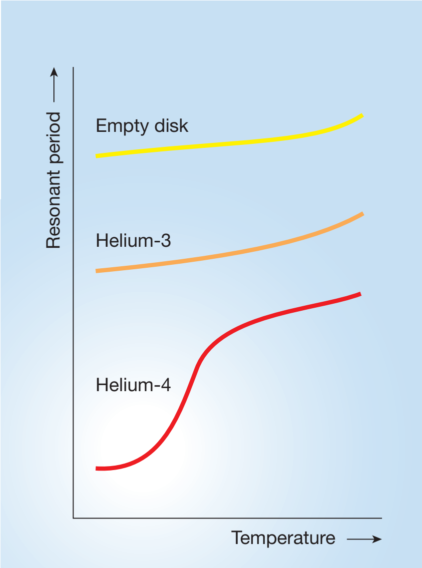

Figure 1 **Super solid. Kim and Chan[8] suspended a porous Vycor glass disk (15 mm in diameter and 4 mm thick) containing solid helium-4 in a torsional oscillator and monitored the disk's rotational inertia as the temperature decreased. Below about 175 mK they saw a sharp drop in the resonant period of oscillations, which is related to the disk's inertia. No such effect was seen for a Vycor disk empty of helium-4, or when the disk was filled with helium-3. Helium-4 was the first superfluid to be discovered; this might be the first evidence of supersolid behaviour.**

have checked their measurements carefully to ensure that the decoupling they observe is real. They have also done the critical comparison with solid helium-3, for which they expect — and see — no decoupling.

Given the nearly atomic dimensions of the Vycor pores, it is hard to imagine that anything other than a superfluid or supersolid could move through them without dissipation. What is less certain is the exact nature of the superflow that Kim and Chan have detected. Although their measurements were done at a pressure of 62 bar, well above the roughly 40 bar needed to solidify helium-4 in Vycor, it is possible that a disordered, liquid-like layer of helium could have remained near the pore walls. Even if such a layer is responsible for the superflow, its high density and the very small critical velocities observed by the authors imply that it must still be different from the superfluidity previously seen for thin films of liquid helium-4 in Vycor and other porous media.

The possible discovery of a new phase of matter, a supersolid, is exciting. The quantum-fluids and quantum-solids community can be expected to test the authors' claims thoroughly, particularly by searching for the persistent currents that are the 'gold standard' test of superfluidity. It will be fascinating to see how robust the phenomenon is; can it be seen in other porous media or even in bulk helium? There are enough questions to be answered about the nature and properties of supersolid helium to keep both experimentalists and theorists busy for a long time. ■

John Beamish is in the Department of Physics, University of Alberta, Edmonton, Alberta T6G 2J1, Canada.
e-mail: beamish@phys.ualberta.ca

1. Kapitza, P. *Nature* **141,** 74 (1938).
2. Allen, J. F. & Misener, A. D. *Nature* **141,** 75 (1938).
3. Osheroff, D. D., Richardson, R. C. & Lee, D. M. *Phys. Rev. Lett.* **28,** 885–888 (1972).
4. Anderson, M. H., Ensher, J. R., Matthews, M. R., Wieman, C. E. & Cornell, E. A. *Science* **269,** 198–201 (1995).
5. Fried, D. G. *et al. Phys. Rev. Lett.* **81,** 3811–3814 (1998).
6. Greiner, M., Regal, C. A. & Jin, D. S. *Nature* **426,** 537–540 (2003).
7. Jochim, S. *et al. Science* **302,** 2101–2103 (2003).
8. Kim, E. & Chan, M. H. W. *Nature* **427,** 225–227 (2004).
9. Andreev, A. F. & Lifshitz, I. M. *Sov. Phys. JETP* **29,** 1107–1113 (1969).
10. Chester, G. V. *Phys. Rev. A* **2,** 256–258 (1970).
11. Greiner, M., Mandel, O., Esslinger, T., Hansch, T. W. & Bloch, I. *Nature* **415,** 39–44 (2002).
12. Andronikashvili, E. L. *Zh. Eksp. Teor. Fiz.* **16,** 780 (1946).

Palaeontology

Lost children of the Cambrian

Graham E. Budd

The initial flowering of animal life on Earth occurred during the Cambrian, some 540–490 million years ago. Fossil embryos from that time can provide clues about the origins of the major animal groups.

When ancient fossil 'trilobite embryos' were reported[1] from China in 1994, the reaction was largely sceptical. After all, biologists had been lamenting (or crowing) for years that fossil embryos could never be found. This bright certainty became mottled with doubts, however, as increasingly convincing material began to appear[2], the oldest and most controversial being some 600 million years old[3].

