Abstractions

SECOND AUTHOR

In 2008, scientists in Australia and the United Kingdom discovered embryos in fossilized placoderms — extinct, jawed fish covered in plates of bony armour. This confirmed placoderms as the earliest vertebrates known to be capable of live birth, and set in motion a re-examination of placoderm specimens in museums. A second look at one of these specimens has yielded a new first — a fossilized pelvic clasper, the male's copulatory structure (see page 888). Kate Trinajstic, a palaeontologist at Curtin University in Perth, Australia, tells *Nature* how the team's work sheds new light on prehistoric animal behaviour as well as biology.

How did the embryo's discovery affect your research?

Once we knew that live births were possible, we were eager to look for more evidence of embryos in placoderms. We also began to search for the reproductive organs necessary for internal fertilization.

How did you find the fossil clasper?

We first found it in 2001 and labelled it as the pelvic girdle. At that time, we didn't realize that live births were possible. Fortuitously, Per Ahlberg, an evolutionary biology at Uppsala University in Sweden, was working with me on a different project earlier this year and looked at this specimen with a new set of eyes. As soon as he got it under a high-power microscope, we both realized we had found the missing clasper.

What else has the new work revealed about placoderm reproductive behaviour?

When we re-examined our specimens, we realized that males of the Arthrodires (the largest group of placoderms) are rare in the collection from the Gogo Formation in Western Australia. Out of thirty fossils of these fishes, only two are males. This tells us that males and females lived separately and probably only came together at certain times of year to reproduce. So, as well as insight into reproductive strategies, we're also getting an idea of reproductive behaviour from fossils — which is a rare opportunity.

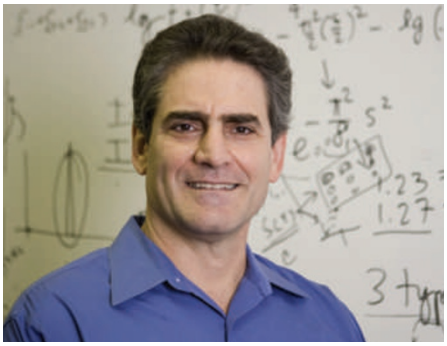
How much more of this story is there?

It's hard to say. We've got nearly 50 species of fish from the Gogo formation. Technological advances are key to how we interpret fossils. For example, we can use computed tomography to get cross-sectional images and confocal microscopy to create three-dimensional images and see a whole new level of detail in these specimens. I am often awestruck that we are able to peer through this window onto the past to make new discoveries. ■

MAKING THE PAPER

Salvatore Torquato

A theory for packing the classic three-dimensional solids.



The problem of packing solid objects as closely together as possible has long fascinated mathematicians. In 1611, German mathematician and astronomer Johannes Kepler proposed that the densest packing for spheres was in a lattice — as a grocer stacks a pyramid of oranges. Salvatore Torquato, a theoretical physicist at Princeton University in New Jersey, and his graduate student Yang Jiao now make an analogous conjecture for the packing of all but two of the classic Platonic and Archimedean solids as compactly as possible.

The five Platonic solids have identical faces of regular polygons: an example is the tetrahedron, with its four triangular faces and four rather sharp vertices. The thirteen Archimedean solids are polyhedra with two or more types of polygon as faces: an example is the cuboctahedron, with eight triangular faces and six square ones.

Torquato was initially interested in the properties of randomly packed spheres — such as grains of sand on a beach. But he soon moved on to tetrahedra. In 2006, he and Princeton mathematician John Conway constructed a packing, which was anything but orderly, of congruent tetrahedra in three-dimensional space with a density (the fraction of the total volume taken up by the solids) of 72% (J. H. Conway and S. Torquato *Proc. Natl Acad. Sci. USA* **103,** 10612–10617; 2006). "At the time, it was the world record for tetrahedra," Torquato says.

But the record was short-lived. Two years later, Elizabeth Chen at the University of Michigan, Ann Arbor, showed that it was possible to pack tetrahedra at 77.8% density. "We concocted these things in our minds using mathematical analysis. But Chen actually used physical models of tetrahedra, which is extremely useful because these are complicated objects," Torquato says.

So he decided to use computer simulation to test many more ways of packing tetrahedra. The result was a new record: 78.2%.

Once he had the computer program working, Torquato tested it on other polyhedra. "What we found was really surprising," he says. "We found that all of the other Platonics, which have central symmetry, like to pack in an ordered lattice arrangement as do spheres."

The theory held true for most Archimedean solids as well: those with central symmetry could be most densely packed in a lattice pattern. But the ones without central symmetry, such as the truncated tetrahedron — with 4 regular hexagonal faces, 4 regular triangular faces, 12 vertices and 18 edges — required a less orderly arrangement (see page 876).

"It became very clear that the central symmetry of the object really played a fundamental role in the arrangement that you need to get a dense packing," explains Torquato.

Having shown by empirical evidence and mathematical analysis that an ordered lattice is the densest packing for solids with central symmetry, Torquato says the conjecture now awaits mathematical proof.

Nearly 400 years elapsed between Kepler's conjecture and its mathematical proof. This one is more challenging, Torquato says, "because these objects have sharp corners. They're not as nice as spheres." Will it take 400 more years? Torquato laughs and says, "We're providing work for future generations." ■

FROM THE BLOGOSPHERE

Ice-core research springs to life in a multimedia post on the Climate Feedback blog of Nature Reports: Climate Change (http://tinyurl.com/l7now2). NRCC assistant editor Anna Barnett explains why ice-core records are unparalleled proxies for climatic history: "Their data stretch back 800,000 years and are conveniently located in some of the world's most climatically sensitive regions."

NRCC has published a timeline (http://tinyurl.com/me5rfq) covering the discoveries made through studies of deep polar ice cores, "from the first efforts to read ice records through to today's hunt for ice a million years old or more." A Google Earth interactive map lets viewers take a spin to the poles to take a virtual tour of the drilling sites.

The post also includes a video made by the American Museum of Natural History in New York on glaciologist Lonnie Thompson's work archiving ice from the world's melting tropical ice caps such as the Quelccaya glacier in Peru. The clip joins Thompson on his latest expedition to document the glacier's retreat and highlights the human side of climate research. ■

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