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# Fossil Focus: Animal Embryos

by John Cunningham [*1]

## Introduction:

Animal embryos are small (typically less than 1 millimetre across), soft and squidgy, so it was traditionally considered impossible for them to be preserved in the fossil record. However, over the past 15 years or so a series of remarkable discoveries have shown that embryos can indeed be fossilized under exceptional circumstances. The microscopic fossils that have been identified as embryos are almost exclusively from the Ediacaran and Cambrian periods, around 635 million to 488 million years ago. This spans the period of time when the major groups of animals are thought to have first appeared, so these fossils allow palaeontologists to study the embryology of some of the earliest animals, shedding light on the evolution of development.

The first fossils to be recognized as embryos were poorly preserved cleavage embryos: early-stage embryos undergoing cell division. Their discovery showed palaeontologists that embryo fossilization was actually possible. As a result, researchers began to search for better-preserved examples. Embryos of three different genera, all preserved in calcium phosphate, have been reported in rocks of Cambrian age.

### Olivooides

***Olivooides*** belongs to the cnidarians, the group that includes jellyfish, corals and sea anemones. Its life cycle can be traced from cleavage embryos, through embryonic development and hatching, to conical adult polyps. The various developmental stages can be linked to the same life cycle with confidence. This is because they are found together in the same rocks, and all the post-cleavage stages possess a distinctive stellate (star-shaped) surface pattern and five-fold symmetry, which is rare in modern cnidarians. ***Olivooides*** might also have had a jellyfish-like medusa stage (that is, a free-swimming form), but at the moment there is no fossil evidence of this.

FIGURE 1 - COMPUTER RECONSTRUCTIONS OF AN OLIVOOIDES EMBRYO (LEFT), TWO HATCHED OLIVOOIDES STAGES (CENTRE) AND A PSEUDOOIDES EMBRYO SHOWING ONE END OF THE GERM BAND (RIGHT; THE GERM BAND IS IN THE CENTRE OF THE LOWER HALF OF THE SPECIMEN). IMAGES NOT TO THE SAME SCALE.

## Pseudooides

***Pseudooides*** is an enigmatic fossil embryo, which is to say that it is unclear what group it belongs to. It has a region called a germ band, where the body of the embryo develops. Living animals with an embryonic germ band include insects and spiders, and are divided into two groups: those with long germ-band development and those with short germ-band development. In long germ-band development, segmentation occurs simultaneously throughout the whole body, whereas in short germ-band development, segments are added sequentially, starting from the front of the animal. ***Pseudooides*** does not fit either of these patterns. The shape of the germ band suggests that segments were added at the centre. Because this pattern is unknown in living animals, the relationship of ***Pseudooides*** to modern groups remains controversial.

## Markuelia

***Markuelia*** is a worm-like animal that is known mainly from late embryonic stages. It is coiled into an S-shaped loop inside a spherical membrane called the chorion. When ***Markuelia*** was first discovered, palaeontologists suggested that it might be the embryo of an annelid worm, an arthropod or an extinct animal group called the halkieriids. An opportunity to test these hypotheses came with the discovery of better-preserved specimens, in which the features of the head – important diagnostic characters – were present. These fossils were analysed using synchrotron tomography, in which a particle accelerator (the synchrotron) is used to build up a three-dimensional image of internal features as small as 1 micrometre (0.001 mm) without destroying the fossil. These analyses showed that ***Markuelia*** belongs to a group called the scalidophorans, which includes the modern priapulids, or 'penis worms' and their relatives.

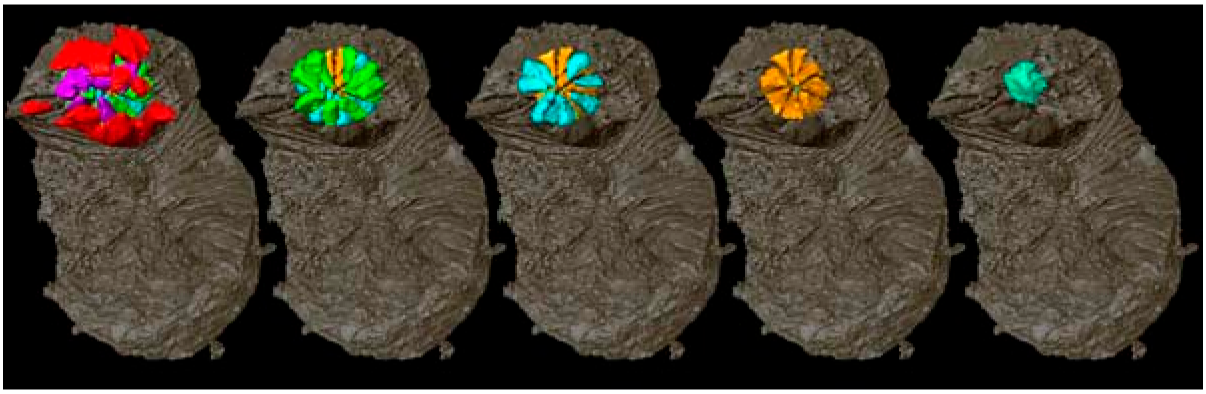

FIGURE 2 - COMPUTER RECONSTRUCTIONS OF MARKUELIA SHOWING A VIRTUAL DISSECTION OF THE SPINES AROUND THE MOUTH.

# Is there a bias in the embryo fossil record?

***Olivooides*** and ***Pseudooides*** are both found only in the rocks of the Lower Cambrian period (about 540 million to 510 million years ago). Apart from rare vertebrate embryos with hard parts, ***Markuelia*** is almost the only embryo fossil found in more recent rocks: it is known from the Cambrian of China, Australia and Siberia, and from the lowermost Ordovician of the USA. This suggests that the early fossil record of embryos is biased in terms of both the intervals of geological time represented and the types of organisms preserved. The time window in which embryos are found ends in the Early Ordovician (about 490 million to 470 million years ago). This is probably the result of two factors. First, levels of phosphate in the oceans were decreasing at the time, which would have made it more difficult to preserve organisms in phosphate-based minerals. Second, burrowing organisms were beginning to mix the ocean-floor sediment more than ever before. This meant that oxygenated water penetrated deep within the sediment, taking with it aerobic (oxygen-requiring) bacteria, which readily broke up, or decomposed, dead organisms. ***Markuelia*** may have persisted after the Early Cambrian, when no other embryos were fossilized, because it grew a cuticle (tough outer covering) earlier in development than did other animals living at the time, so it was more resistant to bacterial decay.

## Possible Precambrian embryos:

In addition to the Cambrian embryos described above, possible fossilized cleavage embryos have also been reported from the Doushantuo Formation in China, which dates from the Ediacaran period (about 635 million to 540 million years ago), the final period of the Precambrian. However, the interpretation of these fossils as animal embryos, and even as members of advanced animal groups, is highly controversial. Some scientists have suggested that the Doushantuo 'embryos' might in fact be bacteria. This is based on a close resemblance to a living giant bacterium called ***Thiomargarita***, which is known to undergo cell division. In support of this model, there are no fossils of what might be considered later developmental stages at Doushantuo.

FIGURE 3 - COMPUTER RECONSTRUCTIONS OF DOUSHANTUO FOSSILS. ON THE LEFT ARE FOUR EMBRYO-LIKE SPECIMENS, ON THE RIGHT IS A PEANUT-SHAPED FORM WITH TENS OF THOUSANDS OF CELLS. IMAGES NOT TO THE SAME SCALE.

Furthermore, ***Thiomargarita*** can mediate phosphate-mineral precipitation, which provides a potential mechanism for preservation that is not reliant on an external source of phosphate.

However, the model does have significant problems. For example, bacteria are prokaryotic organisms and thus do not possess cell nuclei, yet there have been reports of nuclei preserved in the cells of the Doushantuo fossils. The fossils are also sometimes found enclosed in ornate envelopes and highly ornamented cysts, both of which are unknown in living bacteria. Recently, researchers have described peanut-shaped fossils with hundreds of thousands of cells, which they have interpreted as a later germination stage in the life cycle of these organisms. Such germination structures are incompatible with the life cycles of both animals and bacteria. These findings indicate that the Doushantuo 'embryo' fossils are likely to be protists rather than animal embryos or bacteria. Future discoveries may shed further light on the identity of these enigmatic fossils.

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## Suggestions for further reading:

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