These fossils raise several questions, to say the least. First, how could they possibly be preserved? Second, why are they concentrated in a period (600–500 million years ago) that is already unfairly overstocked with exceptionally preserved fossils, such as those of the Burgess Shale in the Canadian Rockies? Third, do they tell us anything about animal evolution?

The preservation of these fossils is slowly being recognized as the product of the unusual geochemistry of the transitional

NATURE

100 YEARS AGO

Dr. Nordenskjöld and the members of his South Polar Expedition arrived at Hamburg on January 6. The unexpectedly early return from the South Polar regions of this expedition has, the *Times* states, enabled Dr. Jean Charcot to recast the plans of the French expedition on board the *Français.* He now proposes to explore the west coast of Graham Land and to carry out a very exhaustive scientific investigation of that region... It is Dr. Charcot's definite intention to return at the end of the season of 1904–5. The *Français,* indeed, is only provisioned for two years, and Dr. Charcot states that if the expedition does not return in the early months of 1905, it must be concluded that they have been involuntarily detained, and a relief vessel must be dispatched to their assistance.
From *Nature* 14 January 1904.

50 YEARS AGO

On December 9, the P.E.N. (Poets, Playwrights, Editors, Essayists and Novelists) Club held an informal discussion on poetry and science… At first sight it might appear that these branches of culture had little to do with each other. But Prof. Dingle gave instances of the antagonism between poets and scientists, and pointed out that the overt attacks arising from this antagonism in the past were made by the poets. This, he said, is understandable; at that time it was thought that there was a real external world, the truth about which was being increasingly found out by the scientists. To poets, this world seemed flat and distasteful, but at the back of their minds the uncomfortable thought grew that any alternative was mere illusion. In Prof. Dingle's opinion, however, there is no need for the poet to harbour such resentment… In fact, science is the organized description of the relations between experiences; poetry, the expression of the experiences themselves. This description of the limits of science, abnegatory as it might seem, did not dispel the injured suspicion of the poets present. Stephen Spender… said that the psychologist may attribute the cause of conscience to infantile experiences; he himself might attribute it to God; what claim had science to the unique truth of the matter? Not only are the findings of science uncomfortable in detail; they are also so complicated that no one man can understand them, and increase of understanding brings with it disorientation and despair.
From *Nature* 16 January 1954.

Figure 1 **Adult representatives of the three living scalidophorans. Top, two specimens of the priapulid *Priapulus caudatus* (length about 10 cm). Bottom left, the loriciferan *Nanaloricus mysticus* (0.3 mm). Bottom right, the kinorhynch *Pycnophyes kielensis* (0.7 mm). The Cambrian embryo *Markuelia*, the subject of Dong and colleagues' analysis[5], seems to be more primitive than any of these very diverse worms. (Images of *Nanaloricus* by R. M. Kristensen, and of *Priapulus* and *Pycnophyes* by G. E. Budd.)**

time between the Cambrian period and the preceding Proterozoic era. But their evolutionary significance has largely been moot, partly because of the problems of relating the embryos to known groups of animals. All the convincing examples so far have been of apparently 'direct-developing' animals — animals that, unlike most living marine invertebrates, do not have a free-swimming planktonic stage. This apparent lack in the Cambrian suggested that direct development was the primitive state[4] and that indirect development was something that evolved later, in contradiction of many fashionable theories of animal evolution.

On page 237 of this issue, Dong *et al.*[5] present new material of a fossil — *Markuelia* — that was recognized as an embryo a few years ago[2], but in only enough detail to tantalize palaeontologists about its adult affiliations. The inevitable speculation about its adult form brought in members of various fossil groups[2,4], including those with a claim to being the last common ancestor of annelids, molluscs and brachiopods. Dong *et al.* reconstruct the embryonic *Markuelia* as an annulated worm, with a mouth at one end that is surrounded by a series of spines or scalids.

Their new data suggest comparison with a completely different group of animals whose time for world attention has at last arrived. These are the scalidophorans[6], a collection of three gloriously obscure marine worms: priapulids, loriciferans and kinorhynchs (Fig. 1). Molecules and morphology ally these worms with that model of model organisms, the nematode *Caenorhabditis elegans*, although all these living animals differ greatly one from the other. The reason why this motley assortment has suddenly become rather interesting is that molecular data place them and the nematodes, not as some sort of unremarkable scion of early animals, but as the closest relatives[7] to the most important group of all, the arthropods — which includes insects and crustaceans — whose species are numbered in their millions.

Basic embryological data are frustratingly patchy for the living scalidophorans, so the bizarre possibility of their embryology being described better from the fossil record than from the living forms cannot be ruled out — a true reversal of fortune. Dong *et al.*[5] analyse the relationships of the fossils by using cladistics, the methodology of choice for most serious systematists. They show that *Markuelia* does not fall into any of the living major groupings within the scalidophorans, but instead lies in their 'stem-group'[8]: that is, it is related to them all but is more primitive than any living form (Fig. 2).

Thus, Dong *et al.* claim (and convincingly) that *Markuelia* takes us back to a pattern of embryonic development more 'basal' than any of the living groups. Understanding this pattern could, for example, provide clues about whether the arthropods inherited major features such as segments, blood vascular systems and dorsal brains from a very deep ancestor of animals or evolved them anew. All these features are apparently missing from the living scalidophorans and nematodes. But did they never have them, or have they been lost? Here, *Markuelia* already offers one hint of potentially profound significance. The surface annulation of the worm penetrates into the body cavity in the form of septa. Is this a suggestion of segmentation arriving in — or leaving — these animals?

How do these evolutionary questions tie in to the preservational ones? Perhaps the reason why only direct developers are found in the Cambrian is that they tend to have a robust egg shell (or yolky eggs[2]), which unlike the delicate free-swimming forms could act as a template for early mineralization. If so, then the lack of Cambrian indirect developers is apparent rather than real. Further, *Markuelia* is now revealed to sit in the right taxonomic place to be a direct developer, just like all living scalidophorans and nematodes. As Dong *et al.* rightly stress, the palaeontological data here corroborate and extend that from living animals.

The miraculous preservation of these embryos comes with an annoying drawback: it seems to work only with very small fossils. As a result, the embryos known are largely orphans: we have little clue about their adult parents. Still, it is likely that no profound metamorphosis took place in *Markuelia*, and seasoned Cambrian-watchers will no doubt be searching for suitable candidate adults. Given the enormous size increase that takes place after hatching in living priapulids, it is likely that the adult *Markuelia* was quite big: even as an embryo it is larger than most living adult scalidophorans. In any case, the prospect of having complete life cycles described from the Cambrian[2] no longer looks fanciful; and with that, the prospect of making direct comparisons of ancient and living life cycles comes into view. It looks as though the study of 'evolution of development', which has hitherto relied greatly

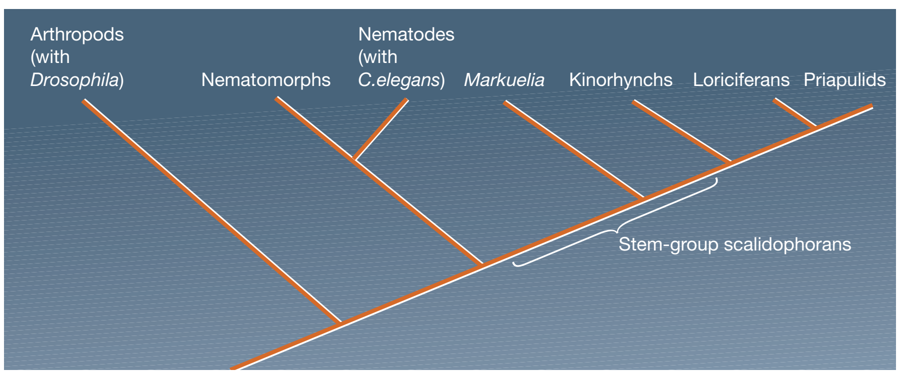

Figure 2 **The place of *Markuelia* in evolution, as inferred from the new work[5]. The positions of the two major model organisms, *C. elegans* and *Drosophila*, are also indicated. Nematomorphs are a group of parasitic worms closely related to the nematodes.**

on comparative gene expression data, is also going to have to start grappling with the message of the lost children of the Cambrian too. ■

Graham E. Budd is in the Department of Earth Sciences, Palaeobiology, Norbyvägen 22, University of Uppsala, Uppsala 752 36, Sweden.
e-mail: graham.budd@pal.uu.se

1. Zhang, X.-G. & Pratt, B. R. *Science* **266,** 637–639 (1994).
2. Bengtson, S. & Yue, Z. *Science* **277,** 1645–1648 (1997).
3. Xiao, S., Yang, Z. & Knoll, A. H. *Nature* **391,** 553–558 (1998).
4. Conway Morris, S. *BioEssays* **20,** 676–682 (1998).
5. Dong, X.-p., Donoghue, P. C. J., Cheng, H. & Liu, J.-b. *Nature* **427,** 237–240 (2004).
6. Nielsen, C. *Animal Evolution: Interrelationships of the Living Phyla* 2nd edn (Oxford Univ. Press, 2001).
7. Aguinaldo, A. M. A. *et al. Nature* **387,** 489–493 (1997).
8. Budd, G. *Nature* **412,** 487 (2001).

Earth science

Keeping score on the core

Erik Hauri

Getting to the bottom of events at the boundary between Earth's core and mantle is fiendishly difficult. The latest analysis invokes evidence from an isotope of tungsten to conclude that the two do not interact.

The report by Scherstén and colleagues (page 234 of this issue[1]) bears on one of the liveliest debates in Earth science — the extent to which Earth's core exchanges matter with the mantle. This topic has been addressed by many groups, and from a number of observational, experimental and theoretical directions[2]. In particular, however, many analyses have centred on the geochemistry of highly metallic elements in mantle rocks, with recent efforts focusing on volcanic hotspots such as Hawaii. Hotspots form above plumes of material, rising up through the mantle, that may (or may not) originate from the core–mantle boundary at the base of the mantle. Over the past few years, persuasive arguments in favour of core–mantle exchange have been made on the basis of osmium isotopes in hotspot lavas, especially the small anomalies in ^{186}Os that may have been derived from the decay of an isotope of platinum (^{190}Pt) in the Earth's outer core[3,4].

Scherstén *et al.*[1] take a new approach to the issue of core–mantle exchange, by looking for anomalies in the isotopes of tungsten (W) in mantle-derived lavas. Tungsten is a highly siderophile — 'iron-loving' — element thought to be present in large quantities in the Earth's core. Its parent isotope ^{182}Hf decays radioactively to ^{182}W with a geologically rapid half-life of about 9 million years. As a result, all of the ^{182}W derived from ^{182}Hf decay was formed within the first 60 million years of Earth's history at a time that encompasses the formation of the Earth's core[5–8]. Searching for anomalies in ^{182}W is thus a powerful approach to studying the flux of material from the core to the mantle, because all of the action in the hafnium–tungsten isotope system occurred in the first 60 million years of Earth's history. Subsequent processes (such as mantle convection, formation of the continental crust and plate subduction) serve only to mix the mantle and thus reduce any primordial differences in ^{182}W that may have existed between different parts of the mantle.

It is widely accepted that the Earth formed from chondritic (stony) meteorites, material in the early Solar System that accreted into increasingly large bodies. High-precision data on ^{182}W in chondritic meteorites[5,6] have shown that the Earth's mantle is comparatively enriched in ^{182}W (by 2 parts in 10,000, or $\epsilon W = +2$). This means that the Earth's iron core separated from the silicate mantle within the first 30 million years of accretion, while ^{182}Hf was still 'alive' and producing ^{182}W by radioactive decay. With most of the tungsten partitioned into the core and most of the hafnium remaining in the mantle, the Earth's core must be depleted in ^{182}W (though, obviously, this has not been directly measured), whereas the mantle is clearly enriched compared to chrondritic meteorites — the $\epsilon W = +2$ enrichment of the Earth's mantle in ^{182}W has been measured directly and independently by various groups[5,6].

Thus, variations in ^{182}W in mantle-derived rocks should faithfully record interaction between the core and mantle — if it takes place. The idea is that if small amounts of material from the Earth's core are added to the mantle, then such mantle should show depletions in ^{182}W (see Fig. 1a, overleaf, which depicts the preferred model of Scherstén *et al.*). Scherstén and colleagues' measurements appear to be of very high quality, and the homogeneity of these plume-related samples suggests that the modern mantle is homogeneous in tungsten isotopes. In particular, the tungsten measurements were

Astronomy

Star maker

FRANCESCO FERRARO (BOLOGNA OBSERV.)/ESA/NASA

Star formation can occur wherever interstellar gas becomes compressed and undergoes gravitational collapse. That compression might be caused by a supernova explosion, or the collision of galaxies. At last week's meeting of the American Astronomical Society in Atlanta, Georgia, Richard Rees and Kyle Cudworth presented the first evidence for star formation triggered by a new mechanism — a globular cluster of stars that punched through the disk of the Milky Way five million years ago.

The globular cluster NGC 6397 (pictured), 12 billion years old and containing a few hundred thousand stars, currently sits about 1,500 light years below the disk of the Milky Way. Its motion has been tracked by various telescopes since 1893, so Rees and Cudworth were able to extrapolate its path back, right through the plane of our Galaxy. And at the point at which the cluster crossed the disk five million years ago lies NGC 6231, a young cluster of stars estimated to have formed less than five million years ago.

The implication is that the passage of NGC 6397 through the Milky Way disk compressed the gas in that region and triggered the birth of NGC 6231 — a mechanism for star formation that was suggested in a little-noticed 1996 paper (J. F. Wallin *et al. Astrophys. J.* **459,** 555–557; 1996). There it was noted that a globular cluster passes through the disk of the Milky Way roughly every million years. So it seems that the star-making talent of globular clusters should be factored into our picture of the evolution of this, and other, galaxies. **Alison Wright**