Palaeontology, palaeobiology and evolution

Faster recovery after mass extinctions (*February 2006*)

Mass extinctions have been the principal time markers in the Phanerozoic stratigraphic column since 19th century palaeontologists recognised sudden changeovers in the fossil record. Two close the Palaeozoic and Mesozoic Eras, two more end Periods (Ordovician and Triassic) and others mark Stage boundaries. Greatest focus has been on the magnitudes of each extinction, greatly assisted by the statistics compiled by the late Jack Sepkoski. The adaptive radiations that filled abandoned niches and restored and, in most cases, expanded diversity are equally interesting. Such recoveries from depleted stocks of organisms have been of immense influence over biological evolution. Resulting from chance events, as far as the Earth's biota are concerned, the families and species that arose would not otherwise have appeared: the most powerful blow to any notion that biological advances are in any way pre-ordained.

Until recently, it seemed that each recovery was an extremely protracted affair. Over 5 to 10 million years seemed to be the case for aftermaths of the largest extinctions. To a marked extent, analysing recoveries from the fossil record is not so easy as tying the great declines in diversity to a time. It is a matter of working out the rate at which new genera arose or originated through speciation, and that is affected by geographic biases in the fossil record. They arise from less collecting in remote areas and variations in the volume of exposed strata in others. Correcting the biases is possible to some extent, but that still leaves the challenge of statistical analysis. From an extraordinary expansion of analytical expertise, which extends to economists' methods of understanding stock market trends and the flair of physicists, a very different story of restocking seems about to emerge. A technique called vector autoregression applied to faunal diversification corrected for biases suggests that recoveries were very much faster than previously thought, in fact almost immediate by comparison with the time-precision of the stratigraphic column (Lu, P.J. Motohiro Yogo, M and Marshall, C.R., 2006**.** Phanerozoic marine biodiversity dynamics in light of the incompleteness of the fossil record. *Proceedings of the National Academy of Sciences*, v. **103**, p. 2736-2739; DOI: 10.1073/pnas.0511083103).

See also: Kerr, R.A. 2006. Revised numbers quicken the pace of rebound from mass extinctions. *Science*, v. **311**, p. 931; DOI: 10.1126/science.311.5763.931a.

Is the Cambrian Explosion real evidence for an evolutionary burst? (*February 2006*)

About 543 Ma ago, remains of organisms that secreted hard parts suddenly appear in the fossil record. Most palaeontology has focussed on such easily fossilised organisms from the Phanerozoic Eon that began at that time. Whether or not the Cambrian Explosion was a truly significant event, bar the appearance of hard parts – that is quite a mystery in itself – is highlighted by the presence of members of almost all modern animal phyla in the Early Cambrian record. Did they all suddenly explode onto the scene at its outset, or were they around well beforehand as almost completely soft-bodied creatures? Comparative molecular biology of living animals, and the concept of molecular 'clocks' has for a while suggested that the origination of modern phyla was considerably earlier than the start of the Phanerozoic. Increasing the database on which such ideas can be based helps improve their precision and scope, assisted by novel methods of mathematical analysis. The 23 December 2005 issue of *Science* contained an analysis of more than 12 thousand amino acids involved in the genomes of members of 9 or 26 extant animal phyla (Rokas, A.. *et al*. 2005. Animal evolution and the molecular signature of radiations compressed in time. *Science*, v. **310**, p. 1933-1938; DOI: 10.1126/science.1116759). Preliminary study suggests that indeed the early history of the metazoans was remarkably compressed in time, probably in the 50 million years after the ~600 Ma Snowball Earth event, and possibly within a few million years of the base of the Cambrian. However, tests of hypotheses based on such indirectly related data are notoriously difficult, and Rokas *et al*. have taken a bit of stick (Jermiin, L.S. *et al*. 2005. Is the 'Big Bang' in animal evolution real? *Science*, v. **310**, p. 1910-1911; DOI: 10.1126/science.1122440). It seems yet more work on molecular biology of the remaining 17 phyla and a great deal of mathematical wrangling is yet to come.

Gaia: the ultimate frontier (*March 2005*)

That life plays a role in surface geological processes is self-evident. Death and the burial of dead organic matter feed back to climate by removing carbon from the atmosphere and hydrosphere, thereby reducing the 'greenhouse' effect and increasing the oxidation potential of the outer Earth – a discovery of the late 20th century. James Lovelock's Gaia hypothesis proposes that life's influence as a means of balancing conditions for its own continuity is a primary factor behind the behaviour of our home world, although a great many geoscientists doubt that bold generalisation. It seems to many that the influence of both deep mantle processes and extraterrestrial forces not only provided the conditions for planetary evolution, both inside and at the surface, but created the conditions for life's emergence and its survival. Life has been pushed to the brink of complete extinction several times by both truly primary parameters. Yet Gaia is still a persuasive idea, or at least a metaphorical itch that must be scratched from time to time. Perhaps the boldest attempt at pushing Lovelock's notions to the limit appears in a recent essay (Rosing, M.T. *et al*. 2006. The rise of continents – An essay on the geologic consequences of photosynthesis. *Palaeogeography, Palaeoclimatology, Palaeoecology* v. **232**, p. 99-113; DOI: 10.1016/j.palaeo.2006.01.007).

Assuming that carbon-isotope evidence from the oldest sediments known (3.8 Ga, West Greenland) that life selectively took up light ^{12}C is valid, there seems to be a remarkable coincidence between the origin of life on Earth and the oldest known continental rocks (4.0 Ga, northern Canada). Rosing *et al*. suggest that this is no coincidence, but the result of the effect of living organisms on magmatism at subduction zones, most particularly on the mineralogy of old oceanic lithosphere that descends there. Their essay starts by emphasizing that modern photosynthesis contributes three times more energy to surface processes than does heat flow from the mantle, and that energy must accomplish a commensurately significant amount of mainly geochemical work, some of which occurs in basalts of the ocean floor as they spread from constructive margins. Continental crust is widely accepted to form as a result of hydrous fluids rising above subduction zones to cause different conditions for melting of the overriding mantle wedge than those for partial melting of mantle rock beneath mid-ocean ridges and oceanic islands. Multistage fractionation processes that operate on basaltic magmas formed by this wedge melting result in separation of residual magmas that are sufficiently enriched in silica and other elements to crystallize as, broadly speaking, granitic rocks. Since they cannot be metamorphosed to a form that exceeds the density of the mantle, such rocks cannot be subducted, unless debris shed from them mixes as sediment with subducting oceanic lithosphere. So continents become more or less permanently growing edifices on the face of the Earth. The central questions that Rosing *et al*. focus upon are: why did continents not form from the outset of the Earth's evolution, once tectonics and oceans had stabilized, and why the coincidence? Their answer to both is that life played a fundamental role in increasing the amount of water that ends up in old, cold oceanic crust, thereby helping the peculiarities of wedge melting to become established. Essentially they appeal to life's ability to transform energy of different sources, for example heat from the mantle and the energy carried by electromagnetic radiation, and transmit it through biogeochemical cycles from its source to the lithosphere. Specifically, they speculate that this life-mediated energy transfer accelerated the conversion of dry minerals in basalt to water-rich clays. In turn, that had its effect on subduction-zone geochemistry.

Rosing *et al*.'s argument seems to have a wilful flaw: they focus on the incorporation of solar energy into the Earth system by photosynthesis from the time when continental materials first appeared in substantial bulk, between 3.8 and 4.0 Ga. So far there is a mere shred of evidence from ambiguous carbon isotope studies that photosynthesising organisms were around before about 3.4 to 3.5 Ga. There is no trace of such shallow-water organisms as stromatolites until that time. Nor is there any significant sign of where one end product of photosynthesis, oxygen, must have been secreted away by reaction with dissolved iron(II) – banded iron formations only become prominent in the later Archaean. Whatever organic activity might alter ocean-floor basalts, it is hardly likely to have used photosynthesis, unless the early oceans were shallow enough (200-300 m) to pass light to their floor. The key to alteration of anyhydrous minerals in basalt to form clays is the availability of hydrogen ions (products of oxidation) to donate electrons through hydration reactions, and they are available from a great many processes other than living ones. Then, of course, there is the key issue of whether any influence – direct or indirect – by photosynthesis can be seen on modern ocean-floor geochemical processes. Since it doesn't go on down there, whereas a great many oxidation reactions that produce hydrogen ions do, makes the hypothesis impossible to test. In fact it is not a hypothesis but speculation, and it has a great deal of company from other ideas to explain the missing 600-800 Ma of Earth's evolution. Most of those centre on the mechanics of slab-pull force, the pace of sea-floor spreading and the angle of likely subduction during geothermally much hotter times. Oddly, the third author, Norman Sleep, introduced a great deal of basic theory behind these other explanations. This is one of two articles from March 2006, whose time of publication – close to 1 April – may give a clue to its weight. It is interesting seasonal reading, and everyone should look forward to further debate. However, like the magnificent Verneshot hypothesis (See *Mass extinctions and internal catastrophes* June 2004), it may die in a deafening silence.

Methane, methanogens and early climate control (*March 2006*)

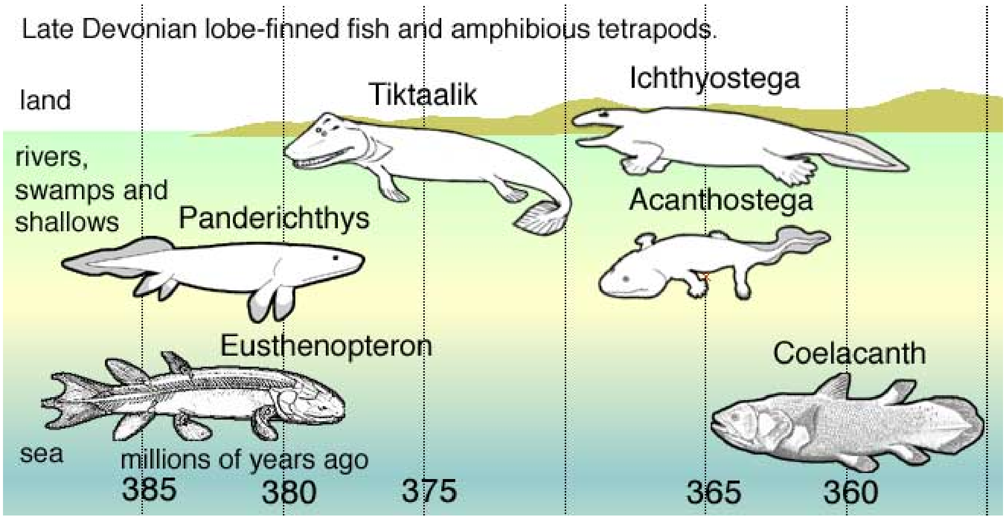
Expulsion of methane from gas hydrates in shallow marine sediments has been implicated several times as the likely cause for sudden bouts of global warming, such as that at the end of the Palaeocene 55 Ma ago. The gas, produced by primitive, anaerobic prokaryotes known as methanogens, is more powerful at delaying loss of heat to space than is carbon dioxide. It is a greenhouse gas of enormous potential power, although in an oxygen-rich atmosphere it has a short life before being oxidised to CO_2 and water. Methanogens themselves, which survive only in airless places, evolved very early in the Earth's history as witnessed by their genetic molecules being very different from those of other members of the Bacteria and Archaea domains. The ambiguities of carbon isotopes in ancient carbonaceous rocks being able to discriminate different metabolic processes, has led to considerable debate about when methanogens first made their appearance. That was probably well before the oceans were able to contain dissolved oxygen, which is highly toxic to anaerobic prokaryotes, i.e. in the Archaean. A good sign that such cells were around would be, in some way, to detect their main metabolic product, methane. The place to look would be in fluid inclusions enclosed in minerals that were definitely produced by seafloor sedimentary processes. The best candidate would be quartz in cherts precipitated from seafloor hydrothermal vents, where such organisms would have both the energy and the fuel to thrive. A group of Japanese geochemists have systematically looked for such fluid inclusions in a variety of Archaean cherts and they found sufficient evidence to at least give a minimum age for the presence of methane-producing bugs (Ueno, Y. *et al*. 2006. Evidence from fluid inclusions for microbial methanogenesis in the early Archaean era. *Nature*, v. **516**, p. 516-519; DOI: 10.1038/nature04584).

The Dresser Formation (3.45-3.50 Ga) in the early Archaean of Western Australia contains abundant pillow basalts and chemogenic, silica-rich sediments. These cherts seem to have been fed by fissures through which hydrothermal fluids moved, and it is quartz from these syn-sedimentary quartz-rich dykes that revealed abundant fluid inclusions that had clearly formed as the quartz crystals grew. The inclusions contain carbon dioxide with traces of methane. Most important, the carbon in the methane is highly enriched in heavy ^{13}C, evidently due to cell processes drawing in the lighter isotope ^{12}C; the methane is almost certainly biological in origin. So it is possible to say that methanogens had evolved before 3.5 Ga, and that they added methane to the Archaean atmosphere. Such a highly reduced gas would become a permanent constituent of the air, because oxygen had yet to be released by other organisms so that methane would be oxidise quickly, as happens today. The discovery by Ueno *et al*. is important from another standpoint than the appearance of a particular kind of metabolic process.

From the time of its accretion until well into the early Precambrian, the Earth received a great deal less energy from the Sun than it does today. Solar hydrogen fusion had not then achieved the level of efficiency that it has now. Without some means of trapping heat in the atmosphere, the Earths mean surface temperature would have been well below the freezing point of water. Without a 'greenhouse' effect, the planet, well endowed with water, would have been inescapably locked inside a thick crust of ice. In some respects it would have resembled a large version of one of the Outer Planet's icy moons, such as Enceladus (see *Yet another weird world* Planetary Science March 2006). Life would have found it difficult to emerge, if at all, at such low temperatures. Like Enceladus and other distant moons, some liquid water would have been present due to heating from the mantle and magmas, but the white surface would always have reflected away most of the Sun's heat – geothermal heat is vastly less than that of solar origin. The most recently proposed means whereby the Earth could have escaped permanent frigidity and sterility from the 'weak, young Sun' is that volcanic exhalation of CO_2 would eventually have developed 'greenhouse' conditions. However, it would have had to reach much higher atmospheric concentrations that now, perhaps greater than some geochemists believe to be theoretically possible. Being a much more powerful ‘greenhouse’ gas, methane helps overcome such theoretical difficulties. It can only be produced in quantity by biological processes, and that poses a conundrum, despite Ueno *et al*.s discovery. Without an atmosphere containing gases that could trap solar warmth since shortly after planet formation, the cold trap would have taken an icy grip holding back the emergence of life, such as primitive methanogens. Does that therefore imply that such organisms emerged far earlier than the start of tangible geological history?

A fish-quadruped missing link (*May 2006*)

Rich as the fossil record is, it is terribly incomplete because the chance of preservation over fragmentation and destruction of body parts is extremely small. That is especially the case for the high-energy and oxidising land and freshwater environments. Each fossil species can easily be assumed to be a one-off, appearing, thriving for a short while and then disappearing: ripe for the assumption of divine creation, as Linnaeus assumed. Very rarely, specimens emerge that fill in the many gaps needed by evolutionary theory, the most celebrated being *Archaeopterix* that bridged the gap between dinosaurs and birds. That transition has been enriched by a whole series of older fossils from Chinese lagerstätten, which show the transition in sublime detail.



Late Devonian emergence of terrestrial tetrapods (Credit: Wikipedia)

The comparative anatomy of fish and land vertebrates suggests a common ancestry, and the Devonian to Early Carboniferous terrestrial record has yielded tantalising fish with lobed fins (e.g. *Eusthenopteron* and *Panderichthys*) and almost fish-like animals with four rudimentary limbs (e.g. *Acanthostega* and *Ichthyostega*). Yet a gap remained to be filled in the apparent transition from aquatic to land-dwelling vertebrates. US palaeobiologists engaged in seeking candidates from the Late Devonian of Arctic Canada have found one that reduces any uncertainty tremendously (Daeschler, E.B *et al*. 2006. A Devonian tetrapod-like fish and the evolution of the tetrapod body plan. *Nature*, v. **440**, p. 757-763; DOI: 10.1038/nature04639. Shubin, N.H. *et al*. 2006. The pectoral fin of *Tiktaalik roseae* and the origin of the tetrapod limb. *Nature*, v. **440**, p. 764-771; DOI: 10.1038/nature04637 ·). The fossil, prepared with lengthy and painstaking care, shows such amazing anatomical detail as to demonstrate clearly that the fin and shoulder girdle are indeed intermediate between fish and tetrapods, whereas previous candidates supporting a transition are either definitely fish or tetrapods. *Tiktaalik* slots nicely into the time gap too, about 2 Ma younger than the most tetrapod-like fish *Panderichthys* and slightly older than fish-like quadrupeds. The outcome of a deliberate search for an animal to fit the gap, *Tiktaalik* above all demonstrates the predictive capacity of palaeontology, which counters a common epithet flung by those bent on divine intervention and/or intelligent design. Based on this outstanding success, fossil hunters will be encouraged to sift on a stratigraphically finer scale for yet more steps in vertebrate evolution, including our own.

See also: Ahlberg, P.E. & Clack, J.A. 2006. A firm step from water to land. *Nature*, v. **440**, p. 747-749; DOI: 10.1038/440747a.

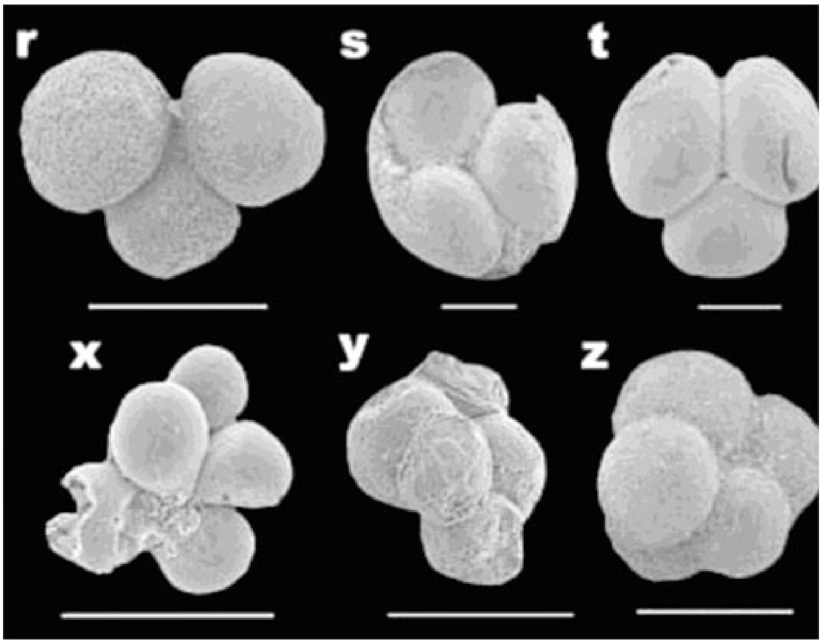
Near-pristine traces of life before Earth's surface became oxidising (*August 2006*)

Only around 2.2 Ga did the atmosphere contain sufficient oxygen to oxidise iron(II) to iron(III) and leave its trace in red soils and terrestrial sedimentary rocks. That opened the way for the emergence and evolution of the Eucaryan domain of organisms, most of which depend on oxygen. For their predecessors, the prokaryote Bacteria and Archaea, oxygen would have been intensely toxic, especially for those which used anoxygenic forms of metabolism. Almost certainly oxygen was released for more than a billion years before the Great Oxidation Event, by blue-green bacteria, only to be mopped up by oxidation of abundant iron(II) ions dissolved in sea water. Getting an idea of the diversity of pre-2.2 Ga life is possible by examining the organic chemicals produced when they decayed under anoxic conditions, i.e. from oil and kerogen. Unfortunately, the great age of their host rocks has resulted in many Precambrian sediments having been heated and metamorphosed, so that different biomarkers break down into less distinctive compounds. There are, however, sediments that may have remained more or less unaffected, and one sequence in the Canadian Shield has yielded astonishing results (Dutkiewicz, A. *et al*. 2006. Biomarkers from Huronian oil-bearing inclusions: An uncontaminated record of life before the Great Oxidation Event. *Geology*, v. **34**, p. 437-440; DOI: 10.1130/G22360.1).

The sediments are conglomerates rich in uranium, having been deposited under reducing conditions that helps precipitate uranium from solution, and have been mined extensively in the Elliot Lake area of Ontario. Oil seems to have entered fluid inclusions in quartz that cemented the conglomerates, shortly after the conglomerates were deposited at about 2.45 Ga. The oil contains a host of complex organic compounds that have never been degraded by heating. Some can be linked to blue-green bacteria, which undoubtedly created of oxygen continuously. That they gave rise locally to favourable conditions for oxygen-using organisms is clear from other biomarkers. Those are steranes that are derived by breakdown of sterols, which in turn are only known to be created by the enzymes exclusive to Eucaryan metabolism. Steranes have been found in even older sediments, but they were back shales that could easily have been contaminated by much younger organic materials seeping through the host rock. Oil in fluid inclusion within diagenetic minerals is far less likely to have been contaminated, so the Elliot Lake samples define a minimum age for the emergence of the Eucarya far earlier than the appearance of actual microfossils that show the distinctive cell nucleus that defines the domain Eukarya.

Precambrian bonanza for palaeoembryologists (*August 2006*)

Signs of relatedness among groups of organisms often show up well during their early growth as embryos, so their fossils in very old rocks are of great use in establishing when different groups emerged (see *Ancient baby penis worm hits the news* February 2004). A deposit containing possible embryos of deutorostomes (see *Age range of early fossil treasure trove*, March 2005), in which the first orifice to emerge during embryonic development is the anus, is of considerable interest. Nowadays, the group contains animals with mirror symmetry (bilaterians), including the vertebrates. First reports of fossil embryos from the 580 Ma old Doushantuo Formation of southern China in 2004 drew fire from palaeontologists who preferred to believe that the smooth almost spherical objects, like the fictitious life forms in a supposedly Martian meteorite, were probably oolith-like mineral growths. Undeterred, their finders have extracted yet more from the exposures (Chen, J-Y. and 12 others 2006. Phosphatized polar lobe-forming embryos from the Precambrian of southwest China. *Science*, v. **312**, p. 1644-1646; DOI: 10.1126/science.1125964). They demonstrate clearly that the objects do show lobes in an early stage of development that break the embryos initial symmetry so that different kinds of tissue can develop to form adults. The find matches well with evidence from the genes of modern bilaterians that the basic branching of the Animal Kingdom occurred well before the Cambrian Explosion of shelly fossils. Since more or less all modern phyla are represented by Cambrian fossils, that is not surprising.



Fossil embryos from the Doushantuo Formation, southern China. Scale bars 250 µm long. (Credit: Chen *et al*. 2006; Fig. 2)

Pocket sauropods (*August 2006*)

The largest animals to roam the land were vegetarian dinosaurs of the sauropod group. The biggest reached a length of more than 30 metres, and were commensurately tall. These giants permeate our perception of Mesozoic life on the continents, along with their monster predators. Now, children made nervous by such titanic creatures (and I was definitely one of them) can be reassured that there were ones that were not so crushingly big (Sander, P.M. *et al*. 2006. Bone histology indicates insular dwarfism in a new Late Jurassic sauropod dinosaur. *Nature*, v. **441**, p. 739-741; DOI: 10.1038/nature04633). A near-complete skeleton of a sauropod that was only 6 metres long turned up in Lower Saxony in Germany, along with other remains suggesting individuals as small as 1.7 m. *Europasaurus* was first thought to be a juvenile of a much larger species, but Sander *et al*. developed means of microscopic bone analysis that clearly show fully mature bone growth. In the Late Jurassic central Germany was covered by sea, except for a number of large islands. The most likely explanation for such a tiny species is that it adapted to island life in much the same way as other, more recent mammals did, such as pigmy elephants and hippos on many islands in the Mediterranean and the Indonesian archipelago.

Our relationship with sea urchins (*December 2006*)

With their five-fold symmetry, echinoderms seem to be dubious candidates for having shared an ancestor with vertebrates, but that has long been suspected. Like chordates, their embryonic development reveals that they are deuterostomes, with bilateral symmetry (a five-fold symmetry also involves mirrored morphology). The earliest fossil echinoderms also show what seem to be gill slits. The construction of a sea urchin's genome is not only a means of testing that relatedness but extremely useful in studying the development of organisms in general, for which sea urchins have been a favourite object of research. So, it is not surprising that 22 pages of *Science* is devoted to preliminary discussion of the first echinoid genome (10 November 2006 issue of *Science*, v. **314**, p. 938-962). It definitely confirms the link, there being many genes that are also essential to vertebrates, while genes typical of crustacea, molluscs and some worms are missing. A fascinating feature is the large number of genes for proteins that are involved in sensory perception, despite the fact that echinoids are not obviously sighted or able to smell. Similarly, the sea urchin's immune system is far more complex that that of vertebrates, yet several groups of genes involved in it seem to have no practical function, whereas they are central to specialised immune cells in vertebrates. It seems that aspects of the genetic make-up of the deuterostome common ancestor were harnessed in different ways by vertebrates and echinoderms, specifically in the immune and sensory systems. Even a gene central to mammalian brain development is present in the sea urchin, despite its lack of any obvious brain.

As well as opening up masses of work for biologists, the sea urchin genome should encourage a focus on the earliest echinoderms and related organisms, just after the Cambrian Explosion (Bottjer, D.J. *et al*. 2006. Palaeogenomics of echinoderms. *Science*, v. **314**, p. 956-960; DOI: 10.1126/science.1132310). Interestingly, the five-fold symmetry that is so familiar from sea urchins, starfish and crinoids did not appear until the Late Cambrian, earlier, extinct relatives having developed the water vascular system and characteristic biomineralised plates.

Oxygen and the explosion of large, soft animals (*December 2006*)

The newly defined Ediacaran Period of the latest Precambrian takes its importance from the first appearance of large animals, albeit ones without hard parts. Eukaryotes emerged before 2.1 Ga, when their oldest fossil (*Grypania*, probably an alga) appears. Until the Ediacaran, animals were too small to appear as recognisable fossils. All eukaryotes depend on oxygen being available, and the larger they are the more they need. A widely held explanation from the dramatic appearance of the Ediacaran fauna – over a mere metre or so around 575 Ma in each of the occurrences – is that it followed a significant boost to oxygen concentrations in both the atmosphere and the oceans. Two of the most productive Ediacaran sequences, in Newfoundland and the Oman, have now provided evidence for the pacing of such an oxygen build up (Canfield, D.E. *et* al. 2006. Late-Neoproterozoic Deep-Ocean Oxygenation and the Rise of Animal Life. *Science*, v. **314** doi: 10.1126/science.1135013. Fike, D.A. *et al.* 2006. Oxidation of the Ediacaran Ocean. *Nature*, v. **444**, p. 744-747; DOI: 10.1038/nature05345).

In Newfoundland and Oman Ediacaran animals appear shortly after evidence for glaciation, regarded by many as the last of the Neoproterozoic 'Snowball Earth' events: the Gaskiers glaciation around 580Ma. Don Canfield of the University of Southern Denmark and colleagues from the UK and Canada used variations in the proportions of geochemically and biologically active iron minerals (such as sulfides) to those that are largely inert (e.g. hydroxides) in sedimentary rocks to estimate the influence of oxygen. They found a big change following the Gaskiers glaciation to around the same proportions as throughout Phanerozoic rocks. The US group, led by Fife, focused on the sulfur and carbon isotopes in sediments that succeed the earlier Marinoan glaciation (~635 Ma). Changes in the proportions of sulfates and sulfides in seawater affect sulfur isotope data, sulfates indicating oxidising conditions. Carbon isotopes preserved in organic carbon reflect periods when dissolved organic carbon has been oxidised. They reveal three distinct jumps in oxygen levels in the ocean water that covered Oman at the time. It was during the second and third stages (580 to 550, and <550 Ma) that the Ediacaran faunas emerged globally. The first two increases began soon after glacial episodes, and maybe there was a connection between global cooling and conditions that favoured an increase in oxygen – that would have to reflect increases in both production of oxygen by photosynthesis and burial of biologically reduced carbon; i.e. an effect on phytoplankton. Interestingly, it was during the last of the oxygen boosts that small, indeterminate shell-secreting organisms appear in the fossil record: the harbingers of the Cambrian Explosion.

See also: Kerr, R.A. 2006. A shot of oxygen to unleash the evolution of animals. *Science*, v. **314**, p. 1529; DOI: 10.1126/science.314.5805.1529.

Global warming, sour gas and mass extinctions (*December 2006*)

Several mass extinctions show links in time with massive outpourings of flood basalts. The best known is the connection between the Siberian Traps and the end-Permian extinction that probably put paid to 90 % of species, both marine and on land. But, what was the kill mechanism? Since all volcanoes emit carbon dioxide, flood basalt events would have had a major effect on climatic warming, and also there would have been a decrease in the pH of rain and surface seawater. One of the most powerful tools for charting ups and downs in the biosphere uses the isotopic composition of carbon in sediments. Extinctions at the ends of the Permian and the Triassic Periods are associated with repeated fluctuations in ^{13}C that suggest a series of extinction events that culminated in the final catastrophes (Ward, P.D. 2006. Impact from the deep. *Scientific American*, v. **295**, October 2006 issue, p. 42-49).

Ward links the carbon-isotope evidence to signs that in both events the oxygen content of ocean water fluctuated dramatically: it periodically became anoxic. Biomarkers in sediments leading up to both events show that photosynthetic green sulfur bacteria bloomed periodically. These organisms do not produce oxygen, but use oxidation of hydrogen sulfide gas to sulfur as an energy source, and cannot survive in oxygenated water. Their abundance demands large-scale production of H_2S in the oceans, by other anaerobic organisms, such as sulfate-reducing bacteria. Where deep anoxic waters were able to upwell to the surface, they would have released huge amounts of this toxic gas to the atmosphere. That, for Ward, would have been a major killing mechanism for both plants and land animals.

Gliding mammal of the Jurassic (*December 2006*)

Volaticotherium reconstruction (Credit: Palaeoblog)

Non-palaeontologists have grown used to regarding mammals before the Cenozoic as tiny retiring beasts that only came out at night, avoiding dinosaurian predators. Well, as far back as the Middle Jurassic, there were some that could glide to snatch insects (Meng, J. *et al*. 2006. A Mesozoic gliding mammal from northeastern China. *Nature*, v. **444**, p. 889-893; DOI: 10.1038/nature05234). Being found in yet another Chinese lagerstätte, *Volaticotherium* has well-preserved signs of fur and the characteristic skin flap linking all four feet of modern flying squirrels and sugar gliders, without which it would just be another sharp-toothed little mammal. It is 70 Ma older than the earliest, previously known flying mammal, and may have taken to the air before birds did.