Embryo Fossils Reveal Animal Complexity 10 Million Years Before Cambrian Explosion

Fossilized embryos predating the Cambrian Explosion by 10 million years provide evidence that early animals had already begun to adopt some of the structures and processes seen in today's embryos, say researchers from Indiana University Bloomington and nine other institutions in this week's *Science*. James Hagadorn of Amherst College led the multi-disciplinary international collaborative project.

The researchers from the U.S., U.K., China, Sweden, Switzerland and Australia report the first direct evidence that primitive animals 550 million years ago were capable of asynchronous cell division during embryonic development. Asynchronous cell division allows the formation of unique shapes.

"We're learning something about how the very earliest multicellular animals formed embryos and how the embryos developed," said IU Bloomington biologist Rudolf Raff, a coauthor of the report. "This gives us an enormous and entirely surprising look at half-a-billion-year-old embryos in the act of cleaving. What a window on the past. We've had no prior idea what they might have done."

The researchers also believe they've identified specialized structures inside the cells, such as bubble-like vesicles that the cells might have used to transport, store or metabolize molecules. Slight aberrations during the fossilization of dead embryonic cells even reveal what appear to be dividing nuclei. It was assumed such structures existed in early animals, but until now, no known fossils of the structures existed.

The scientists procured 162 "relatively pristine" animal embryo fossils from the Doushantuo Formation of south central China. The embryos were still encased in a fertilization envelope, a protective husk that likely aided the preservation of the embryos long enough for fossilization to occur. To inspect the fossils' surfaces and even innards, the scientists used a bevy of imaging techniques, including X-ray computed tomography, scanning electron microscopy, transmission electron microscopy and thin-section petrography.

Even in larger embryo fossils estimated to contain 1,000 cells or more, the scientists did not observe a blastocoel, a fluid-filled gap in the middle of the embryo and a common feature among modern animal embryos. Raff said there are two likely explanations for the observation: "Either these embryos are primitive and don't have a clear blastocoel, or a blastocoel existed but didn't survive the preservation process."

In another study of embryos published by Raff, IUB Department of Biology Chair Elizabeth Raff and colleagues earlier this year, the scientists reported blastocoels were not always preserved under the kinds of preservation conditions that may have been involved in the formation of fossil embryos.

The Raffs and research associate F. Rudolf Turner provided electron micrographs of internal structures such as embryonic lipid vesicles in modern embryos that served as the key comparisons with structures observed in the fossil embryos, and were a source of expertise on the asynchronous cleavage of embryonic cells. Living embryos contain cell structures that form the basis for interpreting structures seen in fossils.

Biologists can provide critical information from living embryos to the studies of the fossils. Until only recently, many paleontologists doubted claims that fossilized embryos hundreds of millions of years old could exist. The Raffs and Philip Donoghue were lead co-authors of a paper in the April 11, 2006, Proceedings of the National Academy of Sciences demonstrating the feasibility of the fossilization of embryos. The present analysis of fossilized embryos in Science leaves even less room for doubt that such finds are real.

Fossilized embryos are very rare. Intact fossil embryos are even rarer. The Doushantuo Formation has proved a boon to paleontologists and evolutionary developmental biologists interested in the evolution of animal species during and prior to the Cambrian Explosion, a dramatic time period in which animals became bigger, more diverse, ecologically dominant and, in the late Stephen J. Gould's opinion, a lot more wonderful.

Other co-authors of the report are F. Rudolf Turner (IU Bloomington), Matthew McFeely (Amherst College), Kenneth Nealson (University of Southern California), Marco Stampanoni (Paul Scherrer Institut, Switzerland), Shuhai Xiao (Virginia Tech), Philip Donoghue, Neil Gostling and Maria Pawlowska (University of Bristol, England), and Stefan Bengtson (Swedish Museum of Natural History.

Citation: "Cellular and Subcellular Structure of Neoproterozoic Animal Embryos," *Science*, vol. 314, no. 5796

Source: Indiana University

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