to cover how taxa look under different lighting conditions, at different times of year, and differences due to age and sex. This might require six to eight illustrations. With fossils, because of the additional problems thrown up by differential preservation and the often fragmentary nature of material, we need an even higher number of illustrations. Given that people are taking more and more field photos of fossils in digital formats, we should be doing what we can as a community to pool these resources and make them available as widely as possible.

Websites are one possible approach, and the Palaeontological Association honours good palaeontological websites with the *Golden Trilobite* awards. If you find a good site, nominate it. However, websites rely on one person doing all the work, and if that person has other calls on their time, even the best websites can become outdated. An alternative approach would be to use the growth of Wiki tools. Wikis are a way of publishing a website cooperatively, and have the great strength that many people can be involved in the project, but participation can be limited by moderators – so they strike a balance between getting people involved and maintaining some quality control.

A wiki would allow exploitation and dissemination of palaeontological information quickly, particularly photographs. Even some other web applications such as photosharing tools (*e.g.* Flickr) or social networking sites (*e.g.* Facebook) could be used to take the place of the more technical Wiki-based approach. Moderating the quality of contributions is also possible on these sites, but note Flickr is not as flexible as a Wiki. Like the Audubon guide discussed above, a Wiki or website has the advantage of allowing multiple routes to the information that can be taken depending on the user's background.

Some Wikis could start as school or university class projects, others as part of the work of statutory bodies. Local geological groups could preserve much knowledge that stands to be lost and, in the cases where closures and cutbacks have left such groups with limited contact with academics, links with university and museum geologists and palaeontologists could be re-established. As these wikis develop they should give field guide authors clues and pointers to the sort of content, level of detail and presentation style that people want. We may even arrive at a point where some of the online guides can successfully be edited and compiled into field guides that can be printed out and used in the field.

The new members' area of the PalAss website doesn't seem to have been getting much use. I've opened a thread on it to discuss the topic of palaeontological field guides further. Please contribute to the discussion, to give insights into how the palaeontological field guides might work out in the future. Some possible topics would be whether field guides should focus on particular formations, as some of the Association's Field Guides do; or would producing guides that focus on a geographic locality, such as the recent Pentland Hills guide, be of more use? People might want to recommend field guides they have found useful or useless, but it would be helpful to discuss why those guides succeeded or failed. I've laid out what I think we need from our field guides. Now it's your turn.

Al McGowan
Newsletter Reporter

TV Review

Primeval, ITV1

Television companies have an extremely narrow view of many things, and palaeontology is no exception. If the fossils aren't big, fierce and computer-animated they're barely interested, and the possibility that extinct organisms other than dinosaurs could grab the attention of the public if presented in an appropriately stimulating format is given short shrift. Thus, rather than consider new ideas, corporations seem now to be clamouring to see how many different ways they can re-make *Walking With Dinosaurs*. At ITV – where most novel programming was abandoned long ago in favour of soaps, reality shows and the worship of talentless celebrities – this approach spawned an extremely curious offspring.

Broadcast over six Saturday evenings in February–March 2007, *Primeval* cleverly jumped on two bandwagons simultaneously. The computer-generated monsters of *WWD* were spliced with the time travelling concepts of *Doctor Who* to produce a show in which extinct creatures suddenly popped through wormholes into the present day. 'Strange things are going on all over Britain,' claimed the blurb but, as often happens in TV-land, they'd confused Britain with London. Still, it was supposed to be light entertainment rather than serious education, so I thought I'd give it a go. I can't claim to have swallowed my prejudices and approached it with an open mind, but I was quite intrigued to see what delights each episode would throw up.

Not surprisingly, **Episode 1** set the scene. In essence, it was thus: anomalies open up in the Forest of Dean and an ASDA car park, allowing Permian creatures to wander in. These include a *Scutosaurus*, a gorgonopsid, and a small, green, flying lizard thing: expert palaeoherpetologists will be able to furnish you with its scientific name. Understandably baffled, the civil service bods – James Lester (Ben Miller) and Claudia Brown (Lucy Brown) – call in Professor Nick Cutter (Douglas Henshall). He is an Evolutionary Zoologist (more glam-sounding than Palaeontologist?) at Central Metropolitan University and, assisted by his lab technician, Stephen Hart (James Murray), one of his students, Connor Temple (Andrew Lee Potts), and a lizard-loving zoo keeper, Abby Maitland (Hannah Spearitt), he takes it upon himself to figure out what's going on. By way of explanation, it transpires that Cutter's wife Helen (Juliet Aubrey) disappeared in the Forest of Dean some years earlier.

For the remainder of this piece, I shall refer to Lester, Claudia, Cutter and Helen in that fashion, but Connor Temple is extremely annoying, both as a name and as a character, so he is henceforth referred to as "Numpty". Stephen Hart supports Leeds United and is thus re-branded "LeagueTwo", whilst Abby Maitland is so scarily golden in hue she simply has to be renamed "Midwich".

Anyway, back to episode 1. The gorgonopsid attacks a school but, disappointingly, only one student and one teacher are there, and LeagueTwo is able to fight the beast off with a chair. Cutter finds the anomaly in the forest and wanders through into the Permian, whilst Midwich takes the small green lizard home as a pet. This is a cunning plot device that requires the central heating in her flat to be turned up to 11, forcing her to spend a fair amount of time wandering about in her underwear.

Episode 2 sees Carboniferous arthropods invade the London Underground. 'He was babbling about monsters,' says the nurse in regard to a man who'd just been bitten by a mutant arachnid from the Carboniferous. 'Classic signs of too much oxygen,' says LeagueTwo, enigmatically, whilst Midwich exclaims, 'I can help, I've just finished a study on insect behaviour!' LeagueTwo soon needs all the help he can get when he gets bitten, and we then discover, through Cutter, that you can whistle at *Arthropleura* to attract its attention, enabling you to milk it for its venom. More excitingly, it is revealed that the monster millipede can bore its way through breeze blocks: if the government had thought the situation through carefully enough, maybe they could have trained it to excavate new tunnels for the tube network. Sadly, *Arthropleura* is instead killed by Numpty when it sinks its fangs into a wooden stool he is holding and falls into an electrical sub-station.

In **Episode 3**, Cretaceous marine reptiles appear in the London area (where else?). A mosasaur eats a man in a swimming pool, then escapes before the chlorine makes it cry. 'She's babbling on about monsters,' says a policeman in regard to his girlfriend, whilst Cutter tells Lester that the anomalies are 'conclusive proof that the past exists'. Having disappeared for a while, the mosasaur reappears in a [freshwater] reservoir in Stoke Newington, attacking Midwich and Numpty who repel it with an oar. In proper professor-to-undergrad language, Cutter describes Numpty thus: 'he looks like a halfwit but he has a very good brain.'

The next anomaly opens up in the water pipes in a suburban house, with a poor Welsh plumber getting plucked apart by a lost *Hesperornis*. Cutter figures out that his wife has been using the anomalies to go time-travelling, and decides to go and find her. Overlooking the fact that it is impossible to explain it to anyone, Numpty asks, 'She's been in the past for eight years, how will we explain *Celebrity Love Island* to her?' Cutter is then posted through the anomaly, attached to a very long power cable (MI5 must have purchased a special extension lead) and he finds Helen whose clothes are in remarkably good nick, suggesting she may have found a TK Maxx anomaly. She comes back and is arrested. The mosasaur is forgotten about.

Dodos pop up in a (London) football stadium kitchen in **Episode 4**, and Numpty's student mates (one fat, bespectacled geek, one tall, bearded geek) find out about it and manage to capture one. 'We can sell dodo sick on eBay!' they exclaim, but the dodo attacks them and infects the taller one with a nasty parasite. He persuades Midwich to help him; she ushers him past a police guard by telling the guard the student is 'a Home Office scientist', despite the fact that he is wearing a hoodie. If this were the real world the police officer would have shot him, but it matters not as the student soon dies on the touchline of the football pitch.

A dull round of golf gets livened up in **Episode 5** when a pterosaur invades a suburban course. A player is eaten, and the pterosaur is fingered as the suspect, but our heroes know better. LeagueTwo tastes pterosaur dung and says there is no human flavour, only fish and reptiles. One can only presume he knows the subtle flavours of human flesh from his time on the terraces at Elland Road? Anyhow, we soon discover that a) whistling works to attract the attention of Mesozoic winged reptiles as well as Carboniferous arthropods, b) they can then be tranquilized and posted back through the anomaly, and c) a flock of small raptors are the real predators. After implausibly cutting the phone cable these vicious pests try to kill Cutter and Claudia, who are trapped intimately in a stately home, Claudia having mysteriously lost many of her clothes. Luckily, Helen reappears to destroy the raptors using an elaborate microwave oven explosion. Hurrah!

At the start of **Episode 6**, Cutter is playing golf with a leg bone in his enormous office, just like every other professor of palaeontology I've ever met. He thinks he knows where the anomalies will appear but has no proof – it seems certain he needs to apply for a grant, although it is unclear to which research council his application should be made. To shake him out of his daydream, a creature from the future then eats a lion in the zoo where Midwich nominally works. It transpires also that LeagueTwo was Helen's student toy boy, whilst Claudia is having gorgonopsid nightmares and wants Cutter to make them go away.

The creature from the future is probably a highly evolved bat: 'the only explanation is that it came through an anomaly from the future into the Permian and then through into our world,' says Cutter. He should probably leave this statement out of his research grant application, as panels tend not to like such speculation. Next, he kills the bat thing with a big gun, but it turns out there are batlets. 'I suppose bombing is out of the question?' asks Lester.

Being a kindly soul, Cutter decides to take the batlets through the anomaly back into the Permian. His final request as he disappears through the wormhole is curious – 'If I don't make it back push Leicester through the worst anomaly you can find' – but perhaps he was rejected for a PhD by Dick Aldridge. In any case, mummy bat is still alive and charges through the anomaly after Cutter, soon killing a black marksman (reminding me that the only black child in *South Park* is called Token), then the other marksman, before being killed herself by the gorgonopsid. Conclusion: the Permian is better than the future. When Cutter comes back through the anomaly, Claudia no longer exists, and there the episode ends, leaving us perched on the edge of our seats awaiting the next series. I am reliably informed it has been commissioned, so here are a couple of my suggestions for episodes:

Ediacaran – various small, leathery organisms crawl through an anomaly and cause absolutely no havoc or mayhem at all, by virtue of their small size, lack of sharp claws and pointy teeth, and inability to survive on land.

Cretaceous – much higher sea levels means that when a wormhole opens in South Wales, sea water pours in and floods the region. Despite non-stop efforts over two weeks, the Environment Agency is unable to get all the water back through the wormhole and various native-but-non-temporal species invade the ecosystems of the Severn Estuary. Trawlermen around Newport complain that fish stocks are being decimated by the influx of previously extinct cephalopods. DEFRA responds by translocating a population of mosasaurs from NW Scotland where they'd sneaked in through another tear in the fabric of space and time.

Quaternary – Thousands of *Homo erectus* sneak through a wormhole, leading to shrieking headlines about illegal time-immigrants in METRO and the Daily Mail. The hominids are soon propping up the British economy though, and, fearful of what might happen if they should disappear again, the government orders workmen to board up the wormhole so that they can't sneak back into the Pleistocene. Soon, in scenes reminiscent of US soldiers in the Second World War, the erectoids are fathering cross-specific children with British girls; Midwich is harassed by the paparazzi after admitting to a brief affair with a tall, dark, extinct man.

In summary, *Primeval* is a mildly diverting way to spend a Saturday evening, but nothing more than that. Douglas Henshall, Ben Miller and Juliet Aubrey are excellent actors, but the show isn't a patch on *Doctor Who*, which is infinitely better constructed, better written, and with far more plausible, sympathetic characters. Also, contrary to how it may appear in this review, *Primeval* is conspicuously short on humour. As for the palaeontological slant, it can be summarized thus: ancient creatures were either fluffy and cute, or ferocious and carnivorous. Prejudices confirmed.

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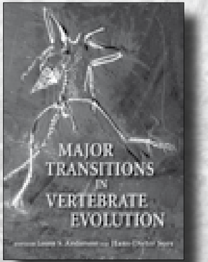
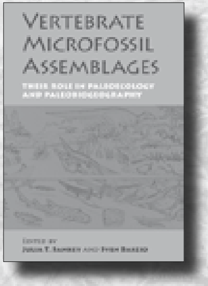

MAJOR TRANSITIONS IN VERTEBRATE EVOLUTION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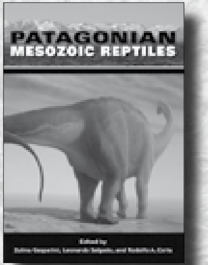
THEIR ROLE IN PALEOECOLOGY AND PALEOBIOGEOGRAPHY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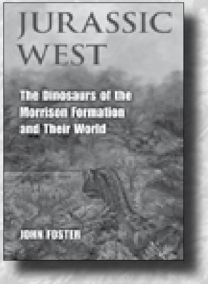
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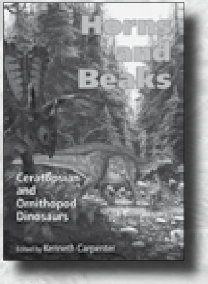
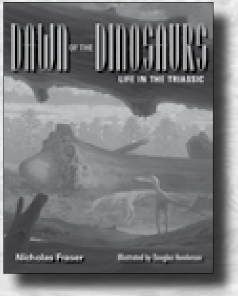
The Dinosaurs of the Morrison Formation and Their World
JOHN FOSTER


Horns and Beaks
Ceratopsian and Ornithopod Dinosaurs
Edited by Kenneth Carpenter


DAWN OF THE DINOSAURS
LIFE IN THE TRIASSIC
Nicholas Fraser
Illustrated by Douglas Henderson

Book Reviews

The Emerald Planet: How Plants Changed Earth's History

David Beerling (2007). Oxford University Press, Oxford. 288pp.
ISBN 9780192806024 (Hardback) £14.99.

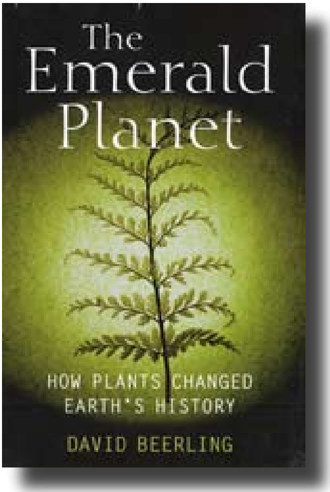


Plate tectonics, liquid water, and living organisms are three important characteristics that mark the Earth out as unique among the rocky planets of the inner solar system, and all three have great influence on the biosphere. In recent years, geochemists and earth system modellers have begun to recognise the significant roles played by plants in climate models and in major geochemical cycles. Plants are at the centre of many complex chemical and physical interchanges, which summed over the vast area of the Earth's land masses turn out to be very significant indeed. When acting *en masse*, plants are a geological force of nature. In *The Emerald Planet*, Beerling argues that a proper understanding of Earth's history must begin by integrating traditional elements of geology with knowledge of plants as living organisms. We need to bring an infusion of physiology, biochemistry, and molecular developmental biology to palaeobotany, plate tectonics and sedimentology. In this fascinating, ambitious and well-written book Beerling shows us how this might be done, and how the pursuit of plants promises to unlock greater riches from their fossil record, bringing a new source of data and a fresh form of critical analysis to bear on some of the major issues of Earth's history.

The key to this book's novelty and to its success is its enthusiastic advocacy of an hypothesis-driven approach which continually looks towards testing and verification with reference to experiments on living systems. Also significant is the liberal use of anecdote and historical reference to introduce subjects and to place them in the broader context of science as a whole. The big picture is always clearly in view, and the author is constantly striving towards big answers. This is not a book about the nuts and bolts of plants, although the author necessarily delves into technical aspects to illustrate his points. It is a book that weaves together sources of information from diverse interrelated fields to illustrate how these may be used to investigate major questions, especially those related to climate change, atmospheric chemistry, and of course plant evolution.

The Emerald Planet is organised into a series of chapters, most of which can be read as standalone essays focusing on particular aspects of Earth's history. These are all based around topics addressed by the author in his own research over the last twenty years. One might therefore think that the book has a rather narrow slant, but this is not the case at all. Beerling's research has covered so much territory that there is rather a fine balance of examples from different geological periods and addressing quite different questions.

Three essays describe how plants are powerful agents of environmental change. They show how a complex web of interactions including plants mediate chemistry, phenomena related to plate tectonics and the inorganic chemistry of ocean and atmosphere, and in combination shunt global temperatures and the gaseous constituents of Earth's atmosphere up and down, with major consequences for living organisms.

The book begins with an essay on the effects of plants acting *en masse*, tracing the origin and early development of leaves as levels of atmospheric carbon dioxide plummeted during the Devonian Period. The geological message here is that plant-mediated weathering on calcium/magnesium silicates in soils is a key factor in the long term geochemical carbon cycle, and therefore of great importance in controlling atmospheric carbon dioxide. Most intriguing from a botanical perspective is the extent to which feedback mechanisms operate on the plants themselves. For example, the author argues that the evolution of roots and their associated weathering effects during the Devonian Period caused atmospheric carbon dioxide to fall, which in turn triggered the development of leaves with broad blades. One wonders how many other aspects of plant form and function might be explained in this way.

Following this is a chapter on the history of atmospheric oxygen and how this is intimately tied to microbial sulphate reduction, the chemistry of photosynthesis in plants, and the recycling of Earth's rocky crust. Atmospheric oxygen is estimated to have peaked at a heady 35% during the Carboniferous Period, and some of the consequences for animal life are explored. Later on Beerling uses the Early Eocene climatic maximum as a vehicle for discussing discrepancies between palaeontological climatic indicators and what climatic models have to say. This includes a valuable discussion on greenhouse gases and how the shortcomings of climate models might be addressed. One comes away with a real sense of the complexity and dynamics of these systems, but one is persuaded that the problems they pose are ultimately decipherable.

In addition to being powerful agents of environmental change, plants are also inveterate recorders of the world around them. Beerling relates how aspects of plant form and biology can be used to draw inferences about the past. The ring structure of wood is an obvious example that is linked to seasonality. Research from numerous sources over the past twenty years indicates that other less obvious aspects of plant form are also likely to be powerful indicators of key environmental variables. Beerling tells us how careful examination of the leaves of herbarium plants collected prior to and during the industrial revolution led to the discovery that stomates can be used to gauge carbon dioxide levels in ancient atmospheres. Stomates are tiny pores in the leaf epidermis that regulate gaseous exchange and water flow. Their density is sensitive to ambient levels of carbon dioxide. In a similar vein, and in the context of an essay on mass extinction at the Triassic–Jurassic boundary, he relates how evidence from the changing leaf shape and stomatal density in fossil leaves from Greenland indicate that early Jurassic climates were significantly warmer that those of the late Triassic and that the atmosphere was richer in carbon dioxide gas. He links this and other geological indicators to the eruption and formation of the Central Atlantic Magmatic Province as a potential cause of mass extinction at the Triassic–Jurassic boundary. Also examined in detail is the curious case of the so-called mutated spores that have been documented in end-Permian rocks as far afield as North America, Asia, and Africa. Palynofloras of this age contain a high proportion of spores preserved as tetrads, which is unusual. In modern plants, spores dispersed in this form are associated with exposure to high levels of ultraviolet-B radiation, which would be compatible with catastrophic breakdown of the ozone layer. These examples indicate the potential of modern plant physiology and biochemistry for unlocking key environmental information from fossil plants.

A couple of chapters are devoted to the evolution of particular vegetation types. One nicely dissects the complex web of interactions and feedback between C4 plants and climate that is implicated in the spread of grass-dominated savannas during the Miocene Epoch. The C4 add on to photosynthesis concentrates carbon dioxide around the enzyme Rubisco, reducing the wasteful effects of photorespiration. One leading hypothesis explains how this became widespread in response to carbon dioxide starvation (low atmospheric concentrations by geological standards) in the latter part of the Cenozoic Era. A critical review of the evidence leads Beerling to reject this explanation in favour of a more complex ecological scenario centred on the effects of wildfire. Moving from tropics to polar regions, Beerling introduces an essay on the extinct biome of the polar forests by reminding us of the heroic deeds and sacrifices of early explorers in the Arctic and Antarctic. The story of Captain Robert Falcon Scott's ill-fated second voyage is retold with an emphasis on the scientific significance of the fossil plants collected by the polar party. From our modern perspective, polar forests are an extraordinary biome where plants had to cope with a unique combination of warm climate and extreme seasonal variation in photoperiod. This essay contains a fascinating discussion on the cost/benefit of being deciduous or evergreen. Does it cost more to hang onto your leaves during a long dark winter than it would to cast them off and grow a new set in the spring? Beerling tackles this question through models and experiment, with some intriguing and counterintuitive results.

Inevitably, given the breadth of subject matter covered in this book, there are things here that one will take issue with. I would like to have seen a more sceptical approach to reading and interpreting the pattern of mass extinction from the fossil record. There is genuine and mounting concern over sampling bias related to incompleteness of the rock record. How much of the rise and fall of diversity through geological time is primarily of biological origin and how much reflects sampling artefact is a contentious matter. Also, it would have been good to have more on leaf margin analysis and the nearest-living-relative approach to extracting temperature and rainfall patterns from fossil plants. One of Beerling's historical anecdotes, a digression into the arcane world of the Cambridge Mathematical Tripos, has a rather too tenuous connection to the discovery of ozone. But these are largely matters of individual taste, interpretation or emphasis.

Beerling's essays are well structured, engagingly written, up to date, insightful and of broad general interest. His anecdotes and historical reference are to the point and well-crafted. He is careful to point out controversy and to indicate the shortcomings in our state of knowledge. The book is suitable for professionals, students, and informed amateurs, and it deserves a wide readership among geologists, geochemists, climate modellers, palaeontologists, and botanists.

Beerling makes a compelling case for the power of plants and for research on living systems as a way of unlocking the potential of the fossil record. He is spot on in his assessment that increasing the precision of earth system models must draw on the work of diverse disciplines and foster links among allied fields.

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Geological Approaches to Coral Reef Ecology

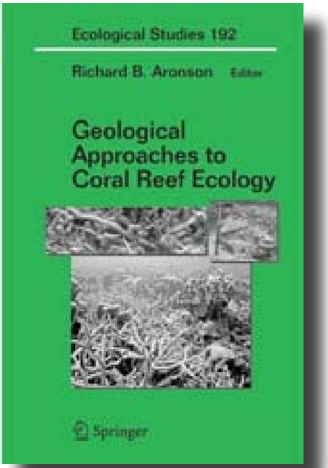
Richard B. Aronson (Ed.) (2007). Springer-Verlag, New York.
ISBN 9780387335384 (hardback) €129.95.

This book addresses modern coral reefs by asking how geological (including palaeontological) research methods can be applied to understanding their ecology. Its more precise scope is covered in Aronson's preface, but is most neatly summarised in Wood's introductory chapter: "How can processes currently observable on human time scales together with the fossil record be extrapolated to predict and manage the future health of coral reefs?".

Why does this subject matter? Well, as everyone must know by now, living coral reefs are widely perceived to be under serious threat from what Devantier & Done call a whole "litany" of anthropogenic influences, as well as from global warming, which most people now accept as having at least some human cause, too. But why might an essentially conservation-directed book matter to palaeontologists in particular? Well, at the very least, since the state of coral reefs has wider implications, this book serves as an excellent reference point for scientifically-educated citizens such as palaeontologists, in demonstrating what we know, and what we do not know, about the future of the complex coral reef ecosystem, particularly in the light of geological methods. But in any case, the study materials in many of the chapters are fossils. These are mostly very young in geological age, mostly Quaternary including Holocene, though there is also reference to the older geological record too.

A broader answer is that there are also numerous interesting palaeontological methods and ideas described in the book, at least some of which might be applied to the study of ancient reefs, regardless of how these methods have been used in the book's immediate context. However, the general thrust is palaeoecological and in this respect – if you are working in the palaeontological mainstream (in Britain, at least) of such fields as stem-group phylogenetics, early arthropods, dinosaurs, and macroevolution – you will probably give this book, and the rest of this review, a miss (assuming you have even reached this far). Before you go, however, please bear with me while I explain why I think this book also has unintended implications for nothing less than the future of palaeontology.

When an *ad hoc* group of us founded the International Society for Reef Studies 27 years ago (<**http://www.fit.edu/isrs/aboutus.html**>), coral reef conservation was the domain of reef-monitors, a few prescient divers and 'pure' scientists, and eco-warriors, whose combined efforts were distinguished from 'pure' academic studies of reefs based on traditional marine biology, reef geology, *etc*. Now, with concern about the future of coral reefs at the forefront of most studies of modern reefs, this former divide has become completely blurred. The need to understand cause and effect for the current state of coral reefs, and to develop predictions and management solutions, is generating many challenging scientific problems, and is also bringing together an ever-widening range of different disciplines. From the earth sciences alone, the effort now embraces oceanographers, carbonate sedimentologists, climate modellers, geomorphologists, meteorologists, geochemists and palaeontologists. One of the most common questions increasingly asked of the earth science community is, 'What does the geological record tell us about the response of fossil corals and reefs to past environmental change?' Similar questions are being asked about other endangered ecosystems (Flessa *et al.*, 2005), but the excellent quality of the fossil record of reefs and other carbonates



associated with reefal organisms, makes them particularly suitable for asking this question. Moreover, the basic raw material of reefs, calcium carbonate, means that their state of health has an impact on rates of carbon burial and ocean acidification, with the latter potentially undermining the former, at least on shorter time-scales (Kleypas). For these reasons, over the last decade or so, I and other palaeontologists have found ourselves invited to take part in high profile workshops on reef ecology and conservation (*e.g.* Done *et al.*, 1996, Hughes *et al.*, 2003). This book is a logical (but independent) development of such workshops, in representing a group of earth scientists (mostly) who have taken their own initiative to address further these same concerns.

The palaeontologists involved at the interface with reef biologists are, broadly-speaking, palaeoecologists. Far back in the 20th century, palaeoecology was once part of mainstream palaeontology, as conveyed by some of the classic sources and text-books of the time (*e.g.* Ladd 1957, Hedgpeth 1957, Valentine 1973, Raup & Stanley 1978). Notwithstanding the valiant efforts of Brenchley & Harper (1998), this seems to have faded for various interesting reasons, too digressive to mention here. But it seems that in Australia and America at least, palaeoecology is now undergoing a rather specialist but important revival, which has hardly registered in Europe (in the present volume, only one of the 19 contributors has a European affiliation). This lack of interest may prove short-sighted – and here's the point about the future of palaeontology. If we are to believe many of the predictions about climate change and anthropogenic impact on ecosystems, they will fundamentally affect the ways in which we all live and work, regardless of how far away Europe lies from coral reefs. The projected time-scales are short: "The globally averaged [sea] surface temperature is projected to increase by 1.4 to 5.8ºC by 2100" (Wellington & Glynn), so as the 21st century progresses, the global scientific endeavour will surely become more concerned with the combined consequences of all these changes, just as scientists from every discipline were drawn into the war-effort during WW2. How relevant will current 'mainstream' palaeontology be then, and will it even continue to be mainstream?

This is not meant to be an argument for rigidly-directed applied research, but an appeal for more palaeontologists to seize an important opportunity to engage more fully with the biggest issue of our times (Rosen 2003, Flessa *et al.*, 2005). Or will we be found deeply buried in the exotica of palaeontological deep time, even as rising waters begin to lap around the walls of our more low-lying research institutions – thanks, ironically, to the burning of fossil fuels which palaeontologists have so obligingly helped the hydrocarbon industries to find? If you have read this far, there is no need to go on and read this particular book to get this general message. But should you be tempted to swing your own palaeontological interests, or those of your charges, in a new and vital direction, and are wondering how to go about this, this hefty volume leads by example in showing in detail what you can, and in some cases cannot, do to take part.

The book consists of twelve formal peer-reviewed chapters in the form of research papers, and a useful summary preface by Aronson, the academic editor. Chapters vary between specific case studies and broader reviews. As an aside, I commend the book for not combining the references for all the chapters in a single final compilation – a seriously inconvenient habit sometimes preferred by publishers. There is also a good index. The chapters are organized into four sections: (I – Coral reefs in context; II – Detecting critical events; III – Patterns of reef development and their implications; IV – Coral reefs and global change). The rationale for these divisions is explained in Aronson's preface, though in practice, key themes recur across these sections. However, the sheer size, detail, and interwoven implications of the whole book make it difficult to summarise key points, or its strengths and weaknesses. With regard to its aims (above), it is stronger on revealing what the geological record has been able to tell us so far, than it is on future management of reefs. But this is perhaps to be expected, not least because many of the factors which are now affecting coral reefs, including global warming and ENSO events (commonly called 'El Niños') cannot really be solved by geologists or reef management schemes alone.

In any case, this is not really a book about coral reef management, as such. More valuably, it stands as a methodological reference, and as a source of current knowledge about the hugely complex synergy of the current 'coral reef crisis'. Indeed, this very synergy, exemplified by the climate-related chapters in Section IV (Riegl, Wellington & Glynn, Kleypas) makes for unavoidably slow reading in many places. In spite of this, several chapters stand out as easy to digest and even enjoyable to read, notably Pandolfi & Jackson on Pleistocene history of Caribbean coral reef communities, Devantier & Done on identification and analysis of past Crown-of-Thorns seastar outbreaks, and Kleypas on the carbon cycle system in relation to predictions of coral reef response to climate change. Macintyre's chapter, on Holocene history of various western Atlantic reefs, is great fun too, engagingly presented in terms of his colourful but actually helpful concepts of Catch-Up, Keep-Up and Give-Up reefs, and – most dramatically of all, "Reefs Shot In The Back By Their Own Lagoons", all embellished with his cartoons as well as formal diagrams. Wood in her very readable opening overview of the "changing fate" of reefs through time shows her trademark verve and nerve in putting forward the notion that Bayesian methods might help in developing hypotheses about reef causes and effects, though we will all eagerly await a worked example.

Wood's introductory perspective (Section I) also provides a useful link for the wider palaeoecology community in connecting the book's concerns to studies of ancient reefs, inviting us to consider the widely-pondered question whether reefs have ever previously been subjected to a combination of changes comparable in kind and scale to those affecting modern reefs. Wood says the latter are "unprecedented", but perhaps it is too soon to say, because, as she herself emphasizes, the problem is that we see changes today on a human time-scale, though most of the past record cannot be resolved as finely. One notable exception is Devantier & Done's elegant use of preserved scars in large massive coral colonies, left by Crown-of-Thorns attacks; their results indicate a progressive recent increase in the frequency of such attacks. Sclerochronology (Deslarzes & Lugo-Fernández, Halley & Hudson) based on annual density banding, fluorescence-banding and stable isotope profiles also gives potential insights on this scale, but as these authors explain, reading this record is far from straightforward.

Beyond human timescales, the record of reef development and history of reef communities, through the later Quaternary, form the basis of the largest proportion of this book. From the community viewpoint, the key issue is posed by Greenstein, namely how far do fossil assemblages correspond to (or otherwise indicate) their original ecological character (*i.e.* "fidelity")? I found this chapter interesting, hard going and rather frustrating, because this question, and taphonomic processes more generally, are crucial, acting as a filter which we must reconstruct before we can sensibly begin to answer many of the questions posed elsewhere in the book. Greenstein focuses on the transition from life to death assemblages mainly by comparing species data, but I wondered if parallel sedimentological and facies data also have provided useful context and further insights. Moreover, taphonomic processes do not stop at the formation of death assemblages, as such. What happens next? Is not a death assemblage just one step on the way to a finally-preserved assemblage – assuming that it is not destroyed before it gets that far? Thus there still remains a broader time-honoured taphonomic question, going back to 19th century pioneers like Ehrenberg, Darwin, and Cullis, which is important to the study of fossil reefs and other biogenic carbonates of all ages, but not tackled anywhere in this book. Expressed in very general terms, there appear to be few if any models which conceptualize the different ways in which a given living coral (or other kind of) assemblage might become preserved as lithological bodies (*cf.* Skelton's "lithosomes", *e.g.* Rosen *et al.*, 2002). To Wood's overriding caveat about time-resolution in reading the past, we must therefore also add this taphonomic caveat. Ironically, in view of my earlier comment about the lack of input from Europe-based palaeontologists, a number of Europe-based carbonate sedimentologists have been working in precisely these taphonomy and modelling areas, and this could have been represented in this volume.

Going beyond the taphonomic gateway into the longer timescale past, four chapters are devoted to reconstructing ecological and geological events and causes in the history of particular modern Caribbean reefs going back through the Holocene (Aronson & Ellner, Macintyre) and into the Pleistocene (Pandolfi & Jackson, Precht & Miller). At nearly 160 pages in total, they constitute 40% of the book, and might be caricatured as 'all you ever wanted to know about Caribbean reefs'. Macintyre's neat holistic approach aside, they do embody some considerable debate and disagreement between them, the intricacies of which I will not try to summarise. Persistence with all the details is rewarding however, since all authors concerned keep their key issues clear. The main points for this review however are that they serve precisely to illustrate the very caveats mentioned already, of synergy, time-resolution and taphonomy. The most consistent picture to emerge is that of the very recent widespread loss or severe reduction of *Acropora* assemblages across the Caribbean, even if the causes are not yet clear (basically, disease *versus* changing ambient conditions). The former prominence of this coral leads to questions about how exactly it shapes reef development, and intriguingly now, how Caribbean reefs will develop with its much diminished presence. Bermuda, whose reefs have developed beyond the biogeographical range of *Acropora*, would seem to be the perfect natural experiment, so suitable synthetic models for its overall reef patterns and development are urgently needed. Perhaps also, those who study older reefs of the Cenozoic can contribute here, since in contrast to other modern reef-builders like *Porites*, and faviids like *Montastraea*, *Acropora* seems to have emerged as a major widespread reef contributor only in the latest Miocene–Pliocene (McCall *et al.* 1994).

The final section of the book is concerned with global climate; two contributions are mainly on ENSO events (Riegl, and Wellington & Glynn), and Kleypas' on global warming, already mentioned. The ocean–atmosphere complexities of ENSO rather overwhelm the uninitiated reader. They are not just a very recent phenomenon as is commonly thought, but from studies such as coral sclerochronology, they do appear to have increased in intensity (duration and amount of temperature fluctuation) over recent decades. The underlying concerns of all three climate chapters are of course increasing sea-surface temperatures (as above), both oscillatory (ENSO) and longer-term progressive (global warming). The most proximal effect on reefs is the much publicised coral bleaching, which particularly kills off *Acropora*. Returning to the questions of timescale and preservation above, it is interesting but seriously awkward that bleaching is a human timescale event which, so far, nobody has been able to identify convincingly in sclerochronological or any other studies.

If there is one chapter in this book which most people should read, it is Kleypas', not only for her particular subject matter, which is the one most relevant to most people everywhere, but because it is exemplary of this book as a whole, in avoiding the temptation to be over-conclusive. While emphasizing that the rate of current rise in carbon dioxide levels and global temperatures are effectively a "shock" to world ecosystems including reefs, Kleypas also gives good reasons for leaving open such issues as coral demise *versus* acclimatization, and the counter-effects of warming and ocean acidification on calcification. Tellingly, but honestly, her summary section is peppered with words like 'uncertainty' and 'difficulty', but the message is clear that while all these processes have, or probably have, happened in the past, it is more the sheer speed of present changes which appears to be "unprecedented" rather than, as Wood mentions, the changes themselves. The problem seems to be that any model of global recovery time is too slow in relation to the pace of current changes.

Overall, this book is fairly typical of Springer, with its rather grey photographic figures, relatively small print, and more a utilitarian production than a design classic. Nevertheless, it is of great value in exploring in detail what events we have so far been able to detect, what causes we can attribute them to, and most importantly in my own view, what methods can be brought to bear on one of the most important concerns of the day, namely the effects of local, regional and global change on modern coral reefs. Above all, we are entering the unknown, because we still have no clear idea whether the apparent direness of the present situation will eventually be offset by ecosystem adjustments and recovery, and on what timescale, or whether we are on the edge of irreversible change, even collapse.

Aronson is brave enough, nevertheless, to outline in his preface three emerging ideas, two of them predictions. I don't want to spoil Aronson's 'ending', so I leave readers to turn to the book to find out more. But of the three, I particularly warmed (pun permitting) to his "coral creep" prediction (the expansion of cold-sensitive species into higher latitudes), since most palaeontologists know that the ancient fossil record demonstrates precisely this over and over again. In the Eocene, for example, *Acropora* itself can be found in inshore siliciclastics of southern England – of all places (Wallace & Rosen 2006)! Perhaps we or our children will live to see this happen again, but at what cost? My apostrophized conclusion to all this however, is that funding bodies and policy makers should take note: there is clearly a long way to go, time is short, and more people, including palaeontologists, are needed to tackle the hugely important task of biotic response to global and environmental change.

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Trace Fossil Analysis

Adolf Seilacher (2007). Springer-Verlag Berlin Heidelberg,
ISBN 9783540472254 (hardback) $69.95.

There is something ever so special about picking up and opening a new book for the very first time that merely clicking on an icon on a computer screen could never hope to emulate. It is that instant and automatic impression of the book's quality, akin to the subconscious and long-lasting judgements that we make about the character and integrity (or otherwise) of new acquaintances in the first few seconds of meeting. The feel of the paper, the look of the text, the ability of the figures to catch the eye, the quality of the binding and even (I suspect) the aroma all combine to create an impression of what is to come. The real reason we will never, thankfully, have truly paperless offices!

So, what of the book to hand? Opening Seilacher's *Trace Fossil Analysis* for the first time, my immediate impression was of a book of the highest quality. Had I been wired up to the necessary equipment, I suspect that I could have recorded my pupils widening in pleasure and anticipation! The layout is striking, simple and in my experience unique, comprising as it does the plates and text of an entire course on the analysis and interpretation of trace fossils – apparently, verbatim, the course that Seilacher himself regularly delivers. There are 15 chapters; each one, according to the Preface, representing a two-hour lecture session and each with a brief introduction, literature section, and set of five one-page plates with accompanying page of text. The plates, being strategically and usefully placed on the right-hand page opposite the text on the left, are what catch one's eye the moment the book is opened, each composed of Seilacher's own beautiful, unmistakable, iconic hand drawings. Reading the book is indeed just like attending a Seilacher lecture; one can almost hear his voice as one reads the text!

The opening chapter took me by surprise. I was expecting the usual introductory approach most of us use, perhaps outlining trace fossil classification or the history of ichnology or some such. Instead the course begins with vertebrate tracks, the reason given being that these were the "first objects of paleoichnology" and that the discovery of *Chirotherium* (the object of the first lecture plate) marked "the beginning of scientific paleoichnology". Fair enough, but apart from being an unusual start, for me this is the weakest chapter, which perhaps might be a reflection of the fact that the author is not renowned as a vertebrate ichnologist. For example, one of the most exciting fields of study in vertebrate ichnology in recent years is the experimental analysis of track and undertrack formation using a variety of tracemakers from elephants to ostriches. None of this work is referenced, despite Plate 2 being devoted to "undertracks in wet sands". In addition, despite the author's own introductory statement that "No other trace fossils impress the public as much as dinosaur tracks" (replace 'public' by 'typical undergraduate student'…), interpretations of dinosaur tracks, herding behaviours, gaits and speeds are all curiously absent.

Despite the slightly shaky start, the book soon takes off and delivers the high quality promised by the initial impression, and expected from the author. The next three chapters cover arthropod trackways, trilobite burrows and arthropod tunnel systems respectively. Topics covered by individual plates range from the detailed analysis of a single slab (Plate 9: Adventures of an Early Cambrian Trilobite – a great lecture title and an interesting read to boot!), through to the detailed documentation and interpretation of the range of possible variation, behavioural and preservational, encountered in a single trace fossil group (*e.g.* Plate 18: Ophiomorphids). In all cases the descriptions of morphological variants are clear and supported superbly by the author's own drawings.

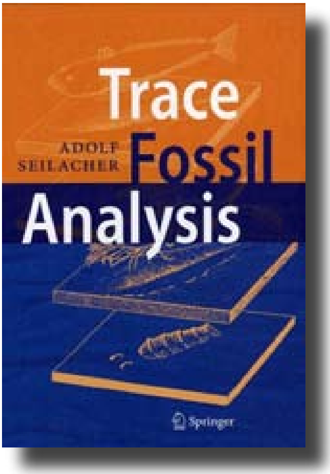
The next chapter describes resting traces, or cubichnia, and includes a plate devoted to asterozoan resting traces (Plate 24). I was looking forward to this plate immensely, having devoted many a happy field day in the Italian Dolomites foraging for specimens of *Asteriacites lumbricalis* in the fine sandstones of the Lower Triassic Werfen Formation. These cute and appealing ichnotaxa, which make wonderful teaching specimens, were described, illustrated and analysed by Seilacher over fifty years ago (Seilacher, 1953). The same set of drawings was reproduced in Häntzschel (1975, p. W31) and now in Plate 24 of this new book. Unfortunately, this is one of the very few instances where one of Seilacher's own drawings could have done with an upgrade – the reproduction is somewhat poor and looks like a low-resolution scan of Häntzschel (1975), which is a great shame.

The next chapter (Chapter VI) has the best title of any trace fossil lecture anywhere: The Burrows of Short Bulldozers. This, of course, is followed by its companion chapter (VII) on The Burrows of Wormlike Bulldozers. I have already adapted my own powerpoint lecture slides to incorporate these titles! Wonderful!

Finally, at long last, we find a lecture on Trace Fossil Classification: plate 31, p. 92, and almost half way through the course. Although neatly done, as expected, and covering all the necessary terminology, the position of this plate is very odd. In my opinion, it occurs far too late in the book, particularly given that terms such as "cubichnia" have been introduced long before.

Chapters VIII through to XI cover the burrows of stripminers, arthrophycid burrows, probers and deepsea farmers respectively. Topics discussed include the nature of Palaeozoic versus post-Palaeozoic *Zoophycos*. Having seen more than my fair share of Permian and Triassic marine rocks, and having been struck by the abundance of *Zoophycos* in the former and near absence in the latter, this is a topic of great personal interest. What was happening to the *Zoophycos* tracemaker(s) during the Palaeozoic–Mesozoic transition? Was there really a physical movement of *Zoophycos* tracemakers offshore during the later Mesozoic? As Seilacher notes "…there is no simple explanation for all the intricacies of *Zoophycos* and its evolutionary modifications. The problem will probably stay with us for a while."

In Chapter XII we make a bit of a sideways leap, from true trace fossils to pseudo-traces. Topics such as tool marks, synsedimentary load structures and septarian nodules are all covered, among others, culminating with a discussion of tectograms (featuring Seilacher's re-interpretation of Vermiforma). The discussion of what makes a true trace fossil leads on nicely to the next chapter (XIII) that deals with evidence for the earliest trace fossils and which begins with a discussion of the 1100Ma Chorhat "burrows". The rest of the chapter details such ichnotaxa as *Kimberella*, and *Treptichnus pedum*, before culminating with a discussion of the agronomic revolution that took place in soft substrates following the appearance of an abundant and enthusiastic infauna.



The penultimate chapter (XIV) deals with the stratigraphic applications of *Cruziana*. I was somewhat surprised that an entire chapter was devoted to this topic, but as it's one of the author's pet subjects I guess that's understandable. I suspect that not many of us would devote so much time in an undergraduate course to *Cruziana* stratigraphy. Of far more importance, to my mind, is the ichnofacies concept, which is covered, albeit briefly, in the final chapter (XV). This is of such importance to a range of fields including sedimentology, palaeoenvironmental studies, and petroleum exploration that I would have liked it to have received more column inches, but what is there is good. The final plate is devoted to those rare but eloquent specimens from Solnhofen that show the final death marches of various unfortunates that were washed, alive, into the toxic bottom waters of the lagoon. These traces are always a favourite amongst the students and Seilacher has now given them a name: mortichnia.

So that's the book: do I recommend it?

Certainly those of us who deliver undergraduate or postgraduate courses on trace fossils will find this volume to be of tremendous use as a source of quality illustrations and examples for lab or lecture theatre. I would also strongly recommend this book for any postgraduate students embarking on a research degree in ichnology: *Trace Fossils Analysis* by Dolf Seilacher will be a source of inspiration to up-and-coming ichnologists for years to come!

However, and unfortunately, I won't be recommending this as a course text for my undergraduate students. One reason is that I think the book assumes too much knowledge for 1st or 2nd year undergraduates to benefit, and is perhaps pitched a little too high. Secondly, although each chapter has a list of relevant literature, none of this is cited in the text. This makes it harder for students to track down the relevant primary sources, and is also against the principles of good referencing that we try to instil into students from day one. Finally, the balance of the book (with not enough on the applied aspects of the subject) is probably not quite right for the general geology undergraduate, especially one with no prior knowledge of the field, and who will (unfortunately, and due to the constraints of the university timetable) only be getting ten hours of ichnology rather than thirty. Perhaps those undergraduates studying for palaeontology degrees would find it of more use.

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Amniote Paleobiology: Perspectives on the Evolution of Mammals, Birds, and Reptiles

Matthew T. Carrano, Timothy J. Gaudin, Richard W. Blob and John R. Wible (eds) (2006). University of Chicago Press, Chicago and London.
ISBN 0226094782 (paperback), $40.00 / £25.50.

Despite the popular appeal of both the furry and the feathered they are rarely united in a single volume such as this second palaeontological festschrift from UC Press. Following not-so-hot-on-the-heels of the popular (628 citations; <**http://wok.mimas.ac.uk/**>) *Evolutionary Paleobiology* (Jablonski *et al.*, 1996), this work honours James Allen Hopson's 35-year stint at the University of

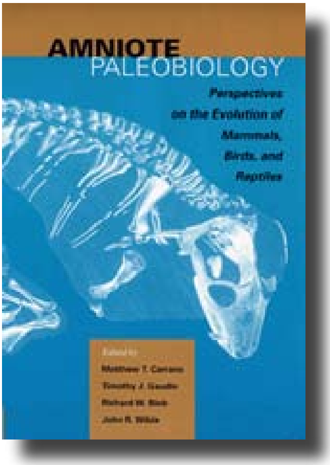
Chicago and features a rather eclectic set of contributions ranging from armadillo phylogeny to plesiosaur brains.

A similar size, style and layout are retained from *Evolutionary Paleobiology*, with the editors including a separate review chapter as well as the obligatory mini-biography. Although the papers are grouped into four sections there is no real unifying theme here. A discourse on the origins of truly terrestrial vertebrates this is not. (Sumida and Martin's 1997 book *Amniote Origins: Completing the Transition to Land* remains the only attempt at such an endeavour).

So what can you expect? Well, rather oddly, the first paper proper isn't on an amniote at all, but the Carboniferous amphibian *Whatcheeria*. (Although an accident, perhaps it is fitting that a volume honouring a proponent of phylogenetic systematics should include an outgroup.) Here Eric Lombard and John Bolt show that the character-rich lower jaw is more consistent with the primitive condition for early tetrapods and hence serves as a useful starting point in understanding the evolution of the tetrapod mandible.

The bulk of the offerings are concerned with a diverse array of stem-mammals. First amongst these is a new biarmosuchian with the best preserved skull of a group Hopson helped erect, although a lack of phylogenetic resolution is blamed on a lack of postcrania. The importance of this is emphasised by Hans-Dieter Sues and Farish Jenkins, who use the back-end of *Kayentatherium wellsei* to argue that tritylodontids, once considered basal mammals primarily based on postcranial characters, aren't even superficially mammalian. Tritylodontids form the starting point of Guillermo Rougier and John Wible's ascent of the mammalian stem, a portion that documents a wealth of anatomical changes in the ear and basicranium that only became possible with the wealth of skulls discovered over the last 35 years. Meanwhile, Richard Blob attempts to identify the point at which mammalian endothermy arose by utilising the observation that modern endotherms exhibit a negative allometry of limb-bone scaling through ontogeny, although *Cynognathia* seems to show the exact opposite trend. *Lystrosaurus* claims its place in the last paper of the volume, with Frederick Grine and colleagues using a variety of metrics to whittle down the 27 species described from South Africa alone to just 17 valid taxa.

Crown-group mammals are represented by three fairly diverse papers. The first of these is a new phylogeny of armadillos that includes both living and fossil taxa, and shows that the group as a whole is paraphyletic. Paul Sereno wrestles with the problem of defining major nodes in the mammalian tree and concludes that theriimorphs (extant mammals excluding the monotremes) may be defined better by features of the shoulder joint rather than the jaw. Finally, Alfred Crompton and colleagues contrast differing adaptive explanations of the complex jaw movement found in primates and herbivores, and favour a model that minimises the movement between upper and lower postcanine teeth during jaw closure.



Avian workers will be disappointed to find their group represented by just three papers, all of which concern those lovable stem-birds, the dinosaurs. The first of these concerns two partial theropod specimens from Mexico's Early Jurassic Huizachal fauna, further suggesting a similarity with the US Kayenta Formation and hence a younger age for the latter. Michael Parrish argues that whatever the long necks of sauropods were for, they didn't appreciably increase maximum feeding height after the Triassic – whereas Matt Carrano applies a barrage of methods to show that the majority of dinosaurian clades do show an increase in size, with the notable exception of that containing birds.

The odd one out here is Robin O'Keefe's paper on plesiosaurs, whose nearest living relatives may be archosaurs (birds and crocodiles), lepidosaurs (lizards, snakes and *Sphenodon*) or turtles, depending on which phylogeny you choose to believe. Here O'Keefe is more concerned with an apparent trend in plesiosaur basicrania to return to a more plesiomorphic condition and suggests that neoteny might be the cause.

The quality of these offerings is variable, although some undoubtedly have a broader appeal, particularly with regard to some of the methodological treatments, which could easily be applied elsewhere. My biggest gripe with this book is the small size of the figures, many of which can be hard to read. Other niggles include minor errors in the text that the editors really should have picked up – what, pray tell, is a stem-sauropterygian? There was also an obvious delay in publication, with some papers clearly finished a couple of years before the publication date. This has led to some unfortunate oversights; for example Carrano makes no mention of an older paper (Hone *et al.* 2005) on exactly the same topic. However, these are mostly minor quibbles and not fatal to the book's appeal.

Despite the disparate nature of the offerings included I would still recommend this book, not least because it represents good value for money (a quick search on **bookfinder.com** should list a copy for less than £20). Ultimately, it is probably the diversity of the contributions that is the book's greatest strength. Such a wide array of approaches to some very different problems ensures that each reader will get something out of it. Although it has some way to go to match the popularity of its predecessor, hopefully it is not the last of what promises to be an influential series of volumes.

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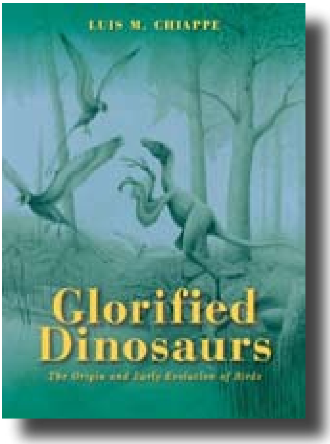
Glorified dinosaurs: The origin and early evolution of birds

Luis M. Chiappe (2007). Wiley, New York,
ISBN 9780868404134 (hardback) £38.95/ $69.95.

Why do sane adults buy lavishly illustrated books about dinosaurs and fossil birds, but not about crinoids or cycads? Luis Chiappe, Curator of Vertebrate Paleontology at the Natural History Museum



of Los Angeles County, has written a remarkable, personal, and highly professional book about the latest research on Mesozoic birds, all 100 genera of them, and his publisher has allowed him a large format, original colour artwork and photographs throughout. And the cover price suggests that Wiley has made a largish print run and expects the book to sell.

Palaeontologists should be glad. At one time, the intelligent reading public would only invest their money in books about human evolution, or perhaps the history of life from the beginning to the present day. No such caution today: first dinosaurs, then fossil birds, then the Cambrian Explosion, then trilobites, fossil mammals, the first tetrapods, the KT event, the end-Permian event, the Quaternary extinctions, even fossil fishes. It seems that palaeontologists can get away with nearly anything. My sedimentologist and structural geologist friends are green around the gills: try as they might, they can't sell a popular book about alluvial fans or kink bands.

I used to think it was big teeth that did it – dinosaurs. Then maybe legs – dinosaurs, birds, trilobites. I think it is just locomotion of any kind, so Burgess worms and fossil fishes are also marketable. The real breakthrough will come when a palaeontologist can sell sessile organisms to the public – corals, crinoids, brachiopods, cycads. There's a challenge.

Luis Chiappe is riding a wave. Not only has he written several books about fossil birds (most notably Chiappe & Witmer 2002), but also about South American dinosaurs. He is also the star in the recent Dorling Kindersley *Eyewitness Expert: Dinosaur* ('written by today's experts for the experts of tomorrow', a pack containing all you need to become a dinosaur palaeontologist – posters, dinosaur profile cards, expert files, clip art CD): Luis is presented as a career model for budding fossilists.

Glorified dinosaurs is a thorough overview of everything that is known about Mesozoic birds. Chiappe presents much that is personal: he was involved in many of the early studies of the remarkable Early Cretaceous birds from Liaoning, and in fact produced what is still the only serious monograph on the confuciusornithids (Chiappe *et al.* 1999). In the text, he tells the story well, painting a picture of the people and the exotic locations in China and elsewhere in the world where he has studied fossil birds: North America, South America, Europe, Mongolia. There are many boxed items in which he presents historical essays and recent research reports. Many of the photographs are his and they have not been used in books before. The drawings are mainly from the original scientific papers, and they have been attractively rendered for the book.

Chiappe does not flinch from presenting the current science in detail. Readers are led gently, but firmly, through the cladistic method, as well as the fine details of disputed phylogenetic arrangements of the basal birds. I note he has the wisdom not to mention the Phylocode, nor crown group renaming. As a former postdoc at the American Museum of Natural History, he has managed to avoid their move to label *Archaeopteryx* and most Mesozoic birds as avialans (substituting Avialae for Aves), and labelling the crown group (ostrich, sparrow and everything else in between) as Aves. This fashion a few years ago led to endless confusion, and I'm glad Chiappe has quietly sidestepped the craze. *Archaeopteryx* is an avian, a bird, a member of Aves, as it always has been.

This is a remarkable book, and it has clearly been a labour of the heart for Luis Chiappe. He is an excellent writer, and his judgment about how to lead the reader through the latest research on phylogeny, morphometrics, biomechanics, and the origin of flight is impeccable. I'm delighted Wiley has dared to make such a fine book, and I hope it sells as well as it deserves.

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Brachiopods from the Upper Ardmillan Succession (Ordovician) of the Girvan District, Scotland

David Harper (2006). Monograph of the Palaeontographical Society, London, (Publ. No. 624, part of Vol. 159) 129–187, pls 23-33
ISSN 02693445 (paperback) £130.

The brachiopods of the Upper Ardmillan succession of the Girvan district, south-west Scotland have been scrutinised for over one hundred and forty years. Initially, Thomas Davidson (1866–1871, 1882–1883) described a number of the brachiopods. The most extensive survey by Reed (1917), was followed by efforts by Lamont (1934, 1935) and others. These earlier works were boosted by the relentless collecting of Mrs Alice Gray (and daughters) that spanned eighty-six years from 1855 to 1941.

The publication of this monographic treatment of the brachiopods has been awaited for a long time (I could have done with it some years ago when undertaking my PhD!) and it is pleasing that it is now available. The first two instalments in the trilogy were published some 20 or so years ago, so the completion of the story was overdue.

The first part of the monograph presents short, concise, chapters on the stratigraphy, taxonomy, palaeoecology and palaeobiogeography of the Girvan faunas. Obviously, parts of this information have been published elsewhere previously, but herein these introductory chapters provide a very useful summary of events in the Girvan district during the uppermost Caradoc to uppermost Ashgill. Updates, mainly on stratigraphical and taxonomic aspects, since publication of the first two parts, allow the reader to consider the latter in the light of the most up-to-date research on the area; the use of clear comparative tables, especially Tables 1 and 2, is particularly helpful. These updates reflect not only the 20 years of research on the specific subject, but the 40 years of research on brachiopod taxonomy recently summarised in the revised version of the *Treatise on Invertebrate Paleontology* (Kaesler 1997–2004). Advances in statistical analysis of data in the intervening period, to which the author has contributed, are also acknowledged.

The main bulk of Part Three is represented by the systematic descriptions. One new genus and a new subgenus are described along with six new species and two new subspecies. The systematic descriptions continue from where Part Two paused, *i.e.* Strophomenacea of the order Strophomenida, and carries on to treat the Rhynchonellida, Pentamerida, Atrypida and finally the Athyridida. This follows the arrangement of the preceding two parts – for the obvious reason of maintaining consistency. The taxonomic descriptions are to the same high standard as in Parts One and Two, with pertinent comparisons and comments included in the 'Remarks' paragraphs.

The text concludes with a comprehensive list of all the generic names used in Parts One to Three. This is in the form of an index, as is usually the case in a Palaeontographical Society Monograph.

Last, but not least, are the plates; these, as you would expect for a Palaeontographical Society Monograph, are of very good quality. The specimens have been optimally whitened with ammonium chloride such that anatomical details are accurately reproduced on the photograph (for example fine ribbing on Pl. 23, fig. 17; internal features on Pl. 26, fig. 7) and not smothered as can sometimes happen.

Not a bedside table book of course, but this is not the aim of such work. This is a specialist work for palaeontologists interested in the phylum Brachiopoda. Highly recommended!

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Evolutionary pathways in nature. A phylogenetic approach

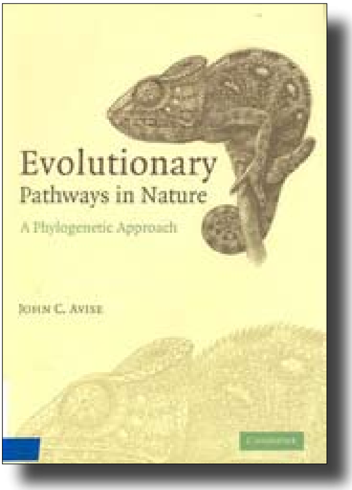
John C. Avise (2006). Cambridge University Press, Cambridge.
ISBN 0521674174 (paperback) £37.50; ISBN 0521857538 (hardback) £70.

What, if anything, is evolutionary biology about? According to some it is at least clear what it is not about. “Evolutionary biology is not a story-telling exercise,” states evolutionary geneticist Michael Lynch (Lynch 2007: 8597). If by that Lynch means that evolutionary biology is not simply an exercise in imaginative writing rooted solely in fantasy, without any mooring in facts and testability, than he is absolutely right. But Lynch’s remark was not intended, for instance, to illustrate the incompatibility of evolutionary narratives and Genesis fantasies.

In contrast, Lynch wrote to rebuff evo-devoist Sean Carroll who has the audacity to claim that he thinks that the study of the evolution of form is a more “inspiring theme” than just the study of changing gene frequencies. Lynch quite rightly claims that the task of population genetics is not to be inspiring, but to be explanatory. It is indeed essential to understand the fundamental population-level forces that govern evolutionary change: natural selection, mutation, recombination, and genetic drift. However, we might also want to know what actually happened to organisms, including their phenotypes. How and when and in what way has evolution changed organisms? Integrating the particular unique details of what actually happened to a group of organisms in the context of the fundamental forces that govern evolutionary change can only take one form, namely that of a story. The construction of such stories, otherwise known as historical narratives, is the ultimate goal of evolutionary biology.

Luckily, readers of Avise’s book do not have to wrestle with such highfalutin conceptual issues. This enjoyable and timely book pleasantly refutes Lynch’s claim that it is a fundamental misunderstanding to think that stories have a role in evolutionary biology. Like Sean Carroll, and dare I say most of us for that matter, Avise is fascinated with stories about the evolution of phenotypes, from physical attributes to behaviours, ecologies, life styles, and even geographical distributions. Avise relates 67 such evolutionary tales in clear prose, and with careful explanations, making this book an attractive read for professionals and the general public alike. All stories take the same form. A molecular phylogeny forms the backdrop of an exercise in character mapping, the principles of which are explicated in a brief introductory chapter. The book concludes with a useful glossary, and an, in my mind, unnecessary appendix that treats several technical aspects of character mapping in more detail. Avise’s careful explanations throughout the book largely remove the need for the appendix. Mastering the extra technical knowledge will likely neither enhance the significance nor the beauty of the stories told.

The stories are grouped into six chapters titled ‘Anatomical structures and morphologies,’ ‘Body colorations,’ ‘Sexual features and reproductive lifestyles,’ ‘More behaviours and ecologies,’ ‘Cellular, physiological, and genetic traits,’ and ‘Geographical distributions.’ They cover ground as diverse as the phylogenetic position of polar bears and pandas, the evolution of kangaroo hopping, web building by spiders, antifreeze proteins in Arctic and Antarctic fish, and many more. If your heart only starts to beat faster at the mention of bacteria or fossils, you will mostly be disappointed, because Avise has selected his case studies to satisfy the interest of the elusive average reader. However, the book contains enough fascinating titbits of evolutionary arcana to satisfy professional evolutionists as well.



Avise uses the phylogenetic tales to instruct the reader gently about general concepts in evolutionary biology, from paedomorphosis to sexual selection and convergence. The importance of convergence is impressed especially strongly upon the reader, for almost half of all tales reveal the polyphyly of some of nature's most successful designs. However, here Avise foregoes an opportunity to discuss the important conceptual dichotomy between convergences and parallelisms with respect to the relative importance of external and internal determinants on the direction of evolutionary change. Yet, it is obviously not one of the book's main goals to present a nuanced discussion of general concepts, and I shall therefore not carp about other conceptual slips (happily a rare occasion) or omissions in the book. The remaining stories deal primarily with the power of paraphyly to reveal evolution's highly priced and much coveted intermediate states (evolution of the elongated jaws of needlefishes), and the power of unexpected monophyly to show the unity of nature's diversity (Afrotheria clade).

One pervasive caveat applies throughout the book, as candidly admitted by Avise: uncertainty. As one descends down the levels of analysis from phylogeny, to character mapping, to scenario of character change, the degree of uncertainty increases. One phylogeny may be compatible with several alternative character mappings, and a given character mapping may be explained by several pathways of character change that could have taken place in several different possible contexts of available variation, constraint and selective pressures. As a result many of the stories in the book are currently only tantalizing first sketches that will hopefully, in due time, grow into fully fledged historical narratives, with clearly specified intermediate stages between the endpoints of evolutionary transformation, and a basic understanding of the historical context in which those changes took place. Reaching such a complete level of understanding, alas, ranks among the most recalcitrant problems in biology.

John Avise has done us a great service. In a market that is dominated by books on "how to do" phylogenetics, it is refreshing to see one that so ably serves as an answer to the question: "why should we bother to do phylogenetics in the first place?" The answer is, obviously, that there are a million and one fascinating stories to be told about the history of life. And we all like a good story.

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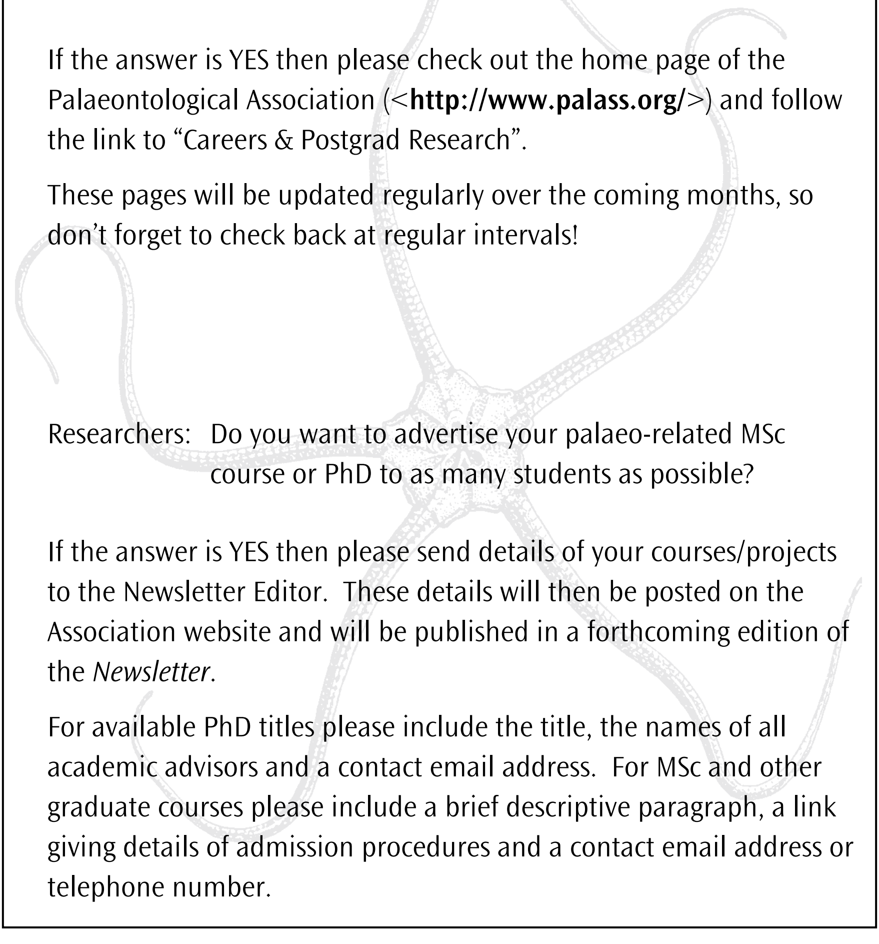

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