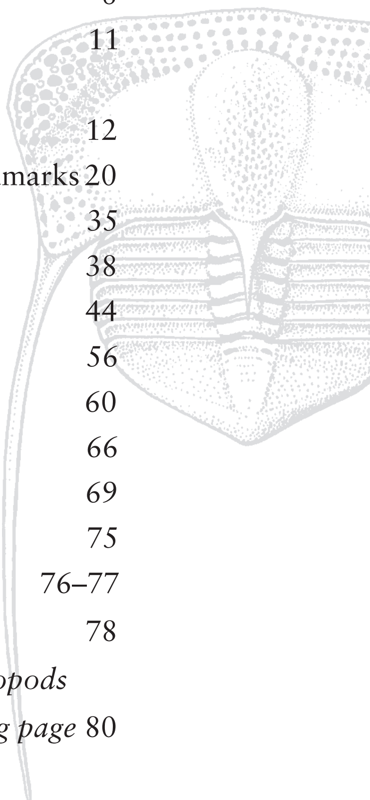
The Palaeontology Newsletter 84



Contents

Reminder: The deadline for copy for Issue no 85 is 10th February 2014.

On the Web: <**http://www.palass.org /**>

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Editorial

With *Newsletter* **84** we have changes in the Association and within the Newsletter. Please do read the proposed changes to the Constitution of the Association prior to AGM and we expect many of you to be present to vote on these changes. We have a number of people stepping down from various roles on Council, who have contributed a great deal to the running of the Association in a voluntary capacity. An up-to-date list of nominees for vacant posts is also printed. We hope many of you will be able to attend the Annual Meeting in Zurich and take part in the AGM.

With Newsletter 84, Norm MacLeod's *PalaeoMath* column comes to an end. Norm has worked on the column for the Newsletter since Newsletter 55. This contribution has been by far the longest-running of the technical columns the Newsletter has published, spanning 30 columns over nine years. As someone who has worked with morphometric tools and analyses in research and teaching, I have personally found the column of great utility. His columns echoed the 'first principles' approach taken by nearly all texts on morphometrics, starting at the beginning with bivariate plots and the correlation co-efficient and ending with the state-of-the-art in eigenanalysis. Norm has always made the columns very much his own in a field of big personalities and sometime heated discussion about the appropriate analytical methods. The accompanying datasets and offers of help with computer code have made this a significant resource that will remain freely available on the Association website.

However, the Newsletter portfolio will continue to contain a column with a strong quantitative focus. Mark Bell has agreed to contribute a series of columns on the free statistical programming language **R**, which has become more and more widely used. The intent of the column is to provide an introduction to the language through a range of examples of use to palaeontologists and palaeobiologists, and the plan is to provide working examples of R scripts that can be copied and pasted directly into the R user interface. If you want to start exploring R, the basic package can be downloaded from <**http://www.r-project.org /**>.

Al McGowan
University of Glasgow
Newsletter Editor
<**newsletter@palass.or g**>

Association Business

Annual Meeting 2013

Notification is given of the 57th Annual General Meeting

This will be held at the University of Zurich, Switzerland, on 14th December 2013, following the scientific sessions.

All the information for the AGM is included at the end of the supplement to this Newsletter (on the coloured pages).

Please note that this information includes proposals to change the Constitution and to amend the subscription rates.

AGENDA

1. Apologies for absence
2. Minutes of the 56th AGM, University College Dublin
3. Trustees Annual Report for 2012
4. Accounts and Balance Sheet for 2012
5. Proposed amendments to the Constitution
6. Proposed changes to subscriptions
7. Election of Council and vote of thanks to retiring members
8. Report on Council Awards
9. Annual address

At the AGM, the following vacancies will occur on Council: President elect, Vice-President, Editor-in-Chief, two Editor Trustees, Internet Officer, Publicity Officer, Outreach Officer, Education Officer, three Ordinary Members.

The following nominations were received by the deadline:

President elect:	Prof. David A. T. Harper
Vice President:	Dr Mark Sutton
Editor-in-Chief:	Dr Andrew B. Smith
Editor Trustees (two posts):	Prof. Charles H. Wellman
	Dr Marcello Ruta
Internet Officer:	Mr Alan Spencer
Publicity Officer:	Dr Liam Herringshaw
Outreach Officer:	Dr Fiona Gill
Education Officer:	Dr Caroline Buttler
Ordinary members (three posts):	Dr Richard Butler
	Dr Cris Little
	Dr Martin Munt

Awards and Grants

Lapworth Medal

The Lapworth Medal is awarded by Council to a palaeontologist who has made a significant contribution to the science by means of a substantial body of research; it is not normally awarded on the basis of a few good papers. Council will look for some breadth as well as depth in the contributions in choosing suitable candidates.

Nominations should be supported by a resumé (single sheet of details) of the candidate's career, and further supported by a brief statement from two nominees. A list of ten principal publications should accompany the nomination. Council will reserve the right not necessarily to make an award in any one year. Details are available on the Association Website or from the Secretary (e-mail <**secretary@palass.org**>). The deadline for nominations is **1st March 2014**. The Medal is presented at the Annual Meeting.

President's Medal

The President's Medal is a mid-career award for a palaeontologist in recognition of outstanding contributions 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 are invited by **1st March 2014**, supported by a single sheet of details on the candidate's career, and further supported by a brief statement from a seconder. A list of ten principal publications should accompany the nomination. Council will reserve the right not necessarily to make an award in any one year. Details are available on the Association Website or from the Secretary (e-mail <**secretary@palass.org**>).

Grants-in-Aid: Meeting Support

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. If the application is successful, we will require that the support of the Association is acknowledged, preferably with reproduction of the Association's logo, in the Meeting literature. Application should be made in good time by the scientific organiser(s) of the meeting on the online application form (see <**www.palass.org**>). Such requests will be considered by Council at its March and October Meetings each year. Completed requests should be made at least six months in advance of the event in question. The next two deadlines are **1st March** and **1st October 2014**. Enquiries may be made to the Secretary (e-mail <**secretary@palass.org**>).

Grants-in-Aid: workshops and short courses

The Palaeontological Association is happy to receive applications from the organisers of workshops and short courses for grants-in-aid. If the application is successful, we will require that the support of the Association is acknowledged, preferably with reproduction of the Association's logo, in the workshop's literature. Application should be made by the scientific organiser(s) on the online form (see <**www.palass.org**>). Such requests will be considered by Council at its March and October Meetings each year. Completed requests should be made at least six months in advance of the event in question. The next two deadlines are **1st March** and **1st October 2014**. Enquiries may be made to the Secretary (e-mail <**secretary@palass.org**>.

Annual Meeting Attendance

The Palaeontological Association runs a programme of travel grants to assist student members (doctoral and earlier) presenting talks and posters at the Annual Meeting. For the Zurich meeting, grants of up to £100 (or the Euro equivalent) will be available to student presenters who are travelling from outside Switzerland. 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 (e-mail <**palass@palass.org**>), once the organisers have confirmed that their presentation is accepted, and before **1st December 2013**. Entitle the e-mail 'Travel Grant Request'. No awards will be made to those who have not followed this procedure.

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. Online guidelines and the application form are available on the website (<**www.palass.org**>) for the deadline of **1st March 2014**.

Undergraduate Research Bursary

Notice is hereby given of the Palaeontological Association's new Undergraduate Research Bursary. Council has agreed that Association funds should be made available to support undergraduate students who wish to gain experience of undertaking original palaeontological research during their degree. A weekly stipend of £200 will be provided to each successful student up to a maximum of eight weeks, and it is anticipated that up to ten awards will be made each year. Further details will be available on the website soon and will be communicated to the membership by e-mail. The first deadline is expected to be in **February 2014**.

Richard J. Twitchett
<**secretary@palass.org**>

Palaeontology – a journal in transition

In July I took over as Editor-in-Chief and acting chair of publications committee and at the same time our new Publications Officer, Sally Thomas, took up post. It has been a steep learning curve for us both, but after three months in the job it seems an appropriate time to let you know what has been happening and to outline how I envisage the journal developing over the next five years.

I'm pleased to report that the journal is in good health, thanks in large part to changes introduced by our previous chair of publications, Paddy Orr, before he handed over. The first thing to note is the revised scope: "The journal *Palaeontology* is devoted to the publication of innovative and timely hypothesis-driven research that significantly advances understanding of the history of life on Earth." That is to say the papers we now accept are those that use empirical data to investigate aspects of Earth history or life in the past that have broad relevance and impact beyond the specific taxa being studied. This doesn't preclude papers that include alpha systematics, but any systematics must be there as supporting data not as an end in itself.

You will also find that papers now pass through a two-stage review process. First a triage committee of five reads each submitted paper to see if it fits the new remit of the journal. Well over half of current submissions get rejected at this stage because they are deemed too narrow in their scope. Papers that survive this first sift are then passed to one of 19 science editors who oversees the review process by two specialist referees. According to the reports received, papers will have to be revised to a greater or lesser extent, but the majority will eventually get published.

Two important changes have recently been instigated to help improve the journal:

The International Commission on Zoological Nomenclature (ICZN) now accepts new taxa erected in electronic publications as valid. In order to conform to ICZN recommendations we now require all new animal taxa in publications to be registered with Zoobank (<**www.zoobank.org**>) and issued with a unique identifier. This ensures that new taxa are validated and we can move swiftly to release papers on early view rather than holding them on embargo until they are ready to print.

We now recommend and expect all supporting data to be lodged as electronic supplementary data with Dryad (<**www.dryad.org**>). This frees up papers from the need to publish large character matrices or tables of specimens and data, and provides a safe and secure long-term repository. There is a cost involved, but the Association pays for this as a service to authors.

Finally we have been working very hard to clear the backlog of papers that had built up, and I am pleased to report that this has now all but disappeared! We are currently processing papers from acceptance to electronic release on early view within four to five weeks, and from acceptance to appearance in print within six months; rapid communications and review articles get pushed through even faster. This is now a standard of service you do not get from many journals.

Looking to the future

It has long been clear that for palaeontology to thrive, it needs to move beyond simple descriptive and *ad hoc* narrative. Many of you are aware of this and the rigour and standards of papers being published has greatly improved over the last decade. I would like the Association's journal

Palaeontology to continue to drive up standards, and in the coming year you will find the journal becoming a bit thinner, with shorter, more pithy research-based contributions and timely reviews. A new series of short, topical reviews is beginning in 2014 in which leaders in their field review recent advances and give a personal view of the most significant discoveries. For 2014 the theme is “origins” and I have lined up 16 contributors to provide overviews of a range of major taxonomic groups, including eukaryotes, seed plants, molluscs and crown group birds.

Beyond 2014 there is likely to be even more drastic change. Shifting to continuous publication and electronic only would make a lot of sense for the journal in reducing costs, speeding up publication still further, and better serving the electronic-based younger generation of palaeontologists. Open access is another critical issue, with funding bodies looking to have research data they have paid for being made freely available. Having research results free to view certainly makes for better communication and higher citation, but a financially viable model for charities like us that depend upon publication income to fund our activities has yet to emerge. One possibility I am looking into is the provision of an open access option at a realistically affordable cost to authors – but that is under investigation as I write.

Finally I am acutely aware that the quality of our science depends upon us maintaining as accurate a taxonomic database as possible. If our taxonomy is awry then conclusions drawn from any analysis of these data is suspect. Yet the painstaking foundational work of taxonomic revision rarely attracts much interest from outside the immediate specialists in the field and, on its own, is now very unlikely to be published in *Palaeontology*. I am therefore looking into ways in which we might provide a platform for high-quality taxonomic papers or papers that require extensive morphological description. The obvious solution is to revamp *Special Papers in Palaeontology* to accommodate these, but precisely what format such a journal will take has yet to be settled.

We hope that with the now rapid publication time and our greater emphasis on research-focused problem solving, *Palaeontology* can become the platform of choice for showcasing the diverse sorts of questions that palaeontological data can be used to address. I look forward to receiving your papers and will endeavour to ensure they are handled efficiently and speedily.

Andrew B Smith
Editor-in-Chief

ASSOCIATION MEETINGS

57th Annual Meeting of the Palaeontological Association
University of Zurich, Switzerland *13 – 16 December 2013*

The 57th Annual Meeting of the Palaeontological Association will be held at the University of Zurich, Switzerland, organised by Christian Klug, Heike Goetzmann and colleagues from the Palaeontological Institute and Museum.

All the information required for the Annual Meeting is provided in the supplement on the coloured pages in this Newsletter.

Please address all queries to <**annualmeeting@palass.or g**>.

We look forward to seeing you in Zurich in December!

Abstract of Annual Address

Sharks and the deep origin of modern jawed vertebrates

Michael Coates
Department of Organismal Biology & Anatomy, University of Chicago, Chicago, USA

New specimens, methods and trees are transforming our understanding of early shark-like fishes and the early evolution of gnathostomes. Chondrichthyes (sharks, rays and ratfishes) tend to be characterized as primitive, but supporting evidence is elusive: living outgroups (agnathans) are phylogenetically remote, and the fossil record of early sharks is well known to be fragmentary. Changes have been triggered by phylogenies assembled in response to discoveries of remarkable Silurian and early Devonian fishes, revealing new sets of primitive conditions for modern clades. Importantly, such analyses are dismembering long accepted groups of early jawed vertebrates: acanthodians are emerging as primitive chondrichthyans, and placoderms as stem lineage gnathostomes. Such studies have benefited significantly from the particular value of CT technology for investigations of early chondricthyan morphology. Implications of these new trees and data are still being assessed. The latest branching patterns are far from stable, but they seem to provide a more balanced view of extant clades: the specializations of sharks *vs.* the primitive retentions of bony fishes. New perspectives are opened on the origins of innovations such as jaws, internal gill skeletons and paired fins, and on the likely influence of Palaeozoic extinctions, re-shaping the roots of the modern vertebrate biota.

Lyell Meeting 2014: Deep sea chemosynthetic ecosystems: where they are found, how they work and what they looked like in the geological past

The Geological Society, Burlington House, London *12 March 2014*

Ocean exploration in the past 40 years has revolutionised our knowledge of ecological adaptations of life in the deep sea and associated mineralogical resources. In the cold and dark ocean depths abundant animal communities flourish where fluids rich in methane, hydrogen sulphide, hydrogen and other chemically reduced compounds are released from the sea floor at hydrothermal vents and cold seeps. Similar communities occur where large pieces of organic matter, such as whales and wood, have sunk to the bottom of the sea. Life teems at these so-called chemosynthetic sites because of the huge amount of chemical energy available, and numerous symbiotic relationships of animals with chemoautotrophic bacteria. The same chemosynthesis-based communities are being increasingly recognised in the geological record, giving important new insights about the evolution of these communities through time. Part of this record comes from massive sulphide deposits, which are a significant economic resource.

This meeting will bring together geologists, marine biologists and ecologists, palaeontologists and geomicrobiologists to highlight recent achievements in our understanding of chemosynthetic ecosystems, past and present. We will explore the complex relationships between geology and life at these sites; details of chemosymbiotic animal-microbial interactions; and how and when animals adapted to life in these extreme environments. Finally, recent hypotheses about the existence of similar ecosystems on other Solar System planets will be presented.

Conveners: Silvia Danise (Plymouth University)
Crispin Little (University of Leeds)

Keynote Speakers : Jon Copley (University of Southampton)
Nadine LeBris (Université Pierre et Marie Curie-Paris, France)
Richard Herrington (Natural History Museum)
Karine Olu-Le Roy (IFREMER, France)
Jörn Peckman (Wien Universität, Austria)
Jillian Petersen (Max Planck Institute, Germany)
John Taylor (Natural History Museum)
Adrian Glover (Natural History Museum)
Steffen Kiel (Universität Göttingen, Germany)
Monica Grady (The Open University)

For further information see <**http://www.geolsoc.org.uk/lyell1 4**>

Palaeocast
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Southampton
2014

Taylor & Francis
Taylor & Francis Group

Progressive Palaeontology

May 21st – 23rd

University of Southampton

2014

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Organizers: Jessica Lawrence, Jon Lakin, Dave Carpenter, Liz Martin, James Hansford and Aubrey Roberts news

PalAss Undergraduate Award scheme

Every year the Association awards free membership for a two-year period (the year in which the award is made, and the following year) to an undergraduate student at each department in the UK and Ireland where Palaeontology is taught as part of a three- or four-year degree programme. Recommendations are made by the Department in question in response to a request from the Association (sent to all relevant Department Heads in May). Usually recommendation is based on summer exam performance, but Departments are welcome to adopt other appropriate criteria.

So far about half of the relevant departments have made recommendations. Students who have been recommended for the 2013–2014 period are:

- O. Bath Enright (NUI Galway)
- J. Bolger (UCD)
- I. Clouting (Plymouth)
- M. Cook (Leeds)
- E. Corbett (TCD)
- R. Dejardin (Leicester)
- D. Delbarre (Sheffield)
- A. Doran (Cork)
- H. Drage (UCL)
- K. Dunn (Southampton)
- J. Foey (Keele)
- F. Jacklin (Durham)
- T. McCormick (Cambridge)
- E. Marquis (Cardiff)
- M. Maynard (Birmingham).
- E. Pedley (Birkbeck)
- A. Peskin (Liverpool)
- A. Rezende Guimaraes (Edinburgh)
- S. Wild (Portsmouth)

Tim Palmer
<palass@palass.or g>

From our Correspondents

Birth of the biosphere

Did the great man have a sense of humour – in his ambitious youth, that is? That has always been at the back of my mind since my very first encounter with his name, in parentheses following the name of one of those graptolite species that – among the dwindling number of palaeontologists whose lot it is to study these problematic Palaeozoic palaeoplankton – tends to make the heart sink and provoke a tired smile simultaneously, as at a joke too oft-repeated.

Pristiograptus dubius (E. Suess, 1851), it reads. And, alas, *dubius* by name and dubious by nature, for sure, with this particular beast[1]. Numerous, unassuming in appearance, not liking to change its form very much for mind-numbing lengths of time (was it the equivalent of a career civil servant, in those Palaeozoic seas?) – it is not the favourite species of a harassed biostratigrapher (of this one at any rate). It has spawned a whole shoal of subspecific variants based upon minute variations in shape that often seem to be of – yes, I'm afraid so – of dubious palaeontological reality. Maybe Eduard Suess, in 1851 and 20 years old, could see into the future, to wryly predict the taxonomic despair that his newly-named baby would cause.

Suess grew to become one of the grand men of European geology. The paper in which he launched *Pristiograptus dubius* and a few kindred graptolite species into the world was Suess's first in a long and extraordinarily productive career.

It was also his last on graptolites. It left, indeed, scars[2]. Suess had the misfortune to let his teenage enthusiasm run away from him within the jealously guarded terrain (both geographic and taxonomic) of the mighty Joachim Barrande – a man who was on the way to reaching grand old man status himself. It was a delicate situation. Suess wished to publish jointly with Barrande, who had worked on these fossils for years. But it was not so common, then, for a young tyro to link up with an established savant. It didn't take much, also, to arouse Barrande's territorial instincts[3]. He declined the offer, and hurried to publish his own *Graptolites de Bôheme* in 1850 – a work that soon became – and remained – a classic of the literature. This was hardly an encouraging omen. Suess nevertheless wrote his own work on these fossils – in which he cited the elder man's new publication, and even dedicated a species ('*Graptolithus barrandei*') to him.

Barrande was not mollified, not one bit. He fired off a riposte of 'Observations' that, at 48 pages, was close to the length of Suess's offending article. He poured scorn on the young interloper's new species – not even sparing the one dedicated to himself – in what was later described as a kind of taxonomic execution. The novice palaeontologist was understandably dismayed: "Such was my entry into the scientific literature – in the worst possible manner!" he later wrote. Luckily for Suess, the post he had acquired, in the museum of Vienna, had by then been secured[4].

[1] Not to mention the synonyms provided by your friendly household thesaurus – dodgy, shady, fishy and so on.

[2] As reported in Siedl *et al*. 2009.

[3] For more on this singular palaeontologist, see 'Of Barrie and Barrande' (*Newsletter* **73**).

[4] The story has a happy ending of sorts – indeed two happy endings. Firstly, Barrande's wrath had cooled some years later. Suess was surprised, one day, to find the older man at his door. He had, it seems, reflected upon events and come to inter a hatchet. Subsequent visits established, finally, an amicable relationship. And, of Suess's much-maligned species, most still survive to this day – including (alas) *dubius*.

Suess, despite his dismay, proved resilient. In the following years he transferred his attentions to brachiopods, then to Cenozoic mammals, with occasional forays into ammonite palaeontology. Then, the stream of palaeontological papers[5] slowed. Suess had wider ambitions. He wanted to take over the world.

In the terms that he set himself, he pretty well succeeded. *Das Antlitz der Erde*, the end result was called, loosely translated into *The Face of the Earth*[6]. Our library has a copy, and the other day I staggered back with it for a swift perusal. The staggering was unavoidable, as the four component tomes are each of imposing solidity. The perusal, therefore, became something of a more daunting prospect[7]. Successively published in German in 1883–1909, in French in 1897–1918, in English in 1904–24 and in Spanish in 1923–28, it is a synthesis of world geology as then known, laying out the structures of mountains and plains around the world. Amid the detailed descriptions, there are some of the Suess ideas: of his inference that slabs of crust rose and subsided through time to create the changing pattern of continents and oceans, and of his more durable concepts of Gondwanaland and the ancient oceans of Tethys and Panthalassa.

The final chapter though, ventures into another realm. It is simply titled 'Life'. After musing on the significance of the many human cadavers examined by an eminent pathologist colleague, he notes that above the earthly lithospheric structure that he had described so minutely, there was a living envelope, that he called the biosphere.

It was not quite the first coinage of the term, for he had introduced it in the slim book that he had written on the origin of the Alps in 1875. In the last and most general chapter on the outer structure of the Earth, he used the metabolic metaphor of a plant living in interference with the three "geological envelopes", namely the lithosphere, the hydrosphere – also both Suessian neologisms – and the atmosphere, but otherwise virtually without comment[8]. Historians of the biosphere concept usually take it as the throwaway comment of a dedicated hard rock man, struck by a passing idea and just noting it down before moving back quickly to more seriously tectonic matters. Well, reading that valedictory chapter of *Das Antlitz* – and knowing the solid palaeontological credentials of his youth – suggest that it was a little more than that (thus it may be no mere accident that the first and the last books of Vienna's famous Academician ended with the biosphere). Nevertheless, it seems clear that Suess regarded Earthly life in fairly straightforward terms as a living envelope, a complex organic outgrowth on a planetary surface of rock, air and water.

The idea of the biosphere, hence, was born in Vienna[9]. But, it was quickly taken to far-off Russia, where it was raised in obscurity, and remained largely hidden from mainstream, western scientific thought for decades, hidden behind the linked barriers of language and politics. It's something of a wonder, indeed, that the guiding muse behind the concept, Vladimir I.

[5] There are sixty-one palaeontological publications in total listed by Zapfe (1981).

[6] It should really be a touch more poetic than that, for in German the usual word for face is the common or garden 'Gesicht', while 'Antlitz' is closer to 'visage' or 'countenance'. In standard barbarian English, though, the translation chosen probably hit the right spot.

[7] Indeed, with the volume now creating a small gravitational anomaly in my room, no one had succeeded in this, in over a century. A number of pages were still joined at the top, having never been cut through.

[8] Suess wrote "eine selbständige Biosphäre", in *Die Entstehung der Alpen*, Wien, W. Braunmüller, 1875, p. 159.

[9] Perhaps no very large concept about Earth and life can ever be said to be truly new, though, given the human impulse to make sense of our surroundings. Reaching farther back, the biosphere in embryonic form is often said to be found in Jean-Baptiste Lamarck's *Hydrogéologie*, published in 1802 (see Ghilarov 1998).

Vernadsky, lived to develop the idea, as he managed to offend both the Tsarist Court *and* the Soviet Establishment that followed it. Survive through it all he did, though, to die of entirely natural causes in 1945, at the grand age of 82. It took another 53 years for Vernadsky's crowning achievement, *The Biosphere*, originally published in Russia in 1926, to be published in full in English in 1998[10].

In this case, the ideas were worth waiting for. It's still a thought-provoking read, by turns illuminating, surprising and at times perplexing. Mercifully, unlike Suess's magnum opus, one does not need a fork-lift truck to help carry it home for study. It is essentially a transcript of a couple of essays written in Paris in 1925 ("The Biosphere in the Cosmos" and "The Domain of Life"), published in Russian in Leningrad in 1926, then in French in Paris in 1929, after which the ideas largely dropped out of sight in the West (and in the Soviet Union, too).

Vernadsky's concept of the biosphere went much deeper than Suess's. He perceived that life was intricately interlinked *biogeochemically* with the rock, water and air at the planet's surface, and powered by solar energy. To him, it was this, *le tout ensemble*, the whole system of life and non-life together that was the planetary phenomenon of the biosphere. This was no passive occupation of a rocky substrate by a film of life (as conceived by another of Suess's admirers, the French geologist and paleontologist Pierre Teilhard de Chardin), but an evolving and interacting whole-Earth system. Not only did the Earth support life, but life as "living matter" shaped the cosmic character of the Earth as a planet in the Solar System. This was the logic that the maverick British scientist James Lovelock, working in the 1960s with NASA's space programme, used to deduce the non-existence of life on Mars (because that planet's atmospheric chemistry is simply in equilibrium with its solid rock surface). He used the self-same logic to develop, in close collaboration with the late microbiologist Lynn Margulis, the still-controversial Gaia hypothesis – that is, of the long-term regulation of the Earth by the totality of that life to maintain the conditions that then allow that life to exist. Lovelock, as he developed his ideas, was unaware (until the mid-1980s) that the Russian biogeochemist Vernadsky had already taken a long walk through this kind of territory.

In the 1920s, Vernadsky did not entertain the notion of an abiotic Earth, or of an origin of life[11]. He knew that some of the oldest rocks then recognized on Earth show signs of life – the characteristic layered structures of stromatolites, for instance – and regarded any attempt to look more deeply into the past as an attempt beyond what science could then do, and therefore not worthy of speculation. The vision is eerily like that of James Hutton's inability to see on Earth the vestige of a beginning, or prospect of an end. Life, to Vernadsky, was always a powerful geological factor, not least because of its ability to take over any piece of land or sea, given even half a toehold.

It's an idea that he developed so vividly that it can seem to veer into the absurd. He noted the way that living organisms may multiply exponentially, if there is space to go into and resources to sustain them. There was, he said, a "pressure of life". He gave the example of microbes, that can divide to produce new microbes every half an hour or so. Allow these to multiply at that

[10] *La Biosphère*, Paris, Librairie Félix alcan, 1929, was presented as the follow-up of *La Géochimie* (Librairie Félix Alcan, 1924), after Vernadsky's lectures at the Sorbonne in 1922-23. To much of the English-speaking world that is still a large barrier to understanding.

[11] Vernadsky's biogeochemical approach was not ignored, nevertheless, by his fellow Russian Alexander Oparin in his own pioneering work on the origin of life from non-living matter.

rate for a little while and they can create a front that can advance, he calculated, at 331 metres per second (while the more reproductively relaxed Indian elephant could only manage 0.9 mm per second). A caricature, for sure, but it demonstrated Vernadsky's view of the impossibility of holding back life from anywhere that it can get into.

What, then, was life? Vernadsky was not concerned with describing it in terms of any conventional (by then) biological classification or distribution of the animal and plant species on Earth. Rather he saw it in total (coining the specific concept of 'living matter') as a mechanism by which a planet may collect, convert and store the energy it receives from its sun. How big is this mechanism? He realized the difficulty of making measurements, but suggested that living organisms formed only a small (but powerful) part of the entire biosphere. How variable is it? Here, Vernadsky stuck his neck out further than seemed geologically sensible, even then. As it had always been an integral part of the Earth system, he stated, the biosphere must have been constant in size and essentially unchanging. Not unchanging as regards its component species, of course – he well knew these had been different in the successive geological periods. But that to him was mere detail: their combined scale and function, he said, were a planetary constant[12].

Vernadsky's 'empirical generalizations', as he called them, give pause for thought, even today. They build to a striking vision that tried to get to the heart of a planetary mechanism, building on – or perhaps cutting clean through – the plethora of data being assembled by the biologists and palaeontologists of the day. True, some of his colleagues considered that he was going too far. He was, one of them said, forgoing his solid and useful studies of rocks and minerals to analyse the 'geochemistry of the soul of the mosquito'. That kind of criticism has, indeed, been levelled at subsequent versions of the concept – witness the decidedly mixed reception to the Gaia hypothesis. But there's no doubting their power in generating ideas regarding the most fundamental aspects of our peculiar planet in the cosmos.

Who was Vernadsky, and how did he arrive at his ideas? There's a fine account of this by the American environmental historian Kendall Bailes, and in addition to the description of Vernadsky himself, it's illuminating about science in Russia before and after the Revolution. Bailes was terminally ill with AIDS in California as he was finishing it, but there's no hint of his own personal tragedy in the elegant – riveting, indeed – account.

Vernadsky grew up in Tsarist Russia, where his father was a professor of political economy who was also a prominent liberal activist and manager of a printing house. Vernadsky absorbed the academic (and independent) spirit – and also became involved in overt political activity. He became a member of Kadets (the Constitutional Democratic Party). This kind of activity could become all too often fatally conspicuous, before and – especially – after the Bolshevik Revolution. However, as the foreword to his biography points out, while a liberal historian could not survive in Stalin's Russia (Vernadsky's son, who was exactly that, had wisely emigrated to the US in the 1920s, like his younger sister), a liberal geochemist (one, moreover, expert in mineral resources and radioactivity) might. And so it was to prove – although there were some close calls along the way.

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[12] In his last, unfinished book, *The Chemical Structure of the Biosphere as a Planet and its Surroundings* published twenty years after his death, Vernadsky did go on to modify his ideas about the origin and evolution of the Earth.

Vernadsky's academic background is a little counter-intuitive for someone who was (eventually) to have such an influence on the Earth's biological history. His early studies were firmly within mineralogy and crystallography. He was, for instance the first person to synthesize the metamorphic mineral silliminite, and he went on to work on 'gliding planes' in crystals – planes of deformation determined by particular patterns of molecular structure. It was detailed and specialist work, and the road from there to the biosphere might seem a long one, but Vernadsky had unusual attributes.

He kept his interests very broad, not simply as an intellectual magpie, but as someone who always wanted to see the relation between phenomena, to see things in context and understand their history – and their use to humankind in general and Russia in particular. For instance, he developed his work on minerals not towards more specialist data-gathering and analyses, but towards trying to map out and catalogue the mineral resources of Russia and the USSR. This was in part because he knew they were useful to the material development of human society, and partly because he wanted to see how the various mineral assemblages had evolved. Considering their evolution, indeed, went as far as thinking to what extent Darwin's ideas on biological evolution might be applied to them. Being first a student and collaborator of V. V. Dokuchaev, the father of Russian soil science, he took a serious interest in soils, a stuff in which life, death and non-life are inextricably mixed, and recognised them as a fundamental part of the life cycle of the whole biosphere.

This breadth of interest was stimulated in his youth by intense discussions with fellow students, the influence of the more charismatic of his teachers (who included Dmitri Mendeleev), and by a strongly international outlook. While still a schoolboy, he had determined to learn science by reading the great works of eminent foreign scientists in the original language. He perfected his German by reading Humboldt's *Cosmos* and *Aspects of Nature*, and his English by reading Darwin's *The Origin of Species* and *The Descent of Man*. He had a struggle over the latter, for his father did not want him to read such a dangerous and controversial book at such tender age. Vernadsky was insistent, though, and got his way. This self-taught polyglot could therefore later travel easily through Europe (he visited Canada and USA in 1913) – and did so through most of his life, with the exception of the worst Stalinist years, meeting or working with the likes of Marie and Pierre Curie, Alfred Lacroix, Henry Le Chatelier, Lord Rutherford, Otto Hahn and other giants of European science – including Eduard Suess, too (in 1911), who he took care to acknowledge in his writings.

Maintaining breadth as a scientist is not generally a sensible career strategy. Vernadsky knew that, periodically berating himself as an encyclopedic dilettante who was all too often distracted by things that stopped him from keeping focus on whatever should have been the task in hand. Perhaps more than most scientists, he left a trail of half-finished research projects, dropped as he followed some other line of inquiry. The tactic was to pay off in the end, but he often doubted that he would ever manage to crystallize the vision that was, slowly and fitfully, incubating within him.

Another quality that helped him greatly to become a professional scientist – but was definitely a mixed blessing as far as actually *doing* scientific research – was a talent for both teaching and organization. Even as a young professional scientist, he was busy creating research teams that developed into a research school that he led for most of his long career. The trouble was, this kind of activity often put him in the position of being caught between the Tsarist government, which was generally trying to exercise direct control over the universities – not least to have a free hand to suppress revolutionary elements, and the student body itself – which did include revolutionary elements (the number of which increased, with depressing predictability, as the government's repression intensified).

Vernadsky did not have much sympathy with either side. His readings of Humboldt and Darwin had strengthened his belief (that he maintained throughout his life) that society should be run on rational, secular lines, and not through the divine right and inherited power claimed by the tsars and the nobility. He was an idealist, too. He did not believe that even a brutal and often plain stupid power system in society should be overthrown by violence, but that it should be transformed by evolutionary means, working within the system to improve it by reasoned persuasion. More close to home, he thought the university system should be independent and free to run itself, not least to preserve the spirit of free and open inquiry; he profoundly disagreed with any dogma, whether of the aristocracy, the revolutionaries or anyone else. When forced to choose, though, he tried to protect the students – even when they were revolutionaries.

This, predictably, led to a hard life. To try to protect the academic system, he became not only a senior university administrator, but also a member of parliament, and devoted much of his energies to try to hold the line of university independence, occasionally – though strictly temporarily – with some success. At the same time, he tried to do his best by his students and his researchers. Fitting in any research around all of that was all too often a distant dream.

The ideas of *The Biosphere* crystallized amid a succession of events that others would find catastrophic in personal terms. Vernadsky became unpopular enough with the Tsarist government to lose his university position, as they tried unsuccessfully to clamp down on the rising tide of revolution in the country. When the Revolution came, he lost the small family estate that had maintained him and his family after his dismissal, and moved to the Ukraine, in part to recuperate after a bout of TB. There, in 1917, while turmoil was being experienced by most of the country, he was taking an enforced break from his many administrative duties. His ideas finally came together. Those few weeks, he later said, were among the most creative of his life. He filled forty pages of graph paper with the ideas that brought biology into geochemistry, to create the discipline of biogeochemistry (a field developed since the 1940s in the United States by the English-born ecologist George Evelyn Hutchinson[13], thanks to Vernadsky's works translated by his Yale friend and colleague, the son George Vernadsky). That, in effect, turned the biosphere from Suess's descriptive green blanket into the dynamic agent that shapes our habitable planet.

His individual peace was not to last. He was later caught between the fighting Red and White armies (the violence of both of which he deplored), and went into hiding from the Bolsheviks after one of his research assistants was killed in the times of the Red Terror. It did not help that he had been mistaken for another former professor who had a similar-sounding name (Bernatsky), a minister in the former government. The research student who ran errands for him at that time, incidentally, was a young man called Theodosius Dobzhansky, later to become one of the great developers of Darwin's ideas in the form of evolutionary genetics.

[13] Hutchinson's 1970 article on the biosphere in *Scientific American* is justly celebrated.

Once things had settled down, and the Bolshevik government took a grip, Vernadsky went back to being a prominent academic. Lenin, at that time, showed an ability to deal with the universities more competently than the clumsy Tsarist powers, instinctively suspicious of an independent science establishment, had done. He wanted the academics on his side, to show a civilized face to an outside world that had looked upon the Revolution with alarm, and also to gain the scientists' active help in finding and using the resources to build his new society. He encouraged, for instance, Vernadsky's idea of mapping the mineral deposits of Russia (though, then as ever, securing some funding for this was not so easy). He allowed the university system to keep significant autonomy and freedom of thought and writing, and, for a while at least, reined in his government ministers who wanted more direct control of the academics. Vernadsky was sufficiently impressed to stay within the new Soviet system.

He could also keep travelling, and he once again spent time in Europe, particularly in Paris, where his most well-known (if ill-documented) contacts were with Pierre Teilhard de Chardin and the philosopher Edouard Le Roy. It was the combination of these that led to a further development of the idea of biosphere, to have yet another 'sphere' (Teilhard and Le Roy) or 'biospheral period' (Vernadsky). This was termed the *noosphere*, in which the emergence of human thought and action are conceived as another accelerating force that emerged from the biosphere to shape the Earth's geology and evolution. He wished to develop these ideas further. In 1923, he published in the *Transactions of the Liverpool Biological Society* a "plea for the estabishment of a bio-geochemical laboratory". It was a proposal ahead of its time[14].

After this prolonged stay in France (from July 1922 to December 1925) Vernadsky returned to the new Soviet Union. It was not an easy decision. Revolutionary Russia was not clearly evolving into a benign and tolerant democracy. His son emigrated to the USA. Vernadsky himself tried to find a position where he could develop but, despite his talents and reputation, did not succeed in this. He returned to a Russia that was to evolve into the nightmare that Stalin presided over, and somehow lived through it all.

Remarkably, even in those times, he even kept arguing for the right of academics to develop their ideas and thoughts freely, without the straitjacket – dialectical materialism – which was supposed to be the guiding principle of their lives. That did not make him popular with the ruling powers, but somehow he did not perish in Stalin's purges as millions of others – including some of his own colleagues – did. Characteristically, Vernadsky tried as best he could to help or find shelter for the families of the victims whenever he could. Why was he allowed to live? His renown in Russia and Ukraine, and to some extent outside it, certainly helped. The practical side of his work (those mineral resources and with the Radium Institute) was also a factor. And, he was not overtly political in this, or any kind of threat in the various struggles for power and position. His criticisms were those of an academic, and they were expressed internally, and not broadcast to the outside world. He did what he could, but probably knew, or guessed, how far he could go.

Through all of this he developed his ideas of the interconnections between the living and non-living world. In that first statement on the biosphere, he had omitted something that he might have been in a position to be aware of, even then. This was the transformation of the Earth that we know now as the 'Great Oxidation Event' some two and a half billion years ago,

[14] Ignored in the west, this was set up within the Academy of Sciences of the USSR in 1928, following Vernadsky's Department of Living Matter within the KEPS (Commission for the Study of Natural Productive Forces), formed during the First Wold War.

when the appearance on Earth of the first photosynthetic organisms changed the composition and chemical activity of the atmosphere. The enormous Banded Iron Formations of those early Precambrian times, which outcrop extensively across Russia, might have alerted him to the fact that the Earth might have existed in very different biogeochemical states in the past.

His ideas in this respect did evolve, though, as one of his last essays (one of the few items of his Soviet-era work to be published in the West) shows. He admitted (after Oparin's work) the possibility of an origin for life, and hence of an abiological early Earth. He recognized successive phases of the biosphere, quoting some proper stratigraphy – the appearance of calcified plant material (the stromatolites, one presumes) in the Precambrian and skeletonized animals at the beginning of the Cambrian, for instance. There is a little improper stratigraphy, too – he quotes 'our green forests' appearing for the first time in the Cretaceous, when something quite satisfactorily forest-like had appeared by a couple of hundred million years previously, in the Carboniferous. A detail, that, and it doesn't affect the material quality of his argument. Suess wouldn't have got that wrong – but then, he wouldn't have thought through the Earth's functioning in the way that Vernadsky did. Stratigraphy's a fine thing, but it's not everything, after all.

From those unfortunate misunderstandings over fossil graptolites, to debates over the utility of analyzing a mosquito's soul, the biosphere has come a long way – in people's minds, not least. How this might translate into the continued function of the biosphere itself is another story, of course – but one can be quite sure that Vernadsky pondered that question, too.

Acknowledgements: My thanks to Jacques Grinevald – a key figure in reviving Vernadsky's reputation in western science – for pointing me in this direction, and for scrupulously correcting the draft manuscript. If this essay has any scholarly merit, it is largely due to him. The small oasis of peace *chez* Ryszard and Grażyna Kryza in Wroclaw, Poland, allowed the words to emerge.

Jan Zalasiewicz

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PalaeoMath 101 A Picture May Be Worth 1,000 Landmarks

I began this series on mathematical methods in palaeobiology in 2004 with a consideration of regression methods that describe the relationship between two simple linear distance variables, illustrating these with data collected from a series of digital images of trilobites. Obviously our discussion has ranged rather broadly across the mathematical, data analysis, and taxonomic landscapes since then. For this essay—the last in the series—I'd like to return to the question of how we can extract data from the morphological information presented to us by organismal forms, usually (these days) through the medium of digital images.

Perhaps the most basic concept in the field of quantitative data analysis is that of the variable. Variables are the observations we make, usually in the form of measurements, on the set of specimens that comprise a sample of some population of interest. Variables come in many types and forms. If you take nothing else away from these *PalaeoMath* essays please let it be that, for the purposes of describing and comparing specimens across a sample (not to mention drawing inferences about the population[s] from which the sample was drawn), the variables *are* the specimen; the only information any data analysis procedure has access to. As such, it is of the utmost importance that the variables chosen to represent our specimens be appropriate, both to the specimens in question and to the hypotheses under consideration. If your variables do not meet these criteria in some reasonable and defensible manner, it is likely that any results you generate from their analyses will be compromised and/or (ultimately) questioned. For example, if you are interested in phenomena pertaining to the arrangement of component parts of the specimen relative to each other, and if the majority of those component parts are not located on the specimen outline, it makes little sense to restrict data collection to the geometry of specimen outlines. Similarly, if you are interested in questions pertaining to the general form of the specimens and if this general form is best represented by the specimen's outline, it makes little sense to restrict data collection to a small set of landmarks located within the outline.

But what if you're not sure what parts of the morphology are important in terms of assessing similarity and/or difference relations among the specimens comprizing the sample? What if the variability in your specimens is such that the identification of corresponding point locations (landmarks, starting points for outline digitization) across the sample is simply not possible? Perhaps even more importantly, suppose you want to include as much morphological information about your specimens as possible and/or are uncomfortable with the idea of abstracting the specimens down to a (relatively) small set of variables a priori? Is there a way of handling this generalized problem within the context of a morphometric analysis?

Recently I ran into a situation of just this sort in the form of a student's MSc project. The student wanted to quantify the pattern of wing ornamentation of mimetic butterfly species morphs (Fig. 1) in order to compare wing colour variation to gene sequence variation. On the face of it this seemed simple enough: just determine which aspects of the ornamentation pattern were common to all specimens in the sample and base the measurement system on those

Figure 1. Morphological variation in a set of Batesian mimic butterfly species. A. Danaus chrysippus *(model species). B.* Danaus chrysippus f. trophonius *(mimic). C.* Danaus chrysippus f. lamborni *(mimic). Note the similarity of all three colour morphs in terms of the general distribution of colours across the wings, but also the level of fine-scale difference in the number, sizes and shapes of spot patterns. These inconsistencies make it difficult to use standard morphometric variables to characterize patterns of wing colour morph similarity and difference.*

using landmarks or outlines or landmarks+outlines where appropriate. After explaining these principles to the student I sent her away to design her measurements and collect the data. Much to my surprise, she reappeared at my office door a few days later in a somewhat disturbed state having tried repeatedly to follow my instructions but failing at each attempt. After a bit of discussion it became apparent why. As can be seen in Figure 1 there are very few features of the wing ornamentation pattern present in Batesian mimic species, and those that are present tend to be of quite a generalized character (*e.g.*, orange region in the centre, black peripheral areas with light-coloured spots and/or blotches). In essence, these mimics are somewhat approximate—not close—copies.

The standard response to a situation like this would (sadly) be either to abandon a morphometric approach entirely or to collect a small set of landmarks or outline semilandmarks and analyse these rather than the colour blotch patterns. After all, if there are no form-related features common to the blotch patterns in all specimens there would appear to be no basis on which to compare them. At least, that's how the logic would typically run. But it's obviously a false logic. The fact is that entomologists, non-specialist collectors, and even butterfly predator species are able to make comparisons between the patterns of these butterfly wings. Indeed, that's the whole point of Batesian mimicry! The former two groups have been making such comparisons for (literally) centuries, and it's been going on for millions of years in the case of the predators. If entomologists and butterfly predators can make comparisons between morphologies like these, quantitative morphologists and morphometricians should be able at least to make a stab at treating the same problem quantitatively. But how?

So as not to compromise the student's ability to publish her mimetic butterfly results, I'll shift at this point to an analogous image dataset I often use to introduce the concept of morphological variation to my students (Fig. 2). While this small collection of ladybird beetle images are decidedly not fossils, they serve to illustrate the full range of morphological variation in biological datasets better than a typical fossil dataset might. Regardless, the methods I'll develop below will apply equally well to images of fossil specimens where colour blotches on the specimen are often irrelevant.

Among these drawings of ladybird beetles, we see copious variation in body shape, leg & antennae pose, and both colouration and colour texture of the elytra, thoracic and head shields.

Figure 2. Drawings of 24 ladybird beetle (Family Coccinellidae) species illustrating a range of body form and colour morphs. As with the Batesian mimic butterflies (see Fig. 1) the complexity of variation in body form, colour, the distribution, numbers, sizes and shapes of spots makes this sample difficult to characterize using standard linear distance, landmark, or semilandmark variables.

Despite being all too typical of morphological datasets—open just about any well-curated museum drawer; this is what you'll see—none of the many tools of numerical data analysis and/or morphometrics I've discussed in this column can handle the problem of characterizing similarity/dissimilarity relations within this sample—or at least not obviously so.

The patterns we see in this figure seem too complexly structured to be characterized adequately by sets of linear distances, landmarks or semilandmarks. Yet, in the absence of taking some sort of measurement we cannot answer even the most basic questions about this sample. What is the mean form and colour pattern of this sample? Is morphological variation distributed continuously or discontinuously? Does the distribution of forms and colour blotches have a single or multiple modes? If the latter, how are those modes arranged relative to one another? More depressing still, these are the easy, descriptive questions. If we want to provide answers to more complex biological and/or evolutionary questions such as how these patterns of morphological variation co-vary with environment, geography, ecology, behaviour, genotype, phylogeny, etc, an ability to compare each of these forms to one another quantitatively is crucial. But if none of the tools, concepts, or methods we have discussed to date are up to this task, have we simply been wasting our time learning methods that might pertain to some small subset of morphological data-analysis problems, but are unsuited to the majority of routine morphological data-analysis situations with which we are confronted? Is it really true that the best we can do in this case is to shrug our shoulders and go back to the qualitative inspection and appeals to 'authority' in deciding these issues?

Of course we can do better than this. Like so many problems in science—and especially in mathematics—this seemingly intractable problem yields with surprising ease to a simple shift in the conceptual frame of reference. The standard way of approaching the morphology sampling problem is to find a series of topologically homologous, relocatable points across the forms of interest and record their coordinate positions. From these coordinate positions either linear distances or shape coordinates can be calculated. However, if the image of a specimen has been digitized it has already been subdivided into a series of topologically homologous coordinate points—the pixel grid (Fig. 3).

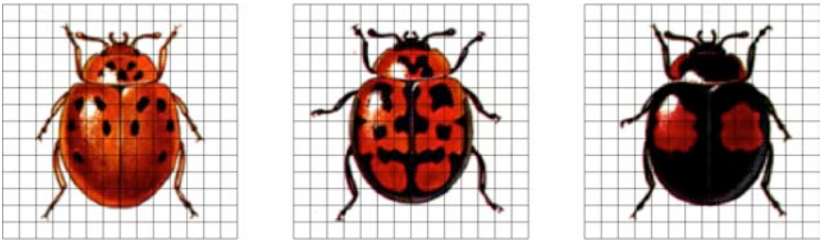

Figure 3. Three example representations of ladybird beetle morphology and ornamentation pattern with a superimposed 14 x 14 pixel grid.

These pixel locations represent a set of semilandmarks that exhibit a consistent spatial structure across the entire set of forms. So long as the dimensions and resolution of this grid remain constant for all images in the sample, and so long as the specimens are oriented in the grid in some reasonably consistent manner, this grid can be used to extract comparable descriptions of these form geometries. Quantitative descriptions of specimen variation extracted in this manner can be organized into many formats. If only the outline of the form is needed all pixels whose colour or grey-level differs from that of the background can be assigned the same colour (usually black or white depending on the background).[1] If colour is not a parameter of interest the grid can be set to sample only the grey-level values of the individual pixels comprizing the image. If colour is of interest the sampling grid can be used to extract the red, blue and green (RGB) values of each pixel. Figure 4 illustrates the effect of various grid sampling decisions on the representation of the first of the three ladybird beetle forms illustrated in Figure 3.

What is remarkable about this comparison of sampling resolutions and colour formats is the level of form and texture information content that's retained even at relatively low sampling resolutions. This suggests that, for the purpose of form and texture characterization, many pixels in a normal-resolution image (*e.g.*, 72 pixels per inch) are redundant: the value of any particular pixel is much the same as the values of the pixels immediately adjacent. In mathematical jargon this self-similarity is termed spatial autocorrelation. If possible the spatial autocorrelation of our raw morphological data should be reduced prior to doing data analysis so that the effective dimensionality of the data-analysis problem can be optimized. But can we accomplish this reduction in the context of a digital image?

As an initial step we can decrease the image resolution to the point where the number of self-similar pixels is minimized relative to the overall information content of the pixel grid. While there are algorithmic ways of accomplishing this minimization, for biological images I recommend adoption of an experimental approach to determining the spatial resolution and colour format required for each analysis on a case-by-case basis. This recommendation reflects my belief that the analyst (or taxonomic specialist), rather than an algorithm, is best placed to determine which morphological features need to be included in an image to ensure the down-sampled image set remains appropriate for the hypothesis test(s) under consideration.

[1] In this case the data would be more efficiently represented as a set of boundary outline semilandmark coordinates rather than a coordinate sampling grid.

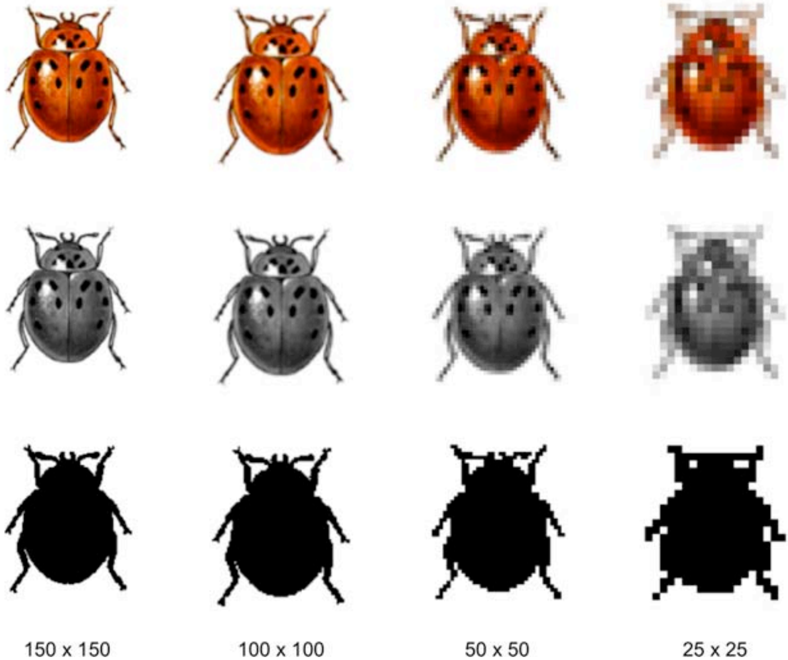

Figure 4. Ladybird beetle morphology represented as four different pixel grid sampling resolutions and three different colour formats: 8-bit RGB values (upper row), 8-bit grey-scale values (middle row), and binary (1-bit) values (bottom row). Note the fidelity with which detail is retained even at low spatial resolutions.

Once the spatial and colour resolutions necessary to represent the set of images have been established it is a simple matter to assemble the resultant pixel brightness or colour values into a mathematical description of the specimen. This is done by rearranging the matrix of pixel values into a single row of values in a standard data matrix. Each of the pixels, then, becomes a variable and the colour or grey-scale data the 'values' of those variables. Since each of the images processed in this manner is composed of the same number of variables (pixels), since each variable has a constant spatial relation to every other variable, and since the values each of these variables can adopt are of the same type and range of magnitudes, collectively these variables (pixels) form a mathematical space within which each of the specimens comprizing the sample can be located. Specimens whose form, colour and blotch patterns are similar will lie close to each other in this space, while those whose morphological attributes are distinct will lie at some remove from one another. This is precisely the same sort of inter-specimen representation we achieve in a linear distance-, landmark-, or semilandmark-based analysis. Nonetheless, by using pixel values as our variables rather than coordinate point locations we are preserving as much of the total morphological content of each image (and so each specimen) as possible, as well as avoiding having to make any a priori decisions about what aspect(s) of the morphology may, or may not, be important for resolving the problem at hand.

This is quite a flexible approach to the analysis of biological specimen morphology as well as one that incorporates many of the data-analysis features we've been discussing in the context of different morphometric data types. The conceptual link to outline and 3D surface analysis seems straightforward. But even in the context of traditional forms of landmark analysis, all we're really doing is changing our focus from the location of a small number of points (implicitly) embedded in a coordinate system to that of the total information content of the coordinate system itself. The price we're paying for this change of focus involves having to deal with a much larger number of variables than would be the case in traditional landmark and semilandmark analyses. But the benefit is that we are able to include much more morphological information that might be relevant to the questions we are asking than would be the case otherwise.

To illustrate this procedure let's take the set of ladybird beetle images in Figure 2 and ask whether this sample represents a continuously variable set of colour morphs (the null hypothesis) or whether we have two basic types of beetles here: orange beetles with black spots and black beetles with orange or red spots (the alternative hypothesis). Using a strictly Gestalt assessment of these morphologies I'll posit that the sample can be subdivided into orange and black colour morphs as listed in Table 1. Within this classification specimens 5 and 6 in row 2 of Figure 2 appear close to the intermediate condition between the two groups, with the former being slightly more orange and the latter slightly more black. However, whether the boundary between these putative groups is gradational or disjunct within this sample I have no idea.

Table 1. Putative ladybird beetle colour morph assignments (by row and specimen no.).

Orange Morphs		Black Morphs	
1-1	2-3	1-5	2-8
1-2	2-4	1-6	3-4
1-3	2-5	1-7	3-5
1-4	3-1	1-8	3-6
2-1	3-2	2-6	3-7
2-2	3-3	2-7	3-8

Before reading any further you might like to consider Figure 2 yourself and come to your own preliminary conclusion as to whether the null or alternative hypothesis is more likely to be correct. It's not as easy as you might think.

In preparation for our analysis we can reduce the spatial resolutions of the images that comprise Figure 2 from 150 x 150 pixels to 32 x 32 pixels (Fig. 5). From inspection of the plate of beetle images at this reduced level of resolution you can see that, despite the fact that we've decreased the total number of pixels representing each specimen by 95 percent, these lower-resolution images preserve virtually all features of the specimens observable in the original image set. Thus, this operation has reduced the number of variables required to represent our specimens (= reduced their dimensionality) by preferentially eliminating redundant pixels (= reduced spatial autocorrelation) while suffering only a very minor loss of information content. So far, so good.

Since these are colour images, and since, in this case, we do want to include an assessment of colour variation in our dataset, each specimen's image can be described completely by converting the pixel format to a 32 x 32 matrix of red, green and blue (RGB) colour intensity values; an

Figure 5. Resampling of 24 ladybird beetle (Family Coccinellidae) drawings (see Fig. 2) using a 32 x 32 colour (RGB) pixel grid. This resampling protocol reduced each specimen's pixel number by c. 80% with little loss in the spatial resolution of features necessary for characterizing patterns of morphological variation.

operation that results in the specification of 32 x 32 x 3, or 3,702 variables. This is a large and somewhat awkward dataset insofar as we have many more variables than specimens. However, it's a dataset we can work with, and such skewed data matrices are by no means uncommon either in data analysis generally or morphometric data analysis in particular.

A covariance-based principal component analysis of these images shows that 95 percent of the observed form, colour, and texture variation can be represented on 18 orthogonal components or axes of variation. This operation further reduces the effective dimensionality of our measurement system from 3,702 variables to 18 (a reduction of 99.5%). This operation also drops the number of variables down below the number of specimens in our dataset. The number of specimens in a morphometric dataset represents an important "curse of dimensionality" threshold (see Bellman 1957, MacLeod 2007, Mitteröcker and Bookstein 2011) of which I'll have more to say below.

We can have a look at this principal component space to see what it tells us about the major features of variation within our sample (Fig. 6). The first two principal components (Fig. 6A) account for the largest single share of observed form, colour, and texture variation (37.44%), but variation in this sample is such that these axes portray a minor share of the sample's variation overall. The distribution of the images in this subspace suggests that there's more going on within this sample than just the simple black–orange distinction that seemed 'obvious' to me after a cursory inspection of Figure 2. Broad-scale clustering of the two putative colour morphs is evident in this plot, but the distinction between them involves both PC axes. Moreover, the character of the inter-morph boundary is not well defined. While the ordination of the orange morphs within this plane appears relatively gradational, the ordination of the black morphs appears highly structured.

Casual, qualitative inspection of this ordination pattern suggests that the black morph comes in two varieties: a black body with orange spots (the subgroup that plots toward the low end of PC-1) and a black body with red spots (the subgroup that plots toward the high end of PC-1). Thus, the main distinction within this sample appears to be that between orange beetles and red-spotted beetles, rather than between orange and black beetles. The orange–black distinction

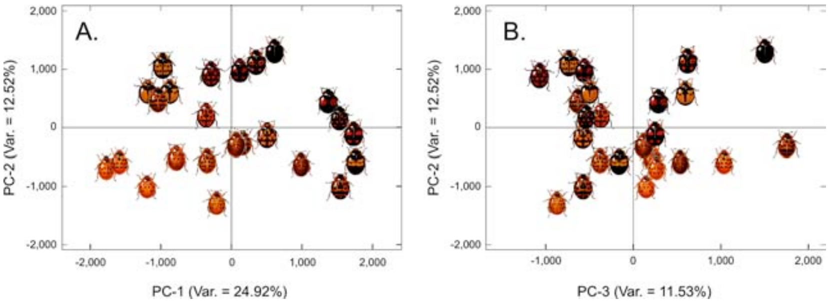

Figure 6. Distribution of ladybird beetle form and colour texture similarity and difference relations on the first three principal component axes of the image covariance matrix. Black icons = putative black beetle morphs. Orange icons = putative orange beetle morphs. A. The subspace formed by PC-1 (x-axis) and PC-2 (y-axis). B. The subspace formed by PC-3 (x-axis) and PC-2 (y-axis). Note the comparative lack of specimens that project to positions along the principal component axes. Lack of the empirical definition of axis form trends that might be afforded by such specimens makes it quite difficult to arrive at detailed geometric interpretations of the overall form space. See text for discussion.

that appeared so striking to me is reflected predominantly in the ordination of specimens along PC-2, along which the former exhibit low scores and the latter high scores. Also, along this axis the putative black morphs appear to exhibit a more-or-less unified distribution whereas the putative orange morphs come in two varieties, a large group of bright orange and dusky orange morphs with small black spots, and a smaller group of morphs in which the black spots have coalesced to the extent that the total number of black and bright/dusky orange pixels is subequal (specimens 2-5 and 3-2). If we add PC-3 into our assessment (Fig. 6B) the interpretation does not change greatly. Along this axis there appears to be a distinction between bright orange (low PC-3 scores) and dusky orange (high PC-3 scores) morphs, at least along the lower reaches of PC-2.

Given the complex character of image variation within this space, detailed interpretations of these axes are surprisingly difficult to devise. We've seen this before with different types of data, but for these images the situation is decidedly more complex owing, no doubt, to the large number of original variables we're dealing with. Using qualitative 'eyeball' methods to interpret these axes, the best we can do is to compare and contrast images that lie at the extremes of variation along each and hope that these represent all, or at least the majority, of the contrasts controlling each specimen's placement. This is a particularly hazardous interpretive strategy to follow, especially when the distribution of forms in this space does not include many that lie close to the actual traces of the PC axes, as is the case here with PC-1, PC-2 and PC-3. In such cases it's far better to calculate models of the image variation at specific positions along any axis you might want to interpret and base your interpretations on those models. Such models can be calculated in precisely the same manner as we have been calculating them for other data types (see MacLeod 2009, 2012, 2013). Along-axis image models for the first three principal components of the ladybird analysis are shown in Figure 7.

Inspection of these models clarifies interpretation of the major modes of variation in our dataset immensely. Here we can see that PC-1 actually captures the distinction between orange morphs with numerous small black spots (extreme negative scores), through dusky orange morphs with

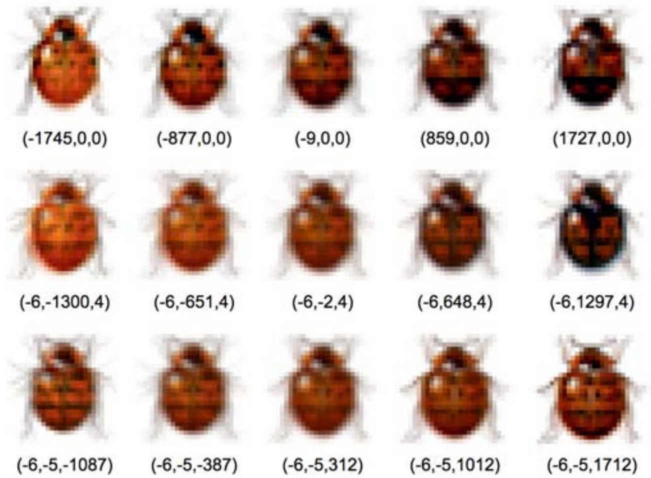

Figure 7. Image models for the ladybird beetle dataset calculated at equally spaced coordinates along the first three principal component axes. See text for discussion. Numbers in parentheses refer to the coordinate positions at which each image model was calculated (see Fig. 6).

larger black spots, to a median region in which forms composed of subequal black and dusky orange regions occur, and on to morphs characterized by a predominantly black body with a single pair of large red spots on the elytra and margins of the thoracic shield (extreme positive scores). The second PC axis is subtly different in that it contrasts bright orange morphs with a smaller number of larger black spots (extreme negative scores), passes through a median region composed of dusky orange morphs with small black spots, and on to forms characterized by black bodies with four symmetrically placed red spots on the elytra, the anterior of which have black spots in their centres, and elongate red spots at the margins of their thoracic shields (extreme positive scores). Finally, PC-3 captures the distinction between forms characterized by black bodies with large, elongate orange spots whose axes are at right angles to the beetles' anterio-posterior axis of symmetry (extreme negative scores), through a median region characterized by dusky orange morphs with black spots, and on to a region characterized by forms with black bodies and dusky orange stripes formed from the progressive amalgamation of orange spots (extreme positive scores). Close inspection of the PC-3 model set also reveals that, during the course of the transition from high negative to high positive scores, a black band along the medial elytral margin changes colour and becomes orange. If we had not had access to these hypothetical image models to use as precisely located points of reference and comparison it is very doubtful that such a detailed interpretation of the major dimensions of form variation could be deduced from a simple inspection of the actual specimen ordinations alone.

Although calculation of along-axis shape models allows more detailed and useful interpretations of the PC ordination space to be made, the interpretations offered above remain only semi-quantitative insofar as comparisons between the models calculated along each axis were done by eye. An even more complete and nuanced picture of similarities and differences among these models can be assembled by calculating difference maps of comparisons between them (Fig. 7).

Difference maps compare the (in this case) RGB values of corresponding pixel locations across two or more images and assign a colour to the mapped pixel whose hue is based on the amount of change recorded at the individual pixel locations. Typically these maps employ a temperature metaphor to express these results visually. Under this convention regions of the image characterized by little or no change are signified by blue (= cool) and regions characterized by high levels of change by (progressively) yellow, orange, and red (= hot). This type of representation has the advantage of being a more objective, quantified and detailed assessment of observed changes than the qualitative inspection of image differences. However, it should be remembered that there is no simple relation between the absolute amount of pixel value change at any particular location and the biological significance of that change. The strength of the difference map approach is that the maps draw our attention to particular aspects of form comparisons, or regions of form change, that might be overlooked as our eyes try to process and pick out consistent patterns or trends in the image model results. Difference maps can be used either in an exploratory sense (*e.g.*, to identify regions of high or low change that we might want to pay special attention to in subsequent analyses) or as a means of testing specific hypotheses (*e.g.*, if a generative hypothesis predicts that some sort of change will be localized in particular regions of the form), but should (almost) never be used on their own to interpret the biological significance of the form changes they record.

When the difference map approach is used to compare differences between extreme low and high score ladybird beetle models in each of the along-axis sequences (Fig. 8) they do pick out unique aspects of variation that were not readily apparent in the qualitative inspection of the models shown in Figure 7. For example, there appears to be a general broadening of the elytra and thoracic shields along PC-1 with elytral colour pattern variation differentially occurring in the posterior portion of the form. Along PC-2 this broadening is confined to the middle part of the elytra with substantial colour pattern variation occurring in the anterior elytral region. Along PC-3, moderate modes of colour pattern variation occur across the elytra accompanied by a slight concentration in the posterior portion of the thoracic shield. However, the predominant mode of form variation expressed along this axis is a slight lengthening of the body that appears to be on the order of 2–3 pixels in aspect.

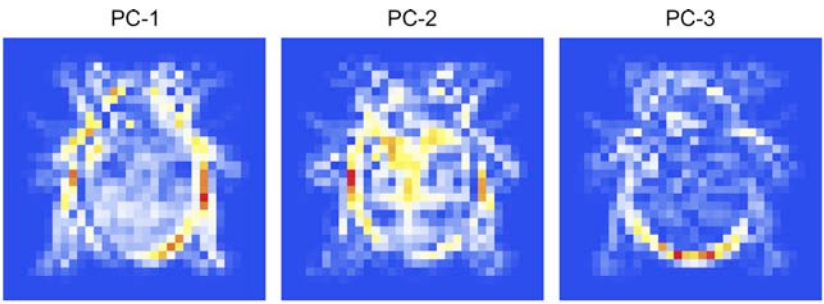

Figure 8. Along-axis image model difference maps for the first three sets of principal component axis models (see Fig. 7). These plots summarize regions of the image at which the different proportions of change in pixel colour values are taking place as one moves along each of the principal component axes. In these plots the individual pixels have been colour-coded as follows: blue = no change, white = moderate change, yellow = moderately high change, orange = high change, red = very high change. Note how different PC axes summarize changes in different regions of the form.

And what of our original question regarding the distinctness of orange and black morphs? Figure 6C suggests (weakly) that the character of this transition might be gradational. However, just looking at a few planes through the original 18-dimensional PC space is insufficient for determining the actual degree of separation between these morphs. If a separation between groups can be located along any of these axes, either singly or when employed in combination, the groups are separable. Since we have neither the time, patience, nor software to visually inspect all possible geometries of points in an 18-dimensional space, some other procedure must be used to settle this question.

Here though we run into a bit of a minor but current controversy among morphometricians. The classic way to handle this problem would be to subject either the raw data or a reduced set of PC scores to a discriminant analysis procedure such as canonical variates analysis (CVA). As I've pointed out before (MacLeod 2009), CVA takes a multivariate dataset and performs a series of standardized axis rotations and transformations that result in the data for two or more groups being projected into a multivariate space in which each group centroid is maximally separated from every other group centroid relative to within-group dispersions. This method cannot usually be applied to raw or Procrustes-aligned morphometric data because of computational difficulties that arise when attempting to invert the within-groups covariance matrix. Nevertheless, these difficulties can be solved (usually) by taking the raw data through an initial PCA and discarding the component axes that represent a statistically or biologically insignificant proportion of the observed form variation.

This procedure has recently been criticised by Mitteröcker and Bookstein (2011) as unsuitable for morphometric data analyses for the following reasons.

1. Orientations of the CV axes are not orthogonal to each other in the space of the original variables used to calculate the CVA; as a result, true Euclidean and/or Procrustes distances between specimens are not represented faithfully in the CVA ordination space.

2. If the number of variables greatly exceeds the number of specimens comprising a dataset, CVA will always be able to find a linear combination of variables that separates groups even in cases of artificially generated data drawn from the same multivariate normal distribution.[2]

3. The scores of objects projected into the CV space do not represent a linear transformation of the original variables, but a linear transformation of these variables after they have been transformed into a distorted space formed by an operation that renders the within-group covariance matrices spherical. Thus, modes of shape variation that optimally separate groups are difficult to interpret and difficult to model properly.

4. Canonical variate results are sensitive to the number and scaling of the variables used in their calculation.

As an alternative, Mitteröcker and Bookstein (2011) advocate the use of a 'between groups PCA' in which the group means are used to determine the orientations of a set of eigenvector axes and the data comprising the sample projected into this group-mean-determined PCA ordination space.

[2] This is an aspect of what I've referred to as the 'curse of dimensionality' and discussed in several columns in this series.

Certainly the between-groups PCA (BG-PCA) is a simple procedure that does have the advantage of preserving true Euclidean and Procrustes distances more faithfully—though not exactly—in the ordination space than a typical CVA would. On the one hand, for datasets in which the number of objects exceeds the number of variables a BG-PCA will, in most cases, produce a result that is suboptimal in terms of group centroid separation within its discriminant space, relative to the discriminant space calculated as the result of a normal CVA. On the other hand, for datasets in which the number of variables greatly exceeds the number of objects a CVA may paint a misleading picture of the true degree of between-groups difference. Both approaches are compromised by the curse of dimensionality, but in different ways. Conducting a preliminary PCA in either case will reduce the influence of this curse and allow more of the original data collected to participate in the analysis. As for the ability of CVA results to be interpreted and modelled, MacLeod (2009) reviewed procedures for projecting CVA axes (or any group-separation trajectories specified in the CVA space) back into the space of the original variables, and MacLeod (2011) presented procedures for modelling the results of this projection in the PCA space. These projection and modelling procedures are (slightly) more complex for a CVA than for a BG-PCA, but not seriously so.

From my personal point of view both procedures have their merits and their limitations. If the purpose is to achieve an optimal group assignment decision or to test hypotheses concerning a morphological distinction referenced to an optimal between-groups discrimination space, and if the size of the sample is large relative to the number of variables being used to define the discriminant analysis, a CVA analysis of PCA scores should return an appropriately robust result. Alternatively, if the purpose is to achieve between-groups discrimination while preserving a high degree of correspondence in the ordination result to the fundamental Euclidean or Procrustes character of the data, and/or if the size of the sample is small relative to the number of variables being used to define the discriminant analysis, a BG-PCA should return an acceptable result. Since both methods are reasonably easy to calculate, prudence suggests that both approaches be utilized and their results compared for agreement.

As my original orange morph *vs*. black morph hypothesis involves only two groups, a single discriminant axis will suffice for testing our hypothesis. Figure 9 presents results of both a BG-PCA and a CVA in the form of frequency histograms of scores for the ladybird image set projected onto their respective discriminant axes.

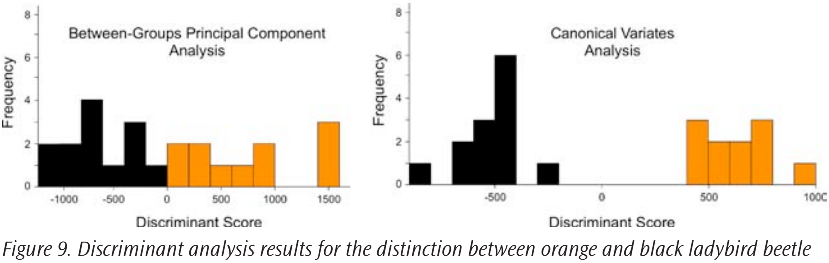

Figure 9. Discriminant analysis results for the distinction between orange and black ladybird beetle morphs. See text for discussion.

As expected, a standard CVA of the PCA scores produced the more definitive result with clear separation between these two putative beetle morphs. The BG-PCA result is consistent with that of the CVA result, but much less resolved. Indeed, if the BG-PCA result had been the only test used, a distinction between orange and black morphs would be confirmed, but the character of the transition between them would have remained ambiguous. Perhaps the best way of conceptualizing the relation between these two results is that the BG-PCA result is what we would see if we could view the 18-dimensional PCA space in an orientation that best separated these two putative morphs, whereas the CVA result (in this case) allows us to perform a similar operation, and at the same time, hold a mathematical magnifying glass up to the critical transition interval. Parametric Monte Carlo simulation tests using hypothetical random datasets of the same size but identical means indicate that the curse of dimensionality has not played a significant role in the determination of either of the ordination results shown in Figure 9.

Although these results do not 'prove' that the ladybird beetles came in two varieties, they do show that, for the dataset illustrated in Figure 2, we can use the data encoded in digital images to test specific hypotheses regarding the character of variation within a morphologically complex sample of organisms, even if we cannot reasonably specify the positions of relocatable landmarks or boundary outlines. This 'image analysis' technique is probably best used in an exploratory context, as a way of generating specific morphological hypotheses that can be tested using more normal landmark, outline, or landmark+outline approaches. Nevertheless, it represents a conceptual link between morphometrics and approaches to computer vision that may have widespread application across the biological sciences, and perhaps even further (see MacLeod *et al.* 2013).

To give credit where credit is due I must admit to not being the first to come across the idea of using digital images directly as input to a morphometric analysis. In researching this article I ran across a similar application, called 'eigenfaces', which is currently being used in biometric face recognition and cognitive neuroscience studies (see Sirovich and Kirby 1987, Turk and Pentland 1991a,b). The approach I outline above also shares certain historical similarities with the Digital Image Analysis System (DAISY) design for generalized semi-automated specimen identification systems (ONeill 2007). Owing to the obvious implications such technology has for the security and surveillance business sectors, much primary research is being done on the general problem of automated object identification at the moment. While this technology has yet to make a substantial impact in the mainstream taxonomic and biological sciences, tantalizing glimpses of what these approaches might be capable of in the near future are available (see MacLeod 2007). In addition, the need for the introduction of such systems into research programmes that rely on rapid, accurate, and consistent taxonomic identifications is becoming more widely recognised with each passing year (*e.g.*, MacLeod *et al.* 2010, Culverhouse *et al.* in press).

How can you experiment with this more direct form of image-based morphological analysis? It's easier than you might think. Most of us are already used to working with digital images these days. Many commercial and public-domain image-processing software packages (*e.g.*, Photoshop, Graphic Converter, Gimp) have the ability to change the spatial resolutions of digital images such that you can control the number of rows and columns in the pixel grid. These same packages will also allow you to convert a colour image into its grey-scale or binary equivalent and give you control over image exposure settings. Once your image set is in the correct format you'll need a way of converting your images into ASCII datafiles. Older versions of Photoshop will do this as will Graphic Converter and Mathematica. Once you've converted your image files into grey-scale or colour (RGB) brightness values, all you need to do is reformat your image data matrices into a single row of values and assemble these into a standard data matrix in which the rows represent the specimens and the columns the pixel variables. This will typically be a large data matrix with many more columns than rows. Once your data are in this format, any reputable PCA program should be able to carry out the preliminary PCA analysis, though run-times for very large datasets may be long. Secondary CVA or BG-PCA analysis can be carried out on the preliminary PCA results as outlined above. All datasets and procedures used in this essay are available as Mathematica notebooks from myself. But all steps in the analysis can be performed by software available to anyone either free of charge or for a small licensing fee (depending on the type of computer you have access to).

As this will be the last essay in the *PalaeoMath 101* series all that's left to do is to thank the past three editors of the Palaeontological Association Newsletter—Phil Donoghue, Richard Twitchett, Al McGowan—for their indulgence over the years of this column's publication, to send a special thanks to Nick Stroud (the unseen force behind the Newsletter) for his kind attention in laying out the column articles sympathetically and instituting the numerous last-minute edits to which I am prone, to thank the Palaeontological Association generally for creating a forum where a series on such an unusual subject might exist at all, and to thank all the people who have contacted me over the years with questions, corrections, extensions, queries, requests for advice, etc. about quantitative data analysis in the palaeontological and biological sciences as a result of these essays. Last but not least, I must thank you, dear reader, for taking the time to consider how quantitative forms of data analysis might be useful in your day-to-day research. Although this series has only covered two aspects of palaeontological data analysis in any depth, I hope it's demonstrated the power and utility of such approaches generally.

When I started this series in 2004 my goal was to write a small series of essays that would provide students, post-docs and young researchers with the sort of practical, easy-to-follow discussions of the ins and outs of palaeontological data analysis that I had often wished I had when I was just starting out in this field. I've enjoyed writing each of these columns immensely and, based on the many appreciative comments I've received over the years from readers like you, am content that I have reached that goal. It's been time well spent.

Norman MacLeod
The Natural History Museum
<N.MacLeod@nhm.ac.u k>

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

Art of Ancient Life

(the arts and endeavours of a pencil pusher)

The value of artistic interpretation and the role of art in reconstructive palaeontology

Palaeontology is a big science, which is to say there is an awful lot to understand; a storehouse of knowledge augmented almost daily by new discoveries as scientists and researchers the world over liberate elusive beasts from their rocky tombs.

It is a science of mystery, of adventure in the lands that time forgot, week-long treks into inhospitable places; high mountain passes that were once under the sea, or endless plateaux where giant bones weather out beneath the barren sun. And I suspect that those who continue to take up this challenge are every bit as determined to find their prize as those bearded gentlemen and stalwart ladies of Victorian fact and fiction were all those years ago, if better equipped and less prone to wearing a shirt and tie in the field.

The trouble is, for all their enthusiasm and endeavour, these purveyors of dusty places are likely, more often than not, to return home with little more than a handful of bones; a few fragmentary pieces; scant remains from which they hope great oak trees may grow.

This then is the reality of vertebrate palaeontology, an absurd equation where lack of funding and preposterous endeavour, plus endless hours of preparation and speculation, equal a rare glimpse of a creature the world might not have seen before.

Of course there are those who strike gold; prospectors who tap seams so rich they hire heavy machinery to move their prize, but these are the exceptions, for the most part fossils tend to come on the small side, some unnoticeable to the untrained eye; long lost glimpses of a vanished world teased out of the stone by those who know what they are looking for.

This is where the artist comes in, for although they are seldom palaeontologists in their own right, they are cut from the same cloth; observers every bit as skilled as their academic counterparts, and like reporters entering uncharted lands they are the eyes of their companions, able to speak the same language and convert what they learn into a visual form.

At its most basic level, an eye can do what a camera cannot. It can interpret, and an artist can pick out and emphasise details that a camera might simply overlook; diagnostic features and morphological characteristics that separate one specimen from another.

This in itself is a phenomenal resource and, working in tandem with scientists, artists are regularly employed as document makers; scribes who take down and record the information in a clear and impartial way.

That then is one facet of an artist's role, another is as an emissary between the scientist and the public, correlating known data and producing a restoration. A restoration is often the pinnacle of a project; the visual depiction of the subject as it may have looked when it was alive.

I say may, for this is not an exact science, rather it is the product of extreme skill and educated guesswork based on years – if not decades – of experience.

Scientific illustrators offer key support to many palaeontologists, sifting through the evidence and reconstructing the victims of time. Of course, like a victim of a crime scene, nothing makes sense if it is not taken in context. Across the world palaeontologists and geologists have sought to identify rock formations, index fossils and diagnostic species – building up an international database to determine this context.

From this we begin to see a picture; a pattern emerges of a world once fully joined together that gradually split apart carrying its assorted occupants on their continental rafts out across the globe.

We still live on those continents; those ice scoured, rain washed, sun beaten rafts, and each has its own unique story to tell, a story that geologists, palaeontologists, palaeobotanists and of course palaeontological artists can read, and it's from this collected information that we piece together our narrative.

What was the climate like? What weather patterns existed? Was it monsoonal, arid, volcanic even? Who were the leading characters and what did they eat? These and many more questions need well-informed answers before an accurate restoration can be attempted.

Of the animals themselves we sometimes know a great deal; so many accurate studies have been made of the big players that it really is hard to go wrong. From the bones and even skin impressions it is possible to gauge an animal's appearance, muscle mass, the movement of its limbs and perhaps even aspects of its daily life. From trace fossils we may find out what it ate or how it walked. But these creatures did not live in isolation, they flourished in worlds long extinct; worlds so bizarre you may as well be viewing another planet.

To understand this you're going to need help. You need to speak with the right people, experts who have spent their careers studying these environments. You are unlikely to bump into a palaeoclimatologist in the pub, indeed even if you did they might not be the right palaeoclimatologist, so the first stage of this endeavour is to determine who to speak with.

This is where modern means of communication are invaluable. You can ask around, find out who has published what, who has spent twenty years writing a monograph on Cretaceous gastropods, the dietary habits of a *Brachiosaurus* or even examined beetle dung inside fossilised tree ferns. No matter how obscure the subject, someone has covered it.

Speak to these people and you shall learn, and willing they are to give up their secrets if it can bring their passions to life. And that's what all this is about, taking fragmentary remains and breathing life into them.

Without palaeontological artists there would be no *Walking with Dinosaurs*, *Planet Dinosaur* or *Jurassic Park*. People simply wouldn't know where to start. These popular shows are born of scientific endeavour and artistic interpretation. Yes, anyone can draw a dinosaur, but can they draw the right dinosaur in the right environment, do they know which species of ferns grew at that time or the morphology of conifer leaves, would they know what lived in the undergrowth or even which craters had yet to make their mark on the moon?

It is unlikely, but a good palaeontological artist knows this, they have asked the questions and, after a good deal of homework, will have found the answers. He or she will have studied the fossils, gained a clear understanding, checked the facts, and will be able to interpret them confidently in a visual form.

Without artist working alongside palaeontologist, the public would hardly know about the ancient past. Yes, they would know that mysterious monumental beasts once roamed the earth, pottering around in the Garden of Eden complete with a volcanic backdrop and monkey puzzle trees, but they wouldn't have any real idea of how these animals looked and whether this Garden of Eden was a semi-arid landscape pockmarked by soda lakes or a river delta cloaked in hot humid forest.

They know this now, for generations of artists have done their work, asked questions, learned skills and painted pictures, depicting everything from insects to mammoths, each presented in a habitat unique to their time.

This then is the value of an artist as an illustrator, and his or her work will appear on museum walls, in university publications, in books, science journals and on TV. And other equally-skilled artists build models and dioramas, paint replica casts and facial reconstructions, paint murals, plan exhibitions – the list goes on. The artists bridge the gap between the academic and the public; weave their magic to bring the deceased back to life and their contribution to the field of palaeontology, and indeed to our understanding of the prehistoric world as a whole, should not be underestimated.

Jon Hoad
Art of Ancient Life: Palaeontological Reconstruction.
Australian Citizenship: Distinguished Talent.

>>***Future*** Meetings of Other Bodies

TMS Annual Conference 2013 – Micropalaeontology and the IO DP: Past, Present and Future Applications
Natural History Museum, London *18 – 19 November 2013*

The Micropalaeontology Society (TMS) will be holding its annual meeting in the Natural History Museum, London this year with the theme of "Micropalaeontology and the IODP: Past, Present and Future Applications". The meeting will include five keynote speakers, TMS awards and society business followed by a drinks reception and conference dinner in the evening. Tours of the NHM micropalaeontological facilities will be conducted during the morning of the first day. The second day will comprise a keynote lecture and open oral and poster presentation sessions covering all aspects of the discipline. Talks and posters from PhD students and early career researchers are particularly welcome.

For further information visit the conference website at <**http://www.tmsoc.org/agm2013.ht m**>.

Forams 2014 – International Symposium on Foraminifera
University of Concepcion, Chile *19 – 24 January 2014*

Papers covering a wide range of research topics are invited, including all aspects of foraminiferal biology, biostratigraphy, biogeography, ecology and palaeoecology, palaeoceanography, molecular evolution, systematics and evolution.

The meeting place for the pre-Symposium field trip is Punta Arenas on 14th January 2014. The mid-Symposium Field Trip to Nahuelbuta National Park will take place on 23rd January 2014. More information and the registration form for this field trip is available at the symposium website (<**http://www2.udec.cl/forams2014/Program.htm l**>). The meeting place for the post-Symposium field trip is Caldera on 25th January 2014. More details/costs for the pre- and post-meeting field trips will be available soon. If you are planning to attend the pre-Symposium field trip to Punta Arenas and/or the post-Symposium field trip to Caldera, please let us know as soon as possible.

A room block has been set aside for FORAMS 2014 participants at Hotel El Araucano in Concepcion. This room block will be available until 15th December 2013. Other lodging options are also available. For further information and registration details visit the conference website at <**http://www.udec.cl/forams201 4**>.

British Council Researcher Link workshop: Jurassic palaeoenvironments and life
Marrakech, Morocco *27 January – 1 February 2014*

Dr Paul D. Taylor (NHM, London) and Prof. Ait Addi Abdellah (Cadi Ayyad University, Marrakech), assisted by Prof. John Cope (National Museum of Wales) and others, will be running a workshop in

Marrakech for early stage researchers interested in the marine Jurassic. The aims of the workshop, which we hope will include a fieldwork component, are to: provide a stratigraphical framework for the Jurassic; survey carbonate Jurassic facies globally, their palaeolatitudinal variations, and how they can be interpreted in terms of depositional environments; and discuss the main fossil groups present and their use in correlation and palaeoenvironmental reconstruction. Participants will be encouraged to bring along posters and there may be an opportunity for brief oral presentations too.

The British Council will provide full funding for travel, accommodation and meals for participants from the UK. If you are interested in participating in this workshop, please email <**p.taylor@nhm.ac.uk**>.

10th North American Paleontological Convention
Gainsville, Florida *15 – 18 February 2014*

The meeting will be hosted by the Florida Museum of Natural History (University of Florida) from Saturday 15th February to Tuesday 18th. Pre-conference and post-conference field trips are tentatively planned for 13th–14th and 19th–20th respectively.

The North American Paleontological Convention is a major international paleontological event administered by the Paleontological Society under the auspices of the Association of North American Paleontological Societies. Initiated in 1969, NAPC meets every 4–5 years. The convention includes active participation from all fields of palaeontology. Over 500 participants from 26 countries attended the most recent NAPC in Cincinnati (2009).

Check The Paleontological Society website at <**http://www.paleosoc.org/**> for updates or e-mail Michal Kowalewski at <**kowalewski@ufl.edu**>.

Mid-Mesozoic: The Age of Dinosaurs in transition
Fruita, Colorado & Green River, Utah*, USA* *30 April – 5 May 2014*

The Morrison Formation is world famous for its Upper Jurassic dinosaur fossils and is one of the most extensively studied dinosaur-bearing units in the world. It is exceptionally well-exposed across the Colorado Plateau and preserves at least two dinosaur faunas. In contrast the overlying Lower Cretaceous Cedar Mountain Formation spans roughly 35 million years, in comparison to the Morrison Formation's seven million years. The Cedar Mountain is approximately half the stratigraphic thickness, but represents about five times as much in geologic time, in comparison to the two closely related faunas in the Morrison; the Cedar Mountain preserves at least six different distinct faunas.

Colorado Plateau's Morrison–Cedar Mountain Formations are contributing critical information about an important period of time in the history of terrestrial life in the Northern Hemisphere. The density of biostratigraphic, chronostratigraphic and palaeoclimatic data make the Colorado Plateau a standard on which to resolve the geological and palaeobiological history of the mid-Mesozoic in the northern hemisphere.

This field conference has been structured to minimize the participant's cost ($230.00 US). It consists of four day-long field trips to visit pivotal sections and localities, with an optional pre-meeting trip to Dinosaur National Monument ($50.00 US). Additionally, there are two days for conference talks and posters of international scope.

Check the conference website at <**http://www.utahpaleo.org/mid-mesozoic-conference.html**>.

Fossil Fishes and Fakes:
The Sir Arthur Smith Woodward 150th Anniversary Symposium
Natural History Museum, London *21 May 2014*

Smith Woodward built his scientific reputation on detailed and meticulous studies of fossil fish, many of which helped to form the foundations of current research on numerous fish groups. However, he also contributed to our knowledge of other extinct animals and regional geology, and he endured some notoriety for his involvement in the Piltdown Man hoax. Almost no attempt has been made to assess Smith Woodward's wider impact on palaeontology. This one-day symposium aims to rectify this omission, with invited speakers who will present papers on Smith Woodward's life and career, his varied scientific outputs, and his involvement in Piltdown.

To pre-register and receive further information please e-mail the Meeting Coordinator at <**ASW150@nhm.ac.uk**>.

Commission Internationale de la Microflore du Paléozoïque International (CIMP)
Ghent-Liège, Belgium *6 – 11 July 2014*

This meeting will include general CIMP sessions, chitinozoan workshops and a field-trip between Ghent and Liège. For more information please contact <**p.steemans@ulg.ac.be**>.

9th European Palaeobotany-Palynology Conference
Padua, Italy *26 – 31 August 2014*

The Italian group of palaeobotanists and palynologists is very glad to be able to invite all of you to Padova in 2014 for the next EPPC. Padua (Padova in Italian) is a picturesque, historic city in Northern Italy (about 40 km west of Venice), with a dense network of arcaded streets, large communal "piazza" (squares), and many bridges crossing the various branches of the Bacchiglione.

All scientific sessions will be held at the new Department of Geoscience, and the famous Botanical Garden and Museum of Geology and Palaeontology will be involved in this conference. Field-trips are planned in the fascinating landscapes of the Dolomites, Sardinia, Emilia-Romagna, Latium and Tuscany.

For further information contact the conference secretary (e-mail <**Evelyn.Kustatscher@naturmuseum.it**>) or look for updates on the conference website at <**http://www.geoscienze.unipd.it/9th-european-palaeobotany-palynology-conference/**>.

9th International Congress "Cephalopods – Present and Past" (ISCPP 9) and the 5th International Coleoid Symposium
University of Zurich, Switzerland *4 – 14 September 2014*

This series of cephalopod meetings was launched in the seventies in York. Thereafter, they were held every three or four years in various cities including Tübingen, Granada, Vienna, Fayetteville, Sapporo and Dijon. It is the only occasion in which cephalopod workers meet from around the world. There are normally three to four days of scientific presentations. The interesting and important aspect of this meeting is that both biologists and palaeontologists meet, although there traditionally have been slightly more palaeontologists. This might change at the 2014 meeting, however, since it will host the International Coleoid Symposium for the first time.

Traditionally, two field-trips are offered in association with the meeting. On this occasion, trips are planned to the Fossillagerstätten of southern Germany, and fossil localities yielding cephalopod fossils in Switzerland, each of which will last a couple of days. Details of these field-trips will be announced in due course.

For further information please visit the conference website at <**http://www.pim.uzh.ch/symposia/ISCPP9/index.php**>.

6th International Symposium on Lithographic Limestone and Plattenkalk
Museo del Desierto, Saltillo, Mexico *15 – 19 September 2014*

The Museo del Desierto invites you to the 6th International Symposium on Lithographic Limestones and Plattenkalk. This multidisciplinary meeting is planned to address aspects of the study of lithographic limestones and plattenkalk deposits across all disciplines, from palaeontology (taxonomy, palaeoecology, taphonomy), to geology (stratigraphy, sedimentology, palaeoenvironments), and also mineralogy and petrology of Plattenkalk deposits and related Fossil-Lagerstätten. The meeting is organized in collaboration with the Institute of Earth Sciences of the University of Heidelberg, Germany. We plan field-trips to the famous plattenkalk deposits of Vallecillo and Cuatro Cienegas.

Please consider submitting manuscripts for the LAK conference proceedings. These are planned to be published in the *Revista Mexicana de Ciencias Geologicas*, which is indexed in several citation indices, including the Science Citation Index. Impact Factor (2010) is 1.136. The *Revista* is an open-access journal.

Please visit the conference website at <**http://isllpsaltillo.uni-hd.de/**> for updates.

Are there limits to evolution?
St. John's College, Cambridge, UK *25 – 26 September 2014*

What will evolutionary biology look like in 50 years? More of the same, or will there be new paradigms, new syntheses? What lies on the horizon?

The impact of evolution is undeniable, but it can be viewed through different lenses. For the scientist it is the investigative discipline, mapping out the history of life, uncovering its intricacies and revealing its mechanisms. For others it might be the grand narrative, and across society it brings different meanings – sometimes to the point of polarization.

This conference is an opportunity to focus on the important research objectives, discuss the best ways to achieve them, and use these to set a considered agenda for the continued study of evolution. This event is part of a larger programme on evolution funded by the Templeton World Charity Foundation. Keynote speakers include Margaret McFall-Ngai (University of Wisconsin), Eors Szathmary (The Parmenides Foundation, Munich), Geerat J. Vermeij (University of California at Davis) and Gunter Wagner (Yale University).

Accommodation will be available in College, and the Conference package will include all meals, a wine reception, and a Conference Dinner in John's medieval Dining Hall. Further information is available by contacting Dr Victoria Ling (e-mail <**vl237@cam.ac.uk**>).

4th International Palaeontological Congress (IPC 2014) to include the 47th AASP-TPS (AASP – The Palynological Society) Annual Meeting
Centro Científico Tecnológico, Mendoza, Argentina *28 September – 3 October 2014*

Local organizers are planning a comprehensive congress with an intellectually motivating scientific programme. The Congress will create opportunities for participants to present and share experiences, explore new directions and debate topics among specialists from across the globe. The meeting will include the 47th AASP-TPS Annual Meeting.

A varied array of meeting styles with a combination of keynote lectures, special symposia on leading issues, interactive workshops, technical sessions, and short courses promises to hold sessions of interest to all palaeontologists.

Delegates will have the opportunity to enjoy a wide range of conference excursions to rich and well-known Argentinean palaeontological sites involving a combination of scientific and touristic attractions. The schedule of field trips covers superbly exposed sedimentary successions, representing a great diversity of marine and continental palaeoenvironments, and encompasses nearly the whole stratigraphic record.

Organizers for the 47th AASP-TPS Annual Meeting are now calling for Symposium topics. If you have any great ideas for palynology-related symposia, please feel free to contact Thomas Demchuk by e-mail to <**tdemchuk@swbell.net**>.

Please see the conference website at <**http://www.ipc4mendoza2014.org.ar/**> for further details. Abstract deadline: March 2014.

Flugsaurier 2015, The International Meeting of Pterosaurology
University of Portsmouth, UK *either late August or early September 2015*

In 2015, Flugsaurier, the International Meeting of Pterosaurology, will be held in the United Kingdom for the very first time. Flugsaurier 2015 will be held at the University of Portsmouth with the dates coordinated to fit in with the Symposium of Vertebrate Palaeontology and Comparative Anatomy.

Anyone who would like to be included on the mailing list so that they receive the first circular should contact Dr Dave Martill (e-mail <**david.martill@port.ac.uk**>).

14th International Palynological Congress and the 10th International Organization of Palaeobotanists Congress (IPC XIV/ IOPC X 2016)
Salvador, Brazil *Late September – early October 2016*

Local organizers are planning the Congress to occur after the Olympics in Brazil. Further details will follow in due course.

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

Meeting REPORTS

Third International Sclerochronology Meeting and Field Workshop
Caernarfon and Bangor, Wales *18 – 27 May 2013*

Sclerochronology is the study of the variation in physical and chemical properties of biological hard tissues, with an emphasis on establishing the time-series of changes in these properties and analysing them to understand patterns of biological change, such as growth, and changes in the physical environment. This meeting addressed a wide range of applications of scleorchronology, as the meeting abstracts show, but this report focuses on the deeper time sessions. However, with the maturing of conservation palaeobiology, palaeontologists should, as a community, be more aware of the use of palaeobiological and Earth Sciences techniques to study very recently dead organisms to contribute to the conservation of living taxa and the reconstruction of environmental conditions from hard tissues. The following report concentrates on sessions that were more focused on palaeontological topics. For a full appreciation of the range of organisms and topics studied, please visit the conference website (<**http://isc2013.bangor.ac.uk/**>).

From a palaeontological perspective, the location of the 3rd International Sclerochronological Conference was superb. It was held in Caernarfon, North Wales, where the geology boasts Precambrian schists surrounding the Menai Straits, a Cambrian dome underlying Snowdonia, and Silurian mudstones situated beneath the Denbigh moorland. The conference organizers took the opportunity to showcase the biodiversity and geodiversity of North Wales by having a welcome break on the Monday afternoon for the delegates. Excellent use was made of local venues and produce, which gave a much stronger sense that the money spent was helping the local economy than one has at most conferences. Excursions were organized to go up Snowdon via the funicular railway or to go on a beach walk to collect shell samples to be used in the post-conference fieldweek training sessions. The whole event was a credit to the conference organizers from the School of Ocean Sciences, University of Bangor: **James Scourse**, **Chris Richardson**, **Paul Butler**, **Iain Ridgway** and **David Reynolds**.

The conference focused on the top of the geological time scale, with the palaeoclimate and palaeoceanography sessions mostly concentrating on climate, ecology, and ocean processes of the Holocene, Pliocene, and Miocene. However, two sessions dug a little deeper and applied sclerchronological techniques to increasing our knowledge of Eocene seasonality.

Nonetheless, most of the sessions, and not just those under the umbrella of palaeoclimate and palaeooceanography, would be of interest to palaeontologists. This is because of the potential for wider applications of techniques, and information discussed in the sessions, which could enhance our understanding of climate processes and ecology in deep time.

Speakers, for example, helped us unravel the mystery of carbon isotopic methods, and their limitations, combined with the valuable information available from this proxy in deciphering modern and palaeomarine environments. Furthermore, the conference highlighted how sclerochronology is developing our knowledge of modern growth patterns of marine organisms (mostly discussed were corals, bivalves and fish), and how these data may assist in our understanding of the taxonomy of more ancient marine organisms.

The conference provided a meeting space for discussion across multiple disciplines, and approaches within the field of sclerochronology. This dialogue is important, as researchers often remain like the fictional secret agent Number Six in the fictional 1960s television programme *The Prisoner* (which was, coincidentally, filmed at Portmeirion and was the location for the conference dinner): we remain isolated in our own research, and conferences like this help provide refreshing insights into others, and ultimately into our own research.

The end of Sunday began the Palaeoclimate and Palaeoceanography session with **James Scourse** chairing. **Peter Swart** started us off with his keynote talk explaining the complications of interpreting variability in the carbon isotopic composition of coral skeletons. **Atsuko Yamazaki** followed with a reconstruction of the Kuroshio Current (the strongest ocean current in the world) over the last 150 years using nitrogen isotopes from *Porites* coral skeletons from the Pacific coast of Japan. Next, we were introduced to a promising new archive of surface water salinity and freshwater changes using Ba/Ca records from encrusting coralline algae by **Steffen Hetzinger**. **Al Wanamaker** finished off with a multi-century master shell chronology using the long-lived *Arctica islandica* to assess variability in the local marine radiocarbon reservoir in the Gulf of Maine.

Monday morning began with the second Palaeoclimate session, chaired by **Carin Andersson**. **Hilmar Holland** peeked into the Late Holocene with an extensive cross-dated annually-resolved chronology using *Arctica islandica* from the North Sea, highlighting increased higher frequency variability during major regime shifts. Next, **Sarah Tynan** discussed an experimental project to test commonly used temperature calibration equations with data from *Ostrea angasi* with instrumental temperatures, with the conclusion that the construction of an *O. angasi* specific equation is needed. **David Reynolds** then presented a multiproxy reconstruction on the Hebridean Shelf Sea based on growth increment series from *Glycymeris glycymeris* and previously published stable oxygen isotope data from benthic foraminifera. **Kristine DeLong** continued with a cross-dated reconstruction of the last 274 years using Sr/Ca records from *Siderastrea sidereal* corals from the Gulf of Mexico. This extensive study shows an impressive comparison to recorded SSTs in the same area. The session finished with **Mary Elliott** championing the usefulness of *Tridacna gigas* as a tool for PaleoENSO studies using modern specimens along with oxygen isotope profiles from *Porites* coral and the ENSO index.

The final Palaeoclimate session, chaired by **Kristine DeLong**, was kicked off by **Bernd Schöne** who stuck with the ENSO theme and discussed the use of *Saxidomus gigantea* (butter clams) from Alaska as a suitable archive of ENSO teleconnections in coastal habitats of the Pacific Northwest. **Lars Beierlein** presented shell growth patterns and well-defined seasonal oxygen isotope signals from *Arctica islandica* from Svalbard during the Holocene Climate Optimum. A first glimpse into deeper time was introduced by **Laurie Bougeois** who highlighted the usefulness of a multiproxy reconstruction of the Middle Eocene in Central Asia using the oyster *Sokolowia buhsii*. This study illustrates how bivalve shells can be very powerful when trying to reconstruct regional variations in temperature and aridity. Remaining in the Eocene, **Anindya Sarkar** used high-resolution oxygen and carbon isotope data from multiple marine bivalves from a new PETM section in western India to suggest enhanced seasonality in the tropics compared to today. The session was concluded by **Andrew Johnson** who issued a word of warning about comparing proxy data and climate models, highlighting an example from the 'mid-Piacenzian warm period.' He also demonstrated the need to used sclerochronolgical methods in deeper time as another method of model validation.

On Tuesday afternoon the Palaeobiology and Evolution session was chaired by **Andrew Johnson**. This started with a keynote talk by **Linda Ivany,** who highlighted the potential for combining stable isotope and increment analysis and stressed the need to used modern expertise to answer evolutionary questions. **Nicola Clark** followed with oxygen isotope temperature reconstructions from the Antarctic coast during the Pliocene, illustrating the constraints and also potential usefulness of such studies. Moving to the Miocene, **Alexandra Németh** presented evidence for tidal cyclicity in a Palaeogene Basin in northern Hungary using variations in growth increments from *Crassostrea gryphoides*. **Daan Vanhove** concluded this short session with a study on early Eocene fish otoliths from the southern North Sea Basin using clumped oxygen isotopes, a method which avoids the need to make assumptions about seawater chemistry changes during growth.

These talks all highlighted the importance of collaboration between modern and palaeosclerochronology and also using multiproxy approaches when interpreting isotope records. They also emphasised that when utilising modern knowledge and techniques we still need to be aware of the shortcomings and difficulties of this in the palaeontological record.

The scientific sessions concluded on 22nd May, but a smaller group of researchers remained behind to take advantage of the training week offered at the School of Ocean Sciences, University of Bangor. The laboratory facilities and setting on the Menai Straits offered an excellent location for the fieldweek to cover all the practical aspects of sclerochronology. Two options were available to participants. One was to learn the skills required to build a chronology from prepared shell sections, starting with the principles of identifying distinctive growth increments in dendrochronological samples to build 'skeleton plots'. From these beginnings the group went on to learn the list method for building a chronology and were introduced to the important differences between studying growth increments in trees and shells. After this introduction, the group collaborated to develop a sclerochronological analysis of material from the Pacific Coast of Canada. The hoped-for identification of a signal of cyclical climate oscillation was dashed by local signal, but the group did learn the basis of the techniques used to carry out such work.

The other option focused on the techniques to select shells for sclerochronological analyses and then the steps in preparing the shells. This involved a lot of laboratory work and training in embedding shells in resin blocks, cutting and polishing sections and staining them to enhance the contrast of different growth increments prior to analysis under the optical microscope. The skills to make acetate peels of shell growth lines were also part of this option.

Although we had long days in the laboratory or poring over microscopes or computer files, there was an opportunity to go out and collect samples on a beach walk and a superb group dinner. Both sections of the workshop received superb support from the instructional teams. The desire to produce outputs – whether sections of specimens or the analysis of the dataset by the analytical group – provided a great incentive to keep people working long hours, and there were always fantastic views from the labs over the Menai Straits when weary eyes needed a rest from the microscopes and computers screens.

Annemarie Valentine
University of Derby

Nicola Clark
University of Leicester

Al McGowan
University of Glasgow

17th International Symposium on Ostracoda "Back to the future"
University of Roma 3, Rome, Italy *22 – 26 July 2013*

The International Symposium on Ostracoda (ISO) is a meeting that features research on both living and fossil Ostracoda. It takes place every four years, each time in a different location. The 17th Symposium took place in Rome, hosted by the University of Roma 3. It was also an opportunity to celebrate 50 years from the first ISO meeting, which took place at the Zoological Station in Naples in 1963. For this reason, the motto of ISO17 was "Back to the future", further developed in "Evolution of concepts and methods in ostracodology during the last 50 years".

The first day of the conference started with the Opening Ceremony. The short welcome of the Head of the Department of Sciences, the Head of the Faculty of Mathematics, Physics and Natural Sciences, and of the president of IRGO (International Research Group on Ostracoda), prepared the ground for an original introduction to the Symposium. The dynamic and engaging **Dan Danielopol**, with contributions from many colleagues from all over the world (the Ostracodophili), presented "From Naples 1963 to Rome 2013. A brief review of how the International Research Group On Ostracoda (IRGO) developed as a social communication system", which was wonderfully delivered and highly entertaining.

The Symposium was organised in five scientific sessions, each introduced by invited lectures. The scientific sessions included: "Evolution and extinction of Ostracoda" (20 presentations), "New and advanced approaches in the study of Ostracoda" (14 presentations), "Ostracoda in palaeoceanographic reconstructions during the Cenozoic" (10 presentations), "Ostracoda in the past and present worlds" (52 presentations), and "Ostracoda as proxies for environmental monitoring and palaeoenvironmental reconstruction" (24 presentations). During the three workshops, more specific topics were addressed such as "Cyprideis – a multi-tool of ostracodology" (six presentations), "Ostracods in environmental archaeology" (nine presentations), and "Neogene brackish and freshwater ostracods in the Paratethys" (seven presentations).

The 132 participants did not spend all their time listening to 72 oral presentations, reading carefully the 72 posters or discussing scientific topics! There were plenty of opportunities to chat with colleagues and friends from 29 different countries, especially during the icebreaker and the farewell parties, the lunches and coffee breaks. And notwithstanding the July heat, also the mid-symposium field trip led by **Elsa Gliozzi** and **Ilaria Mazzini** was enjoyable. Imagine what the usual visitors

Group photo of the ISO17 participants in front of the Aula Magna of the University of Roma 3 of the Appia Antica Regional Park were thinking of this heterogeneous group of people sampling ponds, streams, channels, Roman ruins and springs in search of ostracods. A meeting in Italy could not be complete without a gorgeous social dinner in a unique setting. The conveners enjoyed the delicious roman cuisine dining "al fresco" looking at the Mausoleum of Cecilia Metella along the ancient Appian Way.

The IRGO meeting closed the last day of the Symposium. The future of IRGO was discussed and a new steering committee was elected. Moreover, the winners of the Young Researchers Sylvester-Bradley Awards and of the SF*IRGO poster Award were announced: **Yuanyuan Hong** (University of Hong Kong) was awarded for the best oral presentation (sponsored by TMS); **Josep Antoni Aguilar-Alberola** (University of Valencia) was awarded for the best poster presentation (sponsored by IRGO); **Ilaria Mazzini** (University of Roma 3) and **Jessica Fischer** (LMU-Munich) shared the SF*IRGO Poster Award. Finally, the venue for the next ISO was decided: ISO18 will be held in the USA.

Gianguido Salvi and **Nevio Pugliese** led the post-symposium field trip to the Trieste area, in the northeast part of Italy. The participants sheltered from the heat in the Grotta Gigante, sampling ostracods in karstic pools, and visited Cona Island and the Isonzo River Mouth Reserve and the ancient Latin colony of Aquileia. The visit to the Marine Reserve of Miramare was the right conclusion to a fantastic fieldtrip, since they could snorkel in one of the most pristine areas of the Adriatic Sea.

ISO17 was a big success! This meeting represents an irreplaceable forum for communication between specialists who focus on fossils and those who work on living ostracods. The importance of this communication is constantly increasing in the midst of pending climate change and acceleration of biodiversity loss.

Mid Symposium field trip: Visiting and sampling the Nymphaeum of Egeria at the Appia Antica Regional Park.

The abstract volume was published by the "Naturalista Siciliano" and can be requested from <**secretaryiso17@gmail.com**>. The proceedings of the Symposium are scheduled to be published in 2014 in three international journals. A special issue of the Journal of *Archaeological Science* on "Ostracods and environmental archaeology" is also scheduled for 2014.

To get more details of this meeting and to find out about ISO18 in the USA, visit the websites:

<http://www.iso17.unipr.it/index.htm>

<http://www.irgo.uni-koeln.de/>

Ilaria Mazzini
University of Roma 3

The 61st SVPCA, the 22nd SPPC, jointly meeting with the GCG

National Museums Scotland and University of Edinburgh *27 – 31 August 2013*

This year, the 61st Symposium of Vertebrate Palaeontology and Comparative Anatomy (SVPCA) was held in the wonderful setting of Edinburgh, hosted by the National Museums of Scotland (NMS) and the University of Edinburgh, and painstakingly organised by Stig Walsh, Nick Fraser, Jeff Liston, Steve Brusatte and Vicen Carrino. A record 138 delegates attended SVPCA this year, in this historic city.

The icebreaker on the evening prior to the first day of palaeontological talks was a perfect way to open SVPCA, with the conversation (and drinks!) flowing freely, as old friends greeted each other and new connections were made over a glass of wine and palaeontological conversation.

The talks kicked off bright and early on Wednesday 28th August in the lecture theatre of the Royal Society of Edinburgh (any fuzziness from the night before was swiftly shaken off!), with an introduction by **Stuart Monro** of 'Our Dynamic Earth'. He highlighted the part that the City of Edinburgh has played in geological and palaeontological research, an inspiring thought as the city played host to the largest SVPCA conference so far.

Stuart Monro opens the meeting on Wednesday morning in the Royal Society of Edinburgh.

Mammalian palaeontology was the opening act, chaired by **Steve Brusatte**. The audience heard about the mechanics of feeding in the relatively newly discovered and little known Laotian rock rat (**Philip Cox**), the evolution of mammalian teeth (**Enni Harjunmaa**), and of course, the recent light shed on the notoriously difficult subject of mammalian phylogeny, specifically new evidence on the marsupial-placental dichotomy (**Marcelo Sanchez-Villagra**), the phylogeny of Palaeocene mammals (**Thomas Halliday**) and assessing the presence of a 45 million year old dryolestoid ghost lineage (**Rachel O'Meara**).

Following the first session, we headed upstairs to the reception room for a well-deserved coffee break after our early morning, and saw the first display of posters. The academic hubbub gave a nice atmosphere as people were quizzed on their research and connections were made. It was certainly a perfect place for networking, especially for us newbies to palaeontology!

We soon returned to the lecture theatre awaiting our second instalment, chaired again by Steve Brusatte. We heard about cranial and mandibular variation within Rodentia (**Elizabeth Kerr**), followed by talks on the mechanics of walking in early hominids, and how modern humans manage the dual tasks of walking and object tracking (**Sarita Morse**, **Emma Webster**). **Graeme Lloyd** followed with a presentation on 'Claddis', described as a new R package for automating disparity analyses based on cladistic datasets, and the session drew to a close with **Pierre Gueriau**'s talk on the implications of trace elemental imaging in taphonomy and palaeontology.

The early afternoon session introduced the pterosaur talks, chaired by **Darren Naish**. I think it's safe to say that the pterosaur researchers should win some sort of honorary award for being the most animated collective of palaeontologists, and what followed was a very memorable series of talks. **David Unwin** opened the session by discussing a remarkable specimen that had preserved the 3D structure of a pterosaur wing membrane. This was followed by a talk with the striking title 'Pterosaur overlords of Transylvania', by **Mark Witton**, discussing the short-necked giant azhdarchids from Late Cretaceous Romania. Next, **Michael O'Sullivan** introduced us to the taxonomy of *Parapsicephalus purdoni* thanks to a 3D pterosaur skull specimen from the Alum Shale of Whitby. **Elizabeth Martin** then showed her findings on the air space proportion in pterosaur wing bones. The day was closed by **David Hone**, whose talk was on the evidence for cephalopods being part of the diet of *Rhamphorhynchus*, and the implications of this for the ecology of these pterosaurs. This provoked a lively discussion.

Mark Witton talks about the 'Pterosaur overlords of Transylvania' – apparently they had short necks.

As the first evening event, what could be better when in the wonderful city of Edinburgh than a whisky tasting session? This was led by Steve Brusatte (perhaps taking the edge off after chairing two sessions during the day) with the assistance of more-than-capable **Jeff Liston**. Between the two of them, their knowledge of Scotch whisky was second to none, with a good range of whiskies and tastes. There was also a mystery whisky to test the tasters' skills of deduction … or perhaps just so that Jeff and Steve could laugh at their facial expressions, as it turned out to be Morrisons' own brand

Dave Hone on the fragrant subject of pterosaur coprolites.

The well-attended 'Whisky tasting' on Wednesday evening at the Royal Society of Edinburgh.

whisky from a plastic bottle. This resulted in the take-home message of the day: if it comes in a plastic bottle, don't drink it! Probably good advice to follow regarding all alcoholic beverages!

Talks on Thursday 29th August began at 8:30, with the morning session on dinosaurs chaired by **Mark Young**. The opening talk told us that the concept of *Barosaurus* is based on erroneously referred specimens (**Mike Taylor**). We then heard about a skeletally immature specimen of *Apatosaurus* (**Matt Wedel**), biomechanical evidence of niche partitioning between sympatric sauropod dinosaurs (**Dave Button**), new data on Early Jurassic theropod diversity (**Jeff Liston**) and using a Character Completeness Metric to examine completeness of Mesozoic dinosaurs (**Mark Bell**). The session drew to a close with evidence that large geographic ranges conferred little protection against extinction in terrestrial tetrapods across the T–J boundary (**Alexander Dunhill**).

After another opportunity to view the posters over coffee, we returned to the late morning session, chaired by **Stig Walsh**. **Bernat Vila** closed on the dinosaurs with a talk on updating the Maastrichtian dinosaur record of the South Pyrenees. The bird session was opened by **Ella Hoch**, reviewing Neogene auks from the North Atlantic. She was followed by **Vincent Beyrand** and his studies of endocasts in extant and extinct birds and their implications for flying and behaviour. **Gareth Dyke** discussed the early evolution of the modern avian wing, and **Michael Habib** finished with his talk on the aerodynamics of feather asymmetry and the implications for paravian flight.

After lunch, it was sauropterygians, the session chaired by **Judy Massare**. **James Neenan** opened the session with a talk on tooth replacement in durophagous placodont marine reptiles, with new data on the dentition of Chinese taxa. He was followed by **Mark Evans** and a reassessment of the Paris Plesiosaur. After, **Luke Muscutt** taught us about the hydrodynamics and ecomorphology of plesiosaurs using a computational and experimental approach, incorporating a very memorable and amusing song he had written himself! Next, it was **Tom Stubbs** on the early evolutionary radiation of Triassic marine reptiles, and **Adam Smith** on a new rhomaleosaurid pliosaur from the

Sinemurian (Lower Jurassic) of Lyme Regis. **Benjamin Moon** finished the session with a talk on the morphological and hydrodynamic convergence in pelagic vertebrates.

Now was the turn of ichthyosaurs to take the stage. The session was chaired by **Matt Wedel** and opened with a talk by **Jessica Wujek** about taking a fresh look at the genus *Ichthyosaurus*: species characteristics, phylogeny and evolutionary drivers. **Judy Massare** followed, talking on the variation in the forefin morphology of the lower Jurassic ichthyosaur genus *Ichthyosaurus*. **Jørn Hurum** was next, with a first report on a nearly complete Middle Triassic mixosaurid ichthyosaur from Edgeoya, Svalbard archipelago. **Aubrey Roberts** then told us about a new Upper Jurassic ophthalmosaurid ichthyosaur from central Spitsbergen, and finishing the talks on ichthyosuars. **Erin Maxwell** ended the session with a talk on the taxonomy, life history and evolutionary patterns of diversification of the basal actinopterygian fish *Saurichthys,* leading into the talks on fish which were to continue the next day.

The evening event was the SVPCA charity auction; academics had generously donated books, papers and palaeontological memorabilia to raise money for new studentships. The auction was hosted by the incomparable Jeff Liston, whose combination of jokes and guilt-tripping managed to squeeze every penny possible out of a jovial audience. By the end of the night, it was less of an auction and more of a stand-up comedy act, complete with heckles from and banter with the audience. Memorable lots include Matt Friedman's 'Mystery Box' (bought by Tom Fletcher for £50!), a hand-made felt dinosaur, and casts of an ichthyosaur, an actinopterygian and a sauropterygian.

Friday 30th August started with a session on actinopterygian fish, chaired by **Per Ahlberg** and opened by **John Clarke**, with a fantastic talk on the evolution of neopterygian fish, and the implications this has for notions of teleost superiority. He was followed up by **Jeff Liston**, discussing

Jeff Liston and Dave Hone discuss ichthyosaur casts at the Annual Auction on Thursday evening.

the variability of pectoral fin shape in pachychormids, which until this re-examination of the taxa was considered to be uniformly 'scythe-like'. **Roger Close** then took the stage to educate us on the braincase anatomy of Cretaceous–Palaeogene teleosts, with some exceptional scanned images of internal skull structure. **Matt Friedman** finished the session with two talks, one of his own making on the early pufferfishes from the Eocene London Clay, and one on behalf of his student Sam Giles on virtual views of early actinopterygian endocasts.

Next followed something slightly different for SVPCA: a symposium sponsored by the Palaeontological Association and NERC in honour of the late Stan Wood, a well-known fossil collector from Scotland who was responsible for finding many fossils of great significance. The session was chaired by Stan's good friend **Tim Smithson**, and opened by **Ian Rolfe**, who told of Stan's tenacity and passion for fossil hunting that set him apart from other fossil collectors, both amateur and professional. **John Long** honoured Stan's love of a good fossil by telling us about some amazing fossil finds from the late Devonian of Australia. Then followed a series of talks on research that would not have been possible without Stan's numerous contributions to palaeontology, including new Tournasian tetrapods from Scotland (**Jenny Clack**), an analysis of a tetrapod lower jaw from Scotland (**Per Ahlberg**), and Scottish Lungfish toothplates from Romer's gap and their morphology (**Tim Smithson**). Stan's Wife **Margaret Elliot** (a.k.a. Maggie Wood) then gave a memorable speech on one of Stan's obsessions; the fossil site at Glencartholm. We heard a case study of Stan's determination and persistence in fossil hunting, from when he was a young man up until his death.

Throughout the rest of the day we heard about a widespread Palaeozoic species known only from teeth (**Susan Turner**) and newly recognised chondrichthyan specimens (**Mike Coates**), embryonic development of placoderms from the Gogo Formation of Australia (**Zerina Johanson**), how synchrotron imaging of fossils has shed new light on the evolution of the gnathostome face (**Vincent Dupret**), a re-visitation of the controversial issue of tetrapod/fish cranial bone homologies (**Ulf Borgen**), and as the final palaeontological presentation of SVPCA 2013, the neurology of Devonian lungfish (**Tom Challands**).

As the final evening, it was time for the Annual Dinner, which took place at the Royal College of Physicians. The obligatory group photograph was taken on the staircase, after a little chaotic organisation! The food and drink were very well received, and the evening was finished off with a speech from **Nick Fraser**, thanking the attendees and giving special thanks to **Stig Walsh** for all of his help in the organisation of the whole event. There were also formal goodbyes to those who are not with us any more: John Attridge, Alec Panchen and Farrish Jenkins.

The field trip was organised for the last day in honour of Stan Wood, visiting two of his key excavation sites, Willie's Hole and Burnmouth, as well as a geological 'holy place', Siccar Point. The weather was uncharacteristically beautiful, and made for a very enjoyable day. First stop was Siccar Point, where British Geological Survey's **David Millward** explained its great global significance in geology. Next, on to Willie's Hole – Stan's incorrigible excavation of which was one of his many great successes as a fossil collector. David Millward and **Tim Smithson** gave the background on the site, and then let us off to have a poke about. Plant fragments were found in the plant bed just above Stan's major excavation site, and the spine of a *Gyracanthus* shark was found in a horizon rather higher up the sequence.

The Annual Dinner at the Royal College of Physicians on Friday.

Finally, it was on to Burnmouth. We stopped here to enjoy lunch in a quintessential Scottish pub. There were so many of us that it was a bit of a squeeze for us all to fit in. Nevertheless, we enjoyed a hearty lunch and some relaxed chatter before heading down onto the shore to see Burnmouth, a site that is now becoming world famous for populating 'Romer's Gap'. Tim Smithson told us all about the three most abundant horizons found so far for fossils, and showed everyone so-called 'Bed 1', where fossils are being weathered out by the sea all the time. *Gyracanthus* spines and skull fragments could be seen on the surface of the matrix, and this place became a hubbub of activity for many excitable palaeontologists. The day finished with a last look over the beautiful Burnmouth shoreline, as people had to be reluctantly drawn away from the sunny beach.

Overall, a great week in a great setting; SVPCA saw more delegates and more talks than ever before. Every aspect of vertebrate palaeontology and anatomy was well represented, and the organised social events were a big hit! For a first-time conference attendee, I found SVPCA a great and enjoyable opportunity to be introduced to the world of academic networking, and can't wait to do it all again next year!

Keturah Smithson
University Museum of Zoology, Cambridge

Acknowledgement: All images reproduced courtesy of Richard Forrest.

Vertical beds in bright sunshine at the 'Romer's Gap' site, Burnmouth, on the Saturday.

Grant-in-Aid REPORT

Fossil Colours at the Royal Society

Maria McNamara
University of Bristol

The Royal Society Summer Science Exhibition is the UK's most prestigious forum for the public communication of scientific research. This year's exhibition, held from 1st to 8th July at Carlton House Terrace, London, was attended by 12,530 people and featured exhibits from all walks of science: cosmology, virology, nanotechnology, oceanography, climatology, nutritional science, sports science, and genetics. Our exhibit, 'Prehistoric colours in fossil insects and feathers', flew the flag for palaeontology and was led by University of Bristol researchers (coordinated by myself) and part-financed by a Palaeontological Association Grant-in-Aid.

The exhibit team's 16 members were led by **Mike Benton**, **Stuart Kearns**, **Chris Rogers** (PhD student, University of Bristol), **Paddy Orr** (University College Dublin) and myself. This 'core team' was aided and abetted by nine enthusiastic members of Bristol's MSc Palaeobiology programme (**Lewis Bassett-Butt**, **Terri Cleary**, **Thomas Clements**, **Caitlin Colleary**, **Emma Jarvis**, **Jo Kaye**, **Kara Ludwig**, **Claire Morely** and **Charlie Navarro**), along with **Ed Drewitt** (UoB School of Earth Sciences Outreach Officer), **Dave Hone** (Queen Mary, University of London), and **Emma Locatelli** (PhD student, Yale University).

The purpose of our exhibit was to communicate three key messages, namely that fossils can retain evidence of colour, that the original colours of animals change during fossilisation, and that fossil

Setup day 1. Up she goes!

The finished product.

colours allow us to infer the behaviour of ancient animals. Naturally, we also wanted to show that palaeontology – and science more generally – is fun and immensely exciting. To this end, we designed an exhibit with diverse interactive features. The main activity stations were focused around a top-of-the-range benchtop scanning electron microscope with touchscreen control panel (on loan from JEOL), our 'experimental fossilisation kit'(a high-temperature furnace and hydraulic pressure clamp), a digital microscope, fossil display case, fossilisation video game, and a sandbox-style fossil hunt. Two 42" LCD screens were linked to the SEM and digital microscope, which we used to show colour-producing features in fossil and modern insects and feathers at various magnifications. We ran 'fossilisation experiments' (*i.e.* heating and squashing modern insects) several times each day to show the relative impact of high pressures and temperatures on animal colours. The display

Ready for visitors: 9am, 1st July.

case contained a feathered dinosaur from the Cretaceous Jehol biota plus two museum-quality reproductions of specimens of the feathered dinosaur *Microraptor* and the early bird *Confuciusornis*. The fossilisation video game, 'Zombeetle and the Fossil Colour Quest', involved navigating a metallic beetle through a post-depositional underworld of flesh-eating bacteria, bubbling magma vents, subduction zones and moving faults back to the Earth's surface with its colour intact. The 'Fossil Hunt' sandbox contained magnetic casts (lovingly hand-crafted and painted by Chris Rogers) of metallic beetles of various colours; once recovered from the sand, they had to be placed on a magnetic geological cross section according to how much their colours were 'altered'.

Visitors to the exhibition included schoolchildren, adults, other scientists (retired and active), members of the press, and various VIPs. Our exhibit was an overwhelming success. The team worked in four-hour shifts (5–6 people per shift) from 9am to between 9pm and 10.30pm, and except for a quiet ten–fifteen minute period at the start of the day (as visitors trickled through the building to our hall), we spoke to visitors essentially non-stop. We were often buried in a crowd 5–6 people deep! To attract and sustain interest in visitors in the more 'remote' parts of the exhibit, *i.e.* far from the activity stations, we relied heavily on mobile props, *e.g.* an iPad and A3 laminated sheets showing key images from our research, various handling fossils, pre-made experimental 'fossils', and strikingly coloured modern feathers and insects. Almost all the visitors we spoke with were interested, curious, and eager to interact with our various props. Schoolchildren particularly enjoyed operating the SEM, doing the fossilisation experiments and playing the video game; adults preferred to look at the fossils and speak with the team; the tiny tots enjoyed the fossil hunt; and everyone was keen to look and handle our fossil and modern specimens. Our promotional materials included purpose-designed postcards, DL-sized leaflets, folding Z-cards and keyrings.

In full flow during the soirées …

I can say with complete honesty that the Royal Society Summer Science Exhibition was the most prolonged period of fun (and sleep deprivation) I have experienced during my scientific career. My personal highlights were the black tie soirées, during which we discussed our research with very enthusiastic MPs, OBEs, Lords and Ladies, and movers and shakers from the main funding agencies. Lest there be any illusions, however, hosting the exhibit was incredibly hard work. What began life as a 'little side project' in October 2012 had evolved into a truly all-consuming beast by mid-May. The process of planning and production was fraught with the inevitable complications and delays, culminating in the arrival of our fossils and printed materials via courier just as the doors were opening on the first morning of the exhibition! Despite all this, and the (barely) organised mayhem of the two-day setup period, we all thoroughly enjoyed ourselves and found the exhibition an immensely rewarding experience. We emerged ten days later, exhausted, bleary-eyed and hoarse, back into the 'real world', with no casualties save for aching feet/backs (and a dented transit van).

I can thoroughly recommend participation in the RSSSE. It represented valuable experience in science communication for all of us, particularly the postgraduate team members. For those of us handling the logistics, the event was a very worthwhile exercise in management. Would I like to do it again? Definitely! But not next year…!

Sylvester-Bradley REPORT

Miocene Woods from the Panama Canal: taxonomy, paleoecology and paleoclimatology

Oris Rodriguez-Reyes
Royal Holloway, University of London

In the course of my Sylvester-Bradley work I prepared and analysed modern wood samples from dry forests and wet forests located in Panama. This research is part of my ongoing PhD project on Miocene woods from the Panama Canal at Royal Holloway, University of London, in collaboration with scientists from the University of Natural Resources and Life (BOKU, Vienna, Austria) and the Smithsonian Tropical Research Institute (STRI).

The modification in the xylem attributes is an example of a character that changes with varying environmental conditions (Baas, 1986; Wheeler and Baas, 1991, 1993; Carlquist, 2001; Wheeler and Baas, 2007). Wood anatomical features and their responses to environmental changes are better understood in the temperate forests than in the tropics (Feng, 1999; Saurer *et al.*, 2004; Waterhouse *et al.*, 2004, Brienen *et al.*, 2005). Therefore, more studies relating those variables are required for tropical trees.

In Panama, the use of anatomical characters of the wood as a proxy to understand environmental changes is somewhat unexplored and as a result, there are currently no representative reference collections of microscopic slides of woods, which are crucial for the identification of fossil woods from the Panama Canal. To address these important data needs, I spent the three months funded by the SB grant to achieve three main objectives: (1) to obtain comparative gradual vessel density variation data, (2) to record the occurrence of a set of wood anatomical characters that correlate to climatic variables, (3) to build the first wood microscopic slides reference collection of Panama.

Materials and Methods

The wood samples representing wet forests were collected from Barro Colorado Island (BCI; 9° 09' 00" N and 79° 51' 00" W), a 1,560 ha island located in Gatun Lake in the Panama Canal, where the Smithsonian Tropical Research Institute has based a primary site for the study of lowland moist tropical forests (<**www.stri.edu**>). For the dry forests, the samples were obtained from three localities: Coronado (8° 31' 0" N and 79° 53' 0" W), a beach community in the Pacific Coast, where the dry forest area covers approximately 45 ha; Achiotines (7° 15' 30" N and 80° 00' 15" W), a station for tuna fish breeding and research, with 70 ha of dry forests (<**www.biotapanama**>); and Divisa (8° 8' 0" N and 80° 41' 0"), with a 5 ha dry forest patch.

We selected a set of data which has been shown to correlate with climatic variables (*e.g.* Martinez-Cabrera and Cevallos Ferriz, 2008; Wheeler and Baas, 2012), and recorded the percentage of their occurrence for 211 species of BCI and 46 from the dry forests. We also prepared tangential sections for both forest types. The radial variation of vessel density was estimated following the workflow shown in Figure 1.

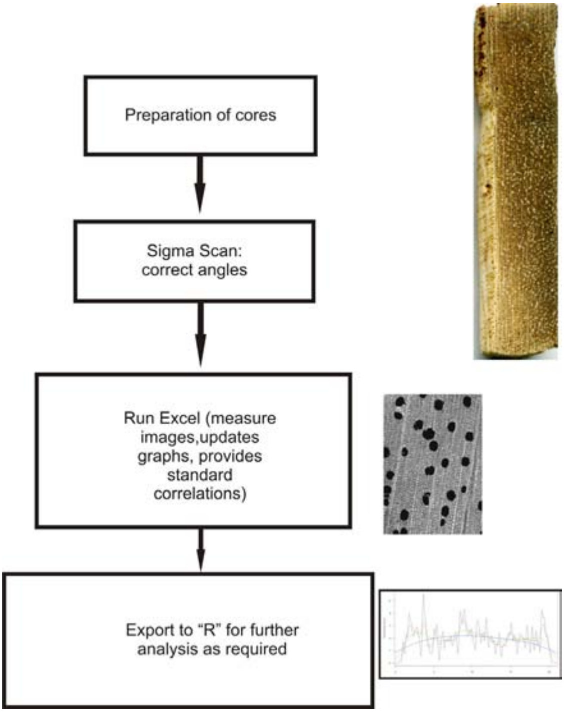

Figure 1. Typical workflow for analysis of radial vessel density and diameter variation.

The microscopic slide reference collection is currently being stored at BOKU.

This work is still in progress, but for the three months of ORR internship, tangential sections of 81 species from BCI and 46 stained transversal and fresh tangential slides from the dry forests were produced. Currently, students in BOKU continue to produce the tangential sections.

Results and discussion

Radial variation of vessel density:

We obtained vessel density and diameter data for 22 wet forest species from BCI and 13 dry forest species. Frequently, the precise semi-automatic estimation of vessel diameters is somewhat complicated; therefore we are more confident with our estimations of vessel densities than with those of the mean vessel diameters for the first analysed samples. The total mean vessel density at species-level is smaller in two of the dry forests (Coronado, 19 v/mm^2 and Divisa, 10.5 v/mm^2) compared to the wet forests in BCI (15 v/mm^2). This is consistent with results from previous studies that found an inverse correlation between vessel density and wood density (Preston *et al.*, 2006; Jacobsen *et al.*, 2007) and that higher wood densities are associated with species adapted to the understory, to dry soils, and to nutrient-poor soils (Martinez-Cabrera *et al.*, 2011; Preston *et al.*, 2006; Nock *et al.*, 2009). Species from one of the dry forest localities (Achiotines, 19 v/mm²) had a higher mean vessel density even compared to those from wet forests. Interestingly, this site has the highest mean annual precipitation of the three localities of dry forests.

From the wet forest samples, only *Ceiba pentandra* (Figure 2) shows clear changes in the vessel density across a radial gradient that could be related to the shift of wet and dry seasons. More species show those changes in the dry forests (*e.g.*, *Dendropanax arboreus*, *Chrysophyllum cainito*, *Platymiscium pinnatum*), as we expected.

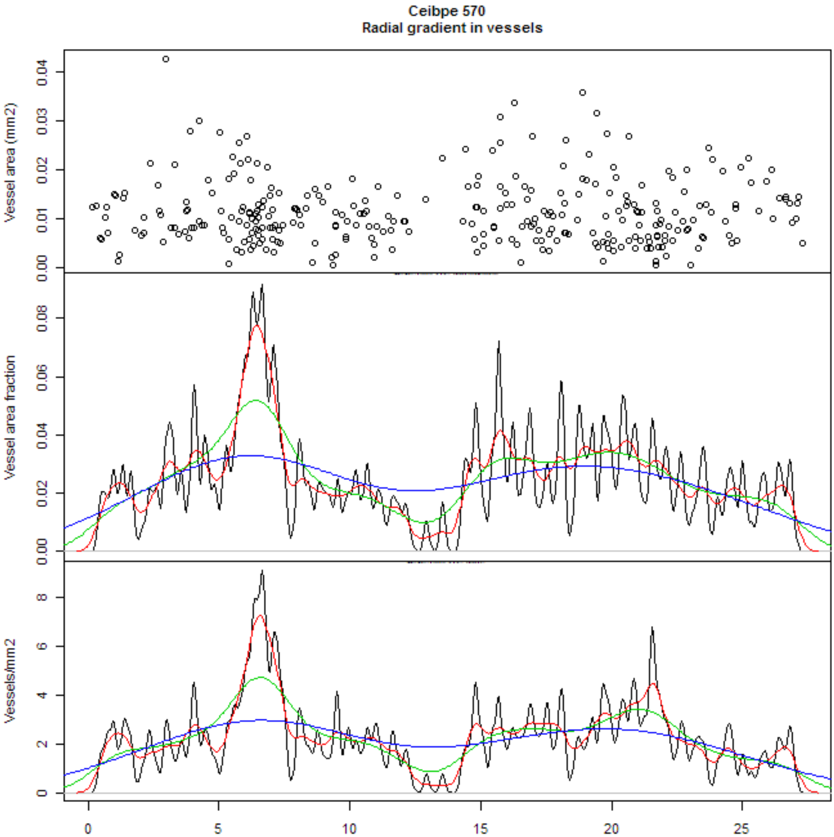

Figure 2. Panels show radial vessel density variation in C. pentandra*.*

Variation in wood anatomical characters:

We recorded the occurrence of the following wood anatomical qualitative characters: distinct rings, semi-ring and ring porous wood, paratracheal parenchyma pattern (scanty, aliform, and confluent), apotracheal parenchyma pattern (rare or absent, scarce, diffuse, narrow bands, broad bands, reticulate and scalariform, marginal), very thin walled fibres, very thick walled fibres, exclusively uniseriate rays.

Table 1. Selected wood anatomical characters proposed to be correlated to climatic variables and percentage of occurrence in wet and dry forests from Panama

Character/forest	Wet (%)	Dry (%)
Rings distinct	11	13
Semi ring/ring porous wood	2	4
Paratracheal parenchyma		
Scanty	12	13
Vasicentric/broad sheath	20	13
Aliform/confluent	45	52
Apotracheal parenchyma		
Rare or absent	11	6
Diffuse/diffuse in aggregates	24	43
Bands 1–3 cells wide	18	28
Bands >3 cells wide	22	20
Reticulate/scalariform	8	9
Marginal	7	13
Very thin walled fibres	13	24
Very thick walled fibres	20	22
Exclusive uniseriate rays	24	22

The development of distinct rings and semi-ring/ring porous wood is considerably higher for the dry forests than in the wet forests. The most frequent parenchyma patterns in the studied species are the paratracheal aliform and the apotracheal diffuse and diffuse in aggregates. Overall, scarcer parenchyma and very thick walled fibres are less frequent in the wet forests compared to the dry forests. The frequency of these characters in dry zones can be interpreted as adaptive strategies to improve the effectiveness of conductivity under water stress (Lindorf, 1994; Wiemann and Williamson, 2002; Wheeler and Baas, 2011).

The occurrence of exclusive uniseriate rays is comparable for both forests. We highlight *Bursera simaruba* (Burseraceae) that was collected from the wet forest (BCI) and two more locations in the dry forests (Coronado and Achotines). The mean ray width and height, in terms of numbers of cells, is similar between wet forest samples from BCI (Mean width: 4.2; Mean height: 18) and dry forest samples from Coronado (Mean width: 4; Mean height: 13), but compared to Achiotines, the other dry forest locality, the rays are shorter and narrower (Mean width: 2.8; Mean height: 9.8). Also *Dalbergia retusa* and *Dendropanax arboreus* show smaller ray dimensions in the dry forests.

Our findings are aligned with current research (Wiemann and Williamson, 2002; Nock *et al.*, 2009; Wheeler and Baas, 2011) suggesting that features such as: distinct rings, semi-ring porous wood, paratracheal aliform and confluent parenchyma, diffuse parenchyma, marginal parenchyma and very thick walled fibres; may be indicatives of dry forests in fossil wood assemblages in Panama.

Acknowledgements

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The Crystal PalAss: new models for palaeontological outreach

It's not difficult to engage people with palaeontology. Fossils are fascinating to young and old. The real challenge is to engage with people meaningfully, to develop more than just a superficial interest, to make them actually think about palaeontology as a science, rather than simply as a bit of object-collecting fun.

As I discussed in the last *Newsletter*, this is particularly important for school pupils. Fossils should be fun, wherever possible, but they should be educational too. If we want to attract the best young scientists to our field, we have to capture their imagination early and keep it captured.

To this effect, the Association Council has been giving this topic some careful thought over the last year or two. We may be an academic organization aiming to publish the highest-quality palaeontological research, but we're also a charity charged with promoting palaeontology. Our strategy is still a work in progress (and we're always keen for input from the membership), but the main idea is to encourage a greater deal of outreach and education activities, and to use our reserves to support such things.

There are plenty of people out there with great ideas, so deciding which to support won't be easy. My feeling at the moment, though, is that we should be encouraging novelty. There's nothing wrong with giving talks in lecture theatres or showing off trays of fossils to school groups in marquees, but we should also be a bit more ambitious. At the moment, in many cases, we're simply preaching to the converted, which is a pity. For true outreach we must truly reach out: outwith the usual media, beyond the usual demographic, out of the fossil box.

As our painter-in-residence, James McKay, demonstrated so elegantly at this year's Lyme Regis Fossil Festival, art and science can unite to startling effect. Bewitch a child by bringing their fossil creation to life right in front of them and not only do you give them something unforgettable, but you can also sneak a fair amount of real science into the time they're with you. They might not even realize the indoctrination that's taking place. It's a pleasure for all involved.

Inspired by such success, the Association has taken part in two recent events that have taken something of a similar line. The first was a new format at a familiar event, whilst the second was – to steal a line from those Flying Circus chaps – something completely different. Both involved models, but perhaps not the models you might be thinking of.

The Association has organized thematic sessions at the British Science Festival for a good many years. This year's Festival was in Newcastle, and we chose 'Bodies of Evidence' as the topic. The idea was to explore new palaeontological evidence on the early evolution of animals. However, rather than just have a line-up of talks, we decided to go a bit more interactive.

In a day-long event at the Great North (Hancock) Museum, we were able to bring together the key fossils, the techniques used to analyse them, and the reconstructions. Durham University looked at the Cambrian Explosion of animal life through the lens of Greenland and its Sirius Passet fauna. The University of Leicester showed off its 'Rotten Fish and Fossils', revealing the challenges of unravelling the origins of vertebrates, and Leiden University and the University of Bristol delved into the evolution of teeth and jaws.

In themselves, the displays were fascinating, but we wanted to go a step further. It was fantastic, therefore, to be able to get scientific model-maker Esben Horn of 10 Tons in Copenhagen to come along too. For many years, Esben has been working with universities and museums across the world, collaborating with scientists to turn lithified, monochromatic fossils into gloriously colourful three-dimensional specimens.

Esben had a series of Cambrian models to go with the Sirius Passet fossils, from the familiar trilobites to the rather more enigmatic halkieriids and wiwaxiids (or is it halwaxiids now?). Sculptures at various stages of size, detail and completeness showed off his process of reconstruction, which he happily explained in more detail to visitors.

For the origins of jaws and teeth, Martin Rücklin (Leiden/Bristol) used posters, computers and iPads to explain how to Synchrotron a placoderm. He also had a table-top *Dunkleosteus* that he and Esben had collaborated to build off the back of that research. It wasn't quite life-sized but it still grabbed the attention of countless customers. For good measure, Esben brought some of his 'Heavy Metal and Punk Fossils' from a recent exhibition at the Geomuseum in Faxe, Denmark, including a Silurian polychaete worm named after Lemmy from the rock band *Motorhead*.

The Leicester team, meanwhile, not only had models of early vertebrates to inspect, some time-lapse taphonomy videos and a magnetic phylogenetic tree, but also a series of sensory interactive activities. Being able to handle vacuum-packed specimens of partially rotted chordates was one thing, but giving the pungent aromas a sniff quite another. Not many were brave enough to try!

Across the day, something like 750 visitors came in to see us, and many of them did so accidentally. This could be seen as a failure of publicity on our part, but last year's BSF event was held in a university lecture theatre and got an audience of about 50. Plenty of this year's crowd weren't at the museum for palaeontological reasons, just for general interest, and they suddenly found themselves coming face to face with fossils. A fifteen-fold increase in visitors sounds like an outreach success to me, especially given how many of those who were lured in were under 16.

If we'd had a PalaeoPop-star in attendance, though, it might have been considerably greater. Lucky then that, together with her 9-year-old niece Taylor, performance artist Bryony Kimmings has decided this is exactly what the world needs.

Aimed at convincing children, particularly girls, that a career in science is both worthwhile and achievable, Bryony and Taylor have launched the Credible Likeable Superstar Role Model project, led by a character called Catherine Bennett (<**http://www.catherinebennett.so/about.html**>). Catherine is a bicycle-riding, tuna-pasta-eating palaeontologist, played by Bryony, and the aim is for her to become famous for the right (rather than Rihanna-esque) reasons.

Videos for three songs – Apathy, Animal Kingdom, and The Future – have been produced already, and if you like short, catchy pop, check out the project website, as they're really rather good. A live stage show of the project began in London recently (<**http://www.sohotheatre.com/whats-on/bryony-kimmings-credible-likeable-superstar-rolemo/**>) and that august periodical *Metro* has described it as 'bold, unflinching, wryly funny … [and] full of warmth' (<**http://metro.co.uk/2013/10/16/credible-likeable-superstar-role-model-wages-war-against-the-web-4148860/**>). Taylor's plan is for Catherine to get a million YouTube video hits, build a Facebook and Twitter army, and appear on the Ellen Degeneres show. No pressure then!

Importantly, since Catherine is supposed to be an expert on fossils but Bryony is not, the Association (along with ScienceGrrl and TrowelBlazers, two projects also working to promote women in science) was asked to help out with the filming of a new video called 'Palaeontology Rocks!'

As a consequence, eight palaeontologists (six female, two male) from across the UK convened in Crystal Palace, South London, on a (fairly) sunny autumn day. With special permission, we were allowed on to the hallowed dinosaur island in the middle of the park, where Catherine and her film crew were waiting for us.

I think everyone – even those of us of a generally invertebrate persuasion – was excited to get up close and personal with Benjamin Waterhouse Hawkins' and Richard Owen's amazing monsters. I have admired them from beyond the other side of the railings, but to be able to inspect them in minute detail was fantastic.

Most of us were a bit more sceptical about the filming, but it was actually pretty painless. The only difficulty came when we were asked to tell fossiliferous jokes. The format was for each of us to be interviewed by Catherine Bennett, explaining what we did as palaeontologists and answering questions put forward by schoolchildren. Susannah Maidment explained her lifelong love of dinosaurs, Anjali Goswami talked about how she'd wanted to be a tiger biologist, Lucy McCobb discussed her museum work on trilobites, and David Legg detailed his spider harassment activities.

As to what sorts of things you'd best be interested in if you want to follow our career paths, Xiaoya Ma said animals, Victoria Herridge suggested discovering the answers to mysteries, I proposed digging around on beaches, and Fiona Gill served up the best line of the entire shoot: "If you like poo, then you'll like my job." If that doesn't attract a new generation of coprologists, I don't know what will (sorry Fiona!).

The finished video can be found at <**http://www.youtube.com/watch?v=1I3TWCNuRXA**>, and will be shown off by Catherine as she goes off to tour schools and attend other events. I'm hopeful we might be able to persuade her to come along to some of next year's festivals – Lyme Regis is running again, the British Science Festival will be in Birmingham, and plans are afoot for something new in the north of England. No one could claim that the project is flawless, but the idea is a great one and its ambitions are laudable.

So if a PalaeoPop-star can be made, whatever next? How are you going to communicate palaeontology in a new way to a new audience? Subway graffiti artists imagining the fossils of the Yorkshire Coast? A virtual museum you can actually visit? A marine palaeoenvironmental reconstruction you're able to swim through? Everyone driving round on Electrobites (<**http://boingboing.net/2009/11/04/test-driving-the-ele.html**>)?

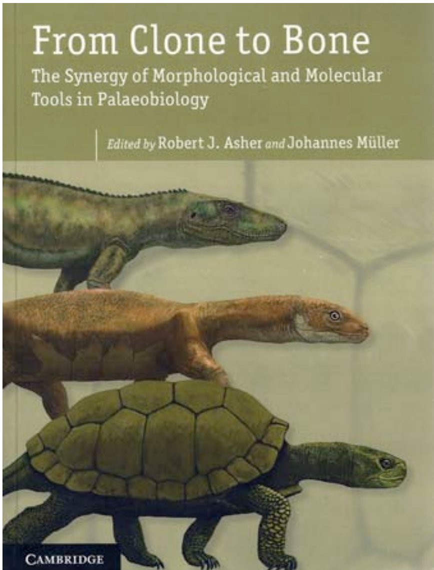
Get your thinking hats on. The funding system isn't quite in place yet, but it won't be long. And though I can't promise that the Association will fund every proposal we receive, we'd love to hear your ideas. In 1851, ingenuity, science and imagination built the dinosaurs of Crystal Palace. 160 years on, perhaps the same principles can build the Crystal PalAss.

Liam Herringshaw
<reporter@palass.org>

Book Reviews

From Clone to Bone: The Synergy of Morphological and Molecular Tools in Palaeobiology

Robert J. Asher and Johannes Müller (Editors). 2012. Cambridge University Press. 387 pp.
ISBN 978-0-521-17676-7 (paperback £29.99; 50 USD)
ISBN 978-1-107-00326-2 (hardback £65; 105 USD)



Following a thoughtful Introduction by the editors, the book is divided into two unequal parts. Part I, comprising five chapters, focuses on divergence. Part II, consisting of the remaining eight chapters, concentrates on mechanisms.

Asher and Müller's Introduction emphasizes the change in working relationships between palaeobiologists and molecular biologists since the publication of *Molecules and Morphology in Evolution: Conflict or Compromise?* in 1987. They explore the balance between the generation of diversity of taxa with the diversity of form, but with a keen awareness that genotype–phenotype correspondence is not perfect. Asher and Müller also stress that 'evo-devo' techniques have progressed far beyond the study of model organisms by big lab groups, to the point where palaeobiologists willing to make the effort can apply these methods.

Chris Organ's chapter opens Part I by reviewing the contribution that palaeontology makes to genomics, giving rise to the emerging discipline of palaeogenomics. The chapter previews some of the possible genetic information that can be reconstructed by judicious use of "next generation" extant phylogenetic bracketing methods.

Binindia-Emonds *et al.* revisit a perennial problem; mismatches between molecular and fossil estimates of divergence. The chapter is a useful summary of the state-of-the-art in molecular dating techniques, and is enlightening about the circumstances under which conflicts are to be expected, while proposing concrete means of reconciling these differences. Two notable highlights are an excellent section on the challenge of incorporating fossils with limited apomorphies into divergence time estimates, and a section on palaeogeography as an independent constraint on hypotheses about diversification.

Chapter 4 (Larsson *et al.*) begins with a wide-ranging discussion of the role of emergent properties in the generation and maintenance of biodiversity. Genotype–phenotype interactions and change are the focus of this chapter, which argues that coupling estimates of molecular and morphological rates offers a powerful, quantitative method for studying the evolution of genotype–phenotype maps. The central analysis focuses on the implications of considering the evolution of the entire organism, rather than single traits within a stochastic framework. The chapter concludes with a manifesto for the future use of morphological data in evolutionary biology. Larsson *et al.* note that molecular data, collected from extant or recently extinct taxa, will struggle to resolve divergence events in deep time. The abundant morphological data from the fossil record could be used to help resolve these divergence events, but with more emphasis on using Bayesian or Maximum Likelihood models for morphological evolutionary analyses.

Simpson and Müller move up the hierarchy in Chapter 5 to consider molecular approaches to the controversial area of species selection. The chapter opens by placing species selection in an ecological-historical framework and reviewing the arguments about species selection, before moving on to the application of Price's theorem, which quantifies the causal covariance between traits and diversification rates. While this sounds complex, the presentation is mercifully clear. An elegant analysis across a wide range of plants and animals follows, which demonstrates that the necessary conditions for species-selection are common across this broad group of taxa.

Chapter 6 (Schmid) opens the Mechanisms section with a discussion of the philosophy of evidence in science while laying out a uniformitarian position for the molecular basis of developmental mechanisms in fossils. Schmid does include the caveat that a condition for such an assumption is that evolution is predictable. The remainder of the chapter explores these ideas via a fossil model organism, the fish *Saurichtys*.

Smith and Johanson (Chapter 7) re-evaluate competing theories about the evolution of gnathostome dentition, in the light of fresh evidence on the molecular underpinnings of the development of the dentition in living vertebrates. Their review of new data is extensive, with the concluding sentence referring to papers from 2012 and 2013.

Anthal and Tucker tackle the phenomenal variation in shape and size of the mammalian dentary from the perspective of developmental modules in Chapter 8. A broad suite of molecular and developmental evidence is marshalled in this chapter, highlighting the shift to non-model animals, while explaining that studies of non-model organisms must always refer back to work on model organisms in the formulation of mechanisms of morphological development.

Flexibility and constraint in the development of the axial skeleton of mammals is considered in Chapter 9 (Buchholtz). The different series of the vertebral column are reviewed and the case for modularity in these series is discussed. Buchholtz then quantitatively examines variation in number of elements within each series. Morphological variation of individual elements is also discussed. The stratigraphic approach of Romer to the appearance of modules is also contrasted with the hierarchical approach based on molecular evidence.

Sears *et al.* (Chapter 10) present a study of the marsupial neonate as an example of the potential power of studying morphology at different developmental stages. Careful investigation of each component of a working hypothesis about constraints upon the marsupial limb, with molecular tools, provides strong evidence that marsupial hind- and forelimbs became decoupled modules early on in the history of the clade.

The problem of the evolution of the shell in turtles is investigated by Kurtani and Nagashima in Chapter 11, using an evolutionary developmental approach. The authors demonstrate how minor changes, at different times in the history of the ancestral lineage of turtles, could culminate in the turtle shell enclosing the shoulder blades. Their work elucidating how both hard parts and soft tissues could have altered their topological relationships during folding of the body wall is well-presented and clear.

Mitgutsch *et al.* consider the mole's thumb, which is, in fact, a large seasmoid bone that develops a sickle shape and is used in conjunction with the true digits to burrow. Mitgutsch *et al.* indicate that a search for universally valid mechanisms of development is now emerging, espousing a uniformitarian approach to evo-devo, echoing Schmid, and they explore the recent growth in use of non-model organisms to test concepts developed in the study of model organisms.

The final chapter, on the identity of bird digits, *Manus horribilis*, wins the Latin Pun Prize. Richardson reviews the long-running controversy about the identity of the digits in the hand of birds. Although perhaps one of the most tightly focused chapters in the book, it does cover ground that is vital to understanding the origin and evolution of the avian wing. Richardson stresses that without the advances in molecular techniques, developmental anatomy would have probably been unable to resolve the digit homology question.

This volume represents an excellent collection of papers, carefully edited and well illustrated. The paperback is certainly good value and references are up to date. Palaeobiological researchers, even those focused on invertebrate groups, should find this text valuable, especially Part I. However, the text would perhaps shine brightest as the basis of a graduate student-style reading course.

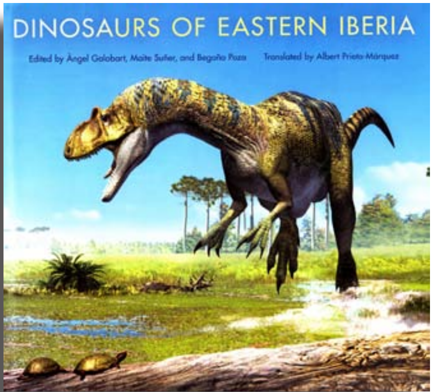
Alistair McGowan
University of Glasgow

Dinosaurs of Eastern Iberia

Àngel Galobart, Maite Suñer and Begoña Poza, editors. Translated by Albert Prieto-Márquez. 2011. Indiana University Press, 323 pp. £29.99 ($45) (hardback). ISBN: 978-0-253-35622-2.

Although some dinosaur remains were discovered in both Spain and Portugal during the 19th century, for a long time the Iberian Peninsula was not considered a major source of dinosaur fossils. Although promising, the early efforts of José Royo y Gómez (1895–1961) in the 1920s were cut short when he had to leave Spain after the Spanish Civil War – he was not on the winning side, as the authors remind us in the chapter on the history of Spanish dinosaur discoveries. In the last 25 years, however, things have changed tremendously and Spain has really become a major "dinosaur country", thanks to the work of a rather large group of active palaeontologists who have spent much time and energy exploring the often spectacular non-marine Mesozoic outcrops of Iberia.

This book tells a part of this remarkable story – a part only, because it deals solely with the dinosaur discoveries from two autonomous regions of eastern Spain, Catalonia and the Valencian community. The important localities of central and north-western Spain, not to mention Portugal, many of them similar in age and fossil content to those of the eastern areas, are hardly mentioned at all. This may reflect a trend in Spanish palaeontology, where research tends to be done on a regional basis. Be that as it may, the dinosaur record from the two above-mentioned regions is abundant and diverse



enough to fill up this 300-page volume. The book is aimed at the general public rather than at a specialist readership, and this is clearly apparent not only from its very numerous colour illustrations, including a large number of generally excellent reconstructions of animals and landscapes by Oscar Sanisidro, but also from the various general sections explaining the basics of dinosaur anatomy and classification, how fossils are formed, excavated, prepared and studied. Nonetheless, the book also includes a considerable amount of up-to-date scientific information about Iberian dinosaurs, their geological setting and the accompanying fauna and flora, and from this point of view it will be useful to specialists too, all the more so as it includes a sizeable list of references. The lack of an index, however, is to be deplored.

Seventeen authors, most of them representative of the "young generation" of Spanish palaeontologists, have contributed to this volume. After a first chapter on the history of dinosaur discoveries in eastern Iberia, two chapters deal with their geological context, one about the Upper Jurassic and Lower Cretaceous, and one devoted to the Upper Cretaceous. Although written for the general public, they will be of use to specialists as well, because they provide an interesting introduction to important sites, many of which have been discovered in recent years and are not yet widely known outside the Spanish palaeontological community. The three following chapters, on the history and classification of dinosaurs, on their origin and diversity, and on the study of dinosaur fossils, will mainly be of interest to the lay reader, but they are competently written and remarkably well illustrated (this applies to the book as a whole).

The two chapters that follow are devoted to saurischians and ornithischians, respectively. Both begin with general introductions to these groups of dinosaurs, followed by a description of their representatives that have been found in eastern Iberia. This provides a useful introduction to those newly discovered assemblages, which have considerably augmented our knowledge of European dinosaurs. Names such as *Koutalisaurus*, *Arenysaurus*, *Losillasaurus*, *Tastavinsaurus* or *Turiasaurus*, to mention but a few, may not yet be familiar to dinosaur fans, but they testify to the diversity of new taxa recently described by Spanish palaeontologists. A further chapter is devoted mostly to other palaeontological finds from eastern Iberia, *viz*. the remains of the animals and plants that inhabited the Mesozoic landscapes of that area together with dinosaurs.

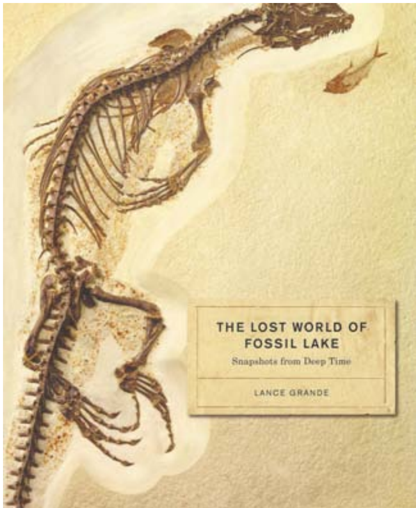
The final chapters become more general again, with one on the palaeobiogeography of dinosaurs and one on dinosaur extinction. As the authors rightly remark, "the dinosaurian extinction record in Eastern Iberia is potentially one of the best represented in the world", with bones, tracks and eggs all the way up to the K/Pg boundary – suggesting sudden extinction rather than gradual decline. The last chapter is a kind of "making of", as it tells the reader how dinosaur reconstructions, including those that adorn the book, are made. A list of museums exhibiting dinosaur remains in Catalonia and the Valencia community and the above-mentioned bibliography round off the book.

This is an attractive, generally well-produced book that will reveal to the dinosaur-minded public the abundance and significance of the remarkable discoveries made in recent years in the eastern regions of Spain. As noted above, it will also be of use to specialists, notably as a handy introduction to the abundant primary literature on those Spanish dinosaurs and their environments.

Eric Buffetaut
Centre National de la Recherche Scientifique
Ecole Normale Supérieure de Paris

The Lost World of Fossil Lake: Snapshots from Deep Time

Lance Grande. 2013. The University of Chicago Press. 425pp.
£31.50 (hardback). ISBN: 978-0-226-92296-6.



This book focuses on the 52 million-year-old (Eocene) Fossil Butte Member (FBM) of the Green River Formation in Wyoming, USA, providing the earliest comprehensive window on a post-dinosaur contemporaneous community spanning a period of probably only a few tens of thousands of years. The short preface explains how the author, a researcher at the Field Museum of Natural History, Chicago – which holds the most important collection of fossils from this locality – became involved with this deposit. It ends with him hoping the book may attract a few new students to palaeontology. I expect it will attract many.

The preliminary chapters include excellent coverage of the geological history of the deposit, contextualizing the locality, age and depositional environment with reference to proximate fossil localities and the most recent literature. Apparently more than 200,000 fossils are excavated annually, so there is still scope for massive quantitative data collection for palaeoecological studies and for new interesting fossil discoveries. There is a detailed account of the history of the site from the 1870s until the present, including the colourful characters who have worked it and the less than ethical means employed by some of those in competition. I enjoyed the account of the thieves at the visitor centre who had signed the visitor book while 'casing the joint' a few days earlier. The conflict between commercial/private collector and scientist is also discussed, but fortunately, FBM seems to represent a case of mutually beneficial equilibrium. The techniques used by the author and his team for excavating fossils are also discussed and well illustrated, followed by a couple of pages explaining how the fossils are prepared for study. The introductory section finishes with a brief explanation of hierarchical taxonomy, phylogenetic trees and the basic rules of nomenclature in order to set the stage for what is referred to as the 'field guide' that follows.

The majority of the book (pages 55–350) documents the palaeobiota under the following headings: Bacteria, Arthropods, Mollusks, Vertebrates, Cartilaginous Fishes, Ray-Finned Fishes, Abundance and Distribution of Fish Species, Tetrapods, Amphibians, Non-Avian Reptiles, Birds, Mammals, Plants, Green Algae, Ferns and Horsetails, Conifers, Non-Eudicot Flowering Plants, Eudicot Flowering Plants, and Trace Fossils. Each section (apart from Bacteria) contains a wealth of information on identification, historical taxonomy, the presumed palaeoecology of the known fossils, extant biodiversity of the relevant groups and their fossil record in general. This entire section contains many exquisite photographs of the fossils. The book includes 221 figures, mostly photographs, of the fossils, and many of the figures include more than one photograph, often of several different specimens. Included are photographs of 25 holotype and five paratype specimens. Some of the remarkable fossils illustrated include a probable mated pair of stingrays, a female stingray with a baby ray curled up inside her, various fishes swallowing other fishes, mass mortality slabs, some huge turtles, and a smaller specimen with evidence of crocodile predation. The photographs include complete skeletons of snakes, a monitor lizard and lots of different birds (some with feathers preserved) and several mammals including some very nice bats. There is also a massive palm frond with a man standing next to it for scale.

The take home message here, other than the great diversity of the palaeobiota, is that some groups (*e.g.* vertebrates) are much better studied than others (*e.g.* insects, arachnids and plants, many of which are figured in this book for the first time). Three undescribed spiders are illustrated for the first time and my suspicions (as a palaeoarachnologist) are that none of them is correctly identified, although the overall superficial morphology resembles that of the proposed families to which they are tentatively assigned. Clearly there is great scope for research on the invertebrate palaeobiota and this book provides a basis for such studies.

In the final pages, the palaeobiota is used to reconstruct the palaeoecosystem within the lake and its surrounding landmass. Various reasons for the numerous regional mass mortalities that have led to this fossil assemblage are proposed and discussed, including: volcanic activity, excessive algal blooms, overgrowth of cyanobacteria, and hydrogen sulphide poisoning from stratified water turnover. The Asian affinities of the palaeobiota are also briefly mentioned. The text culminates with two paragraphs of concluding remarks, a short postscript and the acknowledgments. Six appendices: A – Key to the Major FBM Localities (includes topographic maps); B – Summary List of FMB “Fish” Species; C – Summary List of FBM Bird Species; D – FBM Fossils That Have Been Enhanced, Restored, Inset, or Faked; E – Using This Book and Comments on Bulletin 63; F – Sources of Phylogenies Used in This Book; are followed by a Glossary, References Cited and both taxonomic and subject indices.

It is hard to find fault with this book. One minor quibble is that two new taxa are proposed in the volume: the monotypic family Asterotrigonidae, and on p. 169, the new genus *Hypsiprisca*. This is not really the place for new taxonomy, and despite the author’s justification (p. 96) as illustrating some of the concepts of classification, this will be misleading to the novice as the new taxa appear seamlessly within the running text and no formal diagnosis is proposed for the new genus.

In summary, this is a wonderful book. The production is of a very high quality and the copy-editing is excellent. The text is accessible to a broad readership and will be of interest to amateurs and professionals alike. You will not be disappointed if you buy this book.

Dr David Penney
University of Manchester, UK

Books available to review

The following books are available to review. Please contact the Book Review Editor, Charlotte Jeffery Abt (e-mail <**bookreview@palass.org**>), if you are interested in reviewing any of these.

- *Dinosaur Paleobiology* by Stephen L. Brusatte.
- *The British Silurian Crinoidea* by D. N. Lewis and S. K. Donovan.
- *The Cambrian Explosion* by Douglas H Erwin and James W Valentine.
- *Embryos in Deep Time* by Marcelo R. Sánchez.
- *Pterosaurs: Natural History, Evolution, Anatomy* by Mark P. Witton

Dr Charlotte Jeffery Abt
Book Review Editor,
Department of Earth & Ocean Sciences,
School of Environmental Sciences,
University of Liverpool,
4 Brownlow Street,
Liverpool L69 3GP,
UK

Palaeontology

VOLUME 56 • PART 5

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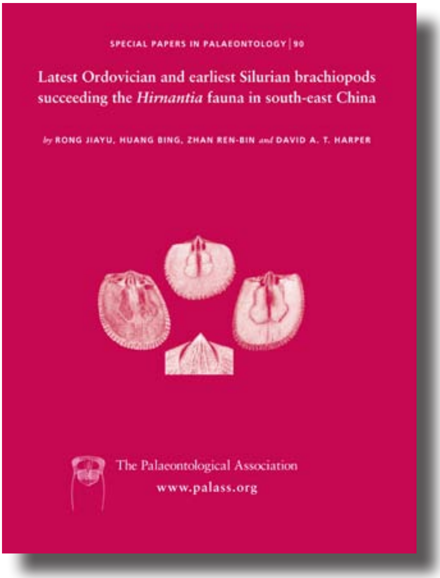
Special Papers in Palaeontology No. 90

Latest Ordovician and earliest Silurian brachiopods succeeding the *Hirnantia* fauna in south-east China

Rong Jiayu, Huang Bing, Zhan Renbin & David A. T. Harper



Abstract: Late Hirnantian and early Rhuddanian shelly faunas dominated by brachiopods are well developed in the clastic facies succeeding the cool and deep-water, very-low diversity *Hirnantia* fauna in Zhejiang and Jiangxi Provinces, south-east China; elsewhere in the world, during this interval, brachiopod assemblages are generally rare. The *Cathaysiorthis* brachiopod fauna, occurring within the *Normalograptus persculptus* to *Akidograptus ascensus* biozones, straddling the Ordovician and Silurian boundary, is systematically described herein. Comparison of the fauna with the preceding *Hirnantia* fauna in South China shows some major contrasts, but similarities in the dominance of orthides and strophomenides, the rarity of pentamerides and atrypides, and the lack of trimerellides. Virtually all the genera recorded are 'hold-over' genera from the diverse latest Katian fauna and have long ranges and wide geographical distributions except for some endemics. A major faunal change in the brachiopod fauna occurred within the *N. persculptus* Biozone, beneath the Ordovician–Silurian boundary. The end of the second episode of the Ordovician extinction event of brachiopods may have extended from the middle *N. persculptus* Biozone, prior to start of the Silurian, coincident with *N. persculptus* Biozone – bearing beds generally overlying the *Hirnantia* fauna and a striking positive carbonate isotope excursion, present in many places in the world. The end Ordovician extinction is substantially different from the end Permian mass extinctions characterized by a sharp decline at all taxonomic levels with high extinction rates, the absence of 'hold-overs', Lazarus and progenitor taxa, prevalent miniaturization of shell size and a much slower recovery rate during the Triassic. This sharp contrast was enhanced by the relative intensity of both extinctions with widely different causes, patterns and consequences and by the relatively weak ecosystem disturbances through the Ordovician–Silurian transition rather than the ecosystem collapse during the early Triassic. A new family, Cathaysiorthidae, and five new genera or subgenera, *Aegiromena* (*Aegiromenella*), *Eopholidostrophia* (*Megapholidostrophia*), *Chunanella*, *Yuhangella* and *Eospirifer* (*Protospirifer*), are established, as well as fourteen new species: *Anisopleurella asiatica*, *Chunanella chunanensis*, *Deliella delicatula*, *Dolerorthis* (*D.*) *multicostellata*, *Epitomyonia subquadrata*, *Eopholidostrophia* (*Megapholidostrophia*) *magnifica*, *Eoplectodonta* (*E.*) *boucoti*, *Eospirifer* (*E.*) *eosinensis*, *Fardenia* (*F.*) *flexa*, *Hesperorthis orientalis*, *Katastrophomena zheganensis*, *Mendacella mutabilis*, *Sulcatospira simplex* and *Yuhangella yui*.

Overseas Representatives

Argentina:	Dr M.O. Manceñido, Division Paleozoologia invertebrados, Facultad de Ciencias Naturales y Museo, Paseo del Bosque, 1900 La Plata.
Canada:	Prof RK Pickerill, Dept of Geology, University of New Brunswick, Fredericton, New Brunswick, Canada E3B 5A3.
China:	Dr Chang Mee-mann, Institute of Vertebrate Palaeontology and Palaeoanthropology, Academia Sinica, P.O. Box 643, Beijing.
	Dr Rong Jia-Yu, Nanjing Institute of Geology and Palaeontology, Chi-Ming-Ssu, Nanjing.
France:	Dr J Vannier, Centre des Sciences de la Terre, Université Claude Bernard Lyon 1, 43 Blvd du 11 Novembre 1918, 69622 Villeurbanne, France.
Germany:	Professor F.T. Fürsich, Institut für Paläontologie, Universität, D8700 Würzburg, Pliecherwall 1.
Iberia:	Professor F. Alvarez, Departmento de Geologia, Universidad de Oviedo, C/Jésus Arias de Velasco, s/n. 33005 Oviedo, Spain.
New Zealand:	Dr R.A. Cooper, New Zealand Geological Survey, P.O. 30368, Lower Hutt.
Scandinavia:	Dr R. Bromley, Geological Institute, Oster Voldgade 10, 1350 Copenhagen K, Denmark.
USA:	Professor Paul Selden, The Paleontological Institute, University of Kansas, Lawrence, Kansas, 66045.
	Professor N.M. Savage, Department of Geology, University of Oregon, Eugene, Oregon 97403.
	Professor M.A. Wilson, Department of Geology, College of Wooster, Wooster, Ohio 44961.

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This publication is not deemed to be valid for taxonomic/nomenclatural purposes
[see Article 8.2 of the International Code of Zoological Nomenclature (4th Edition, 1999)].

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The Palaeontological Association has its own pages on the World Wide Web, including information about the Association, and copies of the *Newsletter*. Internet Officer Mark Sutton can be reached by email at <**webmaster@palass.org**>. The locator is <**http://www.palass.org/**>.

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Book Review Ed.: C. Jeffery-Abt, Earth and Ocean Sciences, University of Liverpool, 4 Brownlow Street, Liverpool L69 3GP
Internet Officer: M. Sutton, Earth Science & Engineering, South Kensington Campus, Imperial College London SW7 2AZ
Meetings Coord: T. R. A. Vandenbroucke, Université Lille 1, Avenue Paul Langevin, 59655 Villeneuve d'Ascq cedex, France

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Editor-in-Chief:
S. Stouge, Geologisk Museum, Københavns Universitet, Øster Voldgade 5–7, DK-1350 København K, Denmark

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