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# Fossil Focus: Cinctans

by Imran A. Rahman*[1]

## Introduction:

The fossil record of early animals — which dates back at least to the Cambrian period, more than 500 million years ago — is packed full of bizarre sea creatures that seem, at first glance, rather different from anything alive today. These include the armoured slug-like *Wiwaxia*, the spiny worm-like *Hallucigenia* and Earth's first big predator, *Anomalocaris*. Collectively, these fossils were termed "weird wonders" by the evolutionary biologist Stephen Jay Gould; they possess some, but not all, of the characteristics shared by their modern relatives, and so are crucial for understanding the early evolution of animal phyla.

This article focuses on a peculiar extinct group of Cambrian weird wonders called the cinctans, which look more like tennis racquets than any living animals! They are known exclusively from the middle part of the Cambrian, in rocks that are around 509 million to 497 million years old. Cinctans have a hard, mineralized skeleton made of calcium carbonate (calcite) with a distinctive porous microstructure called stereom. This clearly identifies them as members of the echinoderms, the major group that includes starfish and sea urchins. However, unlike starfish, sea urchins and all other living echinoderms, they do not have five-fold symmetry. In fact, apart from the skeleton, cinctans have no characters that unambiguously place them with echinoderms. As a result, important aspects of their palaