# *Palaeontology, palaeobiology and evolution*

## Fossil embryos debunked? (*February 2007*)

Late Precambrian (~580 Ma) lagerstätten in China have become quite famous for their supposed fossil embryos of bilaterian animals (see *Age range of early fossil treasure trove* March 2005, and *Precambrian bonanza for palaeoembryologists* August 2006) that often occur in large numbers. The fossils are substantial, ranging up to a millimetre in size. Under the microscope they look convincingly like embryos in the process of cell division. The stir caused by several publications on the Doushantuo embryos may turn out to have been premature and embarrassing (Bailey, J.V. 2007. Evidence for giant sulphur bacteria in Neoproterozoic phosphorites. *Nature*, v. **445**, p. 198-201; DOI: 10.1038/nature05457). Sulfur-oxidising bacteria are the largest known single-celled organisms, up to 0.5 mm in diameter. When their cells divide, the clones often adhere to form larger structures that look very like the putative fossil embryos. Such bacteria also bloom in environments that are highly reducing and rich in phosphorus. The Doushantuo sites of special preservation are phosphorites.

In his late career, the Lapworth Professor of Geology (1932-1949) at Birmingham University, L.J. Wills was immensely attracted to fossil eurypterids (sea scorpions), the largest-ever arthropods. If the weather was kindly, he often worked at a microscope outdoors on his patio. On a notable occasion Wills announced that he had discovered eurypterid eggs in a specimen from the Silurian of Lesmahagow in Scotland. However, once it was pointed out politely that his ‘eggs’ bore a close resemblance to rose pollen, he freely admitted his mistake.

Coincidentally, Bailey’s sceptical view was countered by publication of yet more material from Doushantuo (Xiao, S. *et al.* 2007. Rare helical spheroidal fossils from the Doushantuo lagerstätte: Ediacaran animal embryos come of age? *Geology*, v. **35**, p. 115-118; DOI: 10.1130/G23277A.1). Some looking like minuscule tennis balls with arrays of pores and others with spirally twisted entrances to bodily orifices, the exquisitely preserved and imaged fossils shown by the Chinese and US team bear no resemblance whatever to giant bacteria, being far more complex. They may well be embryos, but look just as convincing as tiny metazoan animal adults to a lay person. Either way, there is no clue to their affinities for either the ignorant or the specialist.

## Microbial carbonate secretion (*February 2007*)

Biological deposition of carbonates, mainly of calcium, has a vital role in the carbon cycle and therefore in helping to regulate climate by drawing down atmospheric carbon dioxide. It is easy to see the secretion of hard parts by metazoan animals and plants as the main way in which this happens, Phanerozoic limestones and the sediments of the deep ocean floor being full of their remains. Single-celled Bacteria and Archaea can have much the same effect, and before 542 Ma they were the dominant creators of carbonate rocks in the geological record. The carbonates produced by microbes are fine grained, and take the form of biofilms that are sometimes finely banded, to produce, for instance, stromatolites that date back to around 3.5 Ga old. Undoubtedly a proportion of all Phanerozoic carbonate deposition was microbial in origin too. Because metabolic processes are disrupted by excessive calcium within cells – it seems that needle-like calcium carbonate develops – yet calcium is abundant in most natural waters, all organisms need means of regulating calcium concentration, both in the cell and in its immediate surroundings. It is possible that the sudden evolution of abundant, calcium-rich hard parts by animals during the Cambrian Explosion stemmed from this necessity, setting off the 'arms versus armour' that has been a major selective pressure during the Phanerozoic. So, how do microbes secrete carbonates?

There are two views: as a direct result of cell metabolism; by secondary means that involve cells helping to nucleate carbonate precipitation. The first would take place on the surface of cells, the other at some distance. A problem with direct precipitation at the cell wall is 'entombment' of the cell. Experiments that induce carbonate secretion can help resolve the issue (Aloisi, G. *et al*. 2006. Nucleation of calcium carbonate on bacterial nanoglobules. *Geology*, v. **34**, p. 1017-1020; DOI: DOI: 10.1130/G22986A.1). The German and French authors used a bacterium that reduces sulfate to sulfide and is known to precipitate carbonates. It lives in highly saline lagoons whose waters are supersaturated with calcium and carbonate ions. Without the bacteria, sterile water with such a composition does not spontaneously precipitate carbonates, but as soon as a culture is introduced, they begin to appear. Under high magnification, the precipitates show up as spherical globules associated with organic compounds excreted by the cells, rather than at the cell surface. The micro-environment around the cells is therefore depleted in dissolved calcium ions and its alkalinity is lowered, to the advantage of the bacteria.

**Robot shows how fishes walked out of water (*May 2007*)**

The salamander robot (Credit: Ijspeert*et al*. 2007)

Now and again palaeontologists relax with toys; they build models. Perhaps the most famous were flying pterodactyl gliders that featured in a BBC natural history programme.

The presenter, David Attenborough, was most impressed. At a society dinner shortly after filming them, 'Whispering Dave' was asked by a formidable old lady what he had been doing lately. 'Well, I was flying pterodactyls last week', he replied, hoping to impress. 'Yes', 'They're so graceful, aren't they', said the dowager in an instant,. The same could not be said about the amphibians of the late Devonian and early Carboniferous, and the earlier lobe-finned fishes that managed to struggle onto land to give rise to all terrestrial vertebrates. While it is demonstrably easy for any land vertebrate to swim if needs be, the opposite would seem to be a problem. To explore the locomotive transition Swiss and French engineers and fossil aficionados built a robot, not entirely unlike a lobe-finned fish but almost so. It has a simple spinal-chord neural circuit designed to swim. Then they let the beast loose near a beach (Ijspeert, A. J. *et al*. 2007. From swimming to walking with a salamander robot driven by a spinal chord model. *Science*, v. **315**, p. 1416-1420; DOI: 10.1126/science.1138353), and it did walk off. So, invasion of the land by vertebrates was not necessarily too difficult. It is almost as if they were predestined to clamber out and eventually reach for the stars…

**Ancient protein (*May 2007*)**

Mass spectrometry is often associated by geoscientists just with radiometric dating and stable isotope techniques. However, it is a prime tool in separating biological compounds according to their molecular mass. Both approaches have steadily improved in their detecting and discriminating power. To my surprise, at least, proteins have been found by mass spectrometry in bones of a late-Cretaceous fright-icon, and in those of one of the more recent monsters of the American West, the mastodon *Mammut americanum* (Schweitzer, M.H. *et al*. 2007. Analyses of soft tissue from *Tyrannosaurus rex* suggest the presence of protein. *Science*, v. **316**, p. 277-280; DOI: 10.1126/science.1138709. Asara, J.M. *et al*. 2007. Protein sequences from mastodon and *Tyrannosaurus rex* revealed by mass spectrometry. *Science*, v. **316**, p. 280-285; DOI: 10.1126/science.1137614).

There is no need to worry about Late Cretaceous Park scenarios, but every reason to expect that tiny quantities of proteins preserved in bones may help establish phylogenetic relationships among long-extinct creatures so that ideas of evolution based purely on skeletal forms can be tested and amplified.

**Ediacaran fauna reviewed (*May 2007*)**

The to-and-fro debate over millimetre-sized spherules in the ~580 Ma Doushantuo lagerstätten in China – giant bacteria versus bilaterian embryos – has overshadowed the far more important 'megafauna' of the latest Precambrian. Thankfully, a timely review has restored the balance (O'Donoghue, J. 2007. Life's long fuse. *New Scientist*, v. **194** (14 April 2007), p. 34-38; DOI: 10.1016/S0262-4079(07)60933-6). That the period before 552 Ma was not devoid of metazoan animals, puzzled over since Darwin's day, emerged with a schoolboy's 1957 discovery of the 'sea pen' *Charnia masoni* contained by Neoproterozic sediments in suburban Leicester's Bradgate Park. A decade earlier, similar fossils had been found in abundance in the eponymous Edicara Hills of South Australia, but their host rocks had been misjudged as Cambrian in age.

The Ediacaran fauna of floppy animals is everywhere in sediments of suitable type deposited after the last 'Snowball Earth' event. Fossils are so abundant that they dominate some of the exposures. Yet they are mere imprints, often found in sandstones, but some are big: up to 4 m. Many of them are quite bizarre-looking, especially those in rocks older than 560 Ma. Despite some palaeontologists having been inclined to shoe-horn all Ediacaran animals into phyla that are living today, a consensus is emerging that some of them were failed evolutionary 'experiments', which left no issue. These are the forms found in deepwater sediments, some of which are known as rangeomorphs (because they all resemble the first to be discovered, frond-like *Rangea*). Post 560 Ma examples from shallow-water sediments do bear some comparison with later phyla of the Phanerozoic and present.

Painstaking searches for better-preserved animals in 2004 turned up rangeomorphs preserved in fine-grained sediments from Newfoundland. These enigmatic fossils revealed an astonishing feature. Their large-scale frondiness was built in a fractal way from fronds of ever decreasing scale. With no apparent orifices, these creatures probably absorbed dissolved organic matter directly from deep seawater.

Once animal hard parts evolved, those that were turned to biting spelled the end for the Ediacaran fauna, and burrowing that began the Cambrian destroyed traces of most of Ediacarans that may have survived the Cambrian explosion. Certainly there are none now, but the selection pressures of the 'arms versus armour' competition of the Phanerozoic would certainly have driven some to evolve new life styles, while others disappeared totally.

**And now the sea anemone genome… (*September 2007*)**

Most of the animals with which palaeontologists are familiar are bilaterians: chordates; arthropods; molluscs; brachiopods; various worms etc. Sometime in the Neoproterozoic they shared their last common ancestor, according to molecular studies of living representatives. The others, such as cnidarians that include corals, are somewhat older in their origins. So the next step in the quest for the origin of metazoan animals had to be sequencing a cnidarian, and the target has been a sea anemone (*Nematostella*). Yes, it is different from the rest of the bilaterians (Putnam, N.H. and 18 others 2007. Sea anemone genome reveals ancestral eumetazoan gene repertoire and genomic organization. *Science*, v. **317**, p. 86-94; DOI: 10.1126/science.1139158), but surprisingly not by much from ourselves and other vertebrates which share a similar degree of complexity with the sea anemone. The implication is that some bilaterian gene sequences became more streamlined and simplified over time, after stemming from a more complex ancestor, whereas that which vertebrates carry shares almost half the anemone's protein-coding genes. Even more surprising, of the 280 odd human genes implicated in a wide range of diseases 226 occur in *Nematostella*.

**See also:** Pennisi, E. 2007. Sea anemone provides a new view of animal evolution. *Science*, v. **317**, p. 27.

**Trilobite evolution speeded up among variable species (*September 2007*)**

Ordovician trilobite of the order Phacopida, which has less variable species than those from the Cambrian. (Credit: Hunt 2007)

Evolution ought to depend on variability among the individuals of a species. That is because the more diverse are forms and functions, and their underlying genetics, the better they can be tested for fitness against one another, those of other species and the environment. Fine, yet the hypothesis requires analysis of a great many individual fossils of several species at times when evolutionary divergence seems to have waxed and waned. Having long excited fossil collectors, almost as much as do dinosaurs, trilobites are a worthy source of data. There are close to twenty thousand species known from the Palaeozoic Era, whose end saw their final disappearance. Mark Webster of the University of Chicago, USA waded through the morphological characters of almost a thousand species that are well-represented numerically (Webster, M. 2007. A Cambrian peak in morphological variation within trilobite species. *Science*, v. **317**, p. 499-502; DOI: 10.1126/science.1142964), and found that Cambrian species were, on the whole, more variable than were those from later Periods. That matches well with the hypothesis, because trilobite diversification was at its peak during the Cambrian. But was the link determined by more 'malleable' arthropod genomes immediately after the Cambrian Explosion, or by environmental factors? Palaeontologists can only guess at the first possibility. A Precambrian supercontinent had begun to break up into drifting fragments, increasing the number of viable habitats and creating a 'diaspora' of increasingly disconnected faunas. There were also fewer families of all organisms that were capable of being fossilized, and which were in competition for potential ecological niches.

**See also**: Hunt, G. 2007. Variation and early evolution. *Science*, v. **317**, p. 459-460; DOI: 10.1126/science.1145550.

**More on earliest signs of Earthly life thwarts Mars fans (*September 2007*)**

In *No graphite in Akilia apatites, no sign of life* (March 2005) I reported what seemed to be concrete evidence that previous claims for isotopically light carbon said to have been found in 3.8 Ga apatite grains were mistaken: no carbon whatever turned up in the West Greenland apatites after a painstaking survey of the supposed host rocks for the earliest life. That sturdy-seeming refutation has itself been refuted (McKeegan, K.D. *et al*. 2007. Raman and ion microscopic imagery of graphite inclusions in apatite from older than 3830 Ma Akilia supracrustal rocks, west Greenland. *Geology*, v, **35**, p. 591-594; DOI: 10.1130/G23465A.1). Not only have the UCLA team found graphite in the Akilia apatites, but also they have confirmed that it is depleted in $^{13}C$. The most likely means of selective fractionation of $^{12}C$ is widely agreed to be autotrophy; i.e. by some form of life.

Aficionados of an origin of life in the Solar System beyond the Earth, i.e. on Mars, leaped on the earlier refutation of graphite inclusions in the Akilia apatites. Putting off evidence for the earliest terrestrial life suits their case, which calls for living Martian organisms to be flung Earthwards after meteorite impacts, thereafter to get a grip on an otherwise lifeless but watery planet. It would be a puzzling view, were the vast sums of finance for Mars-related research to be ignored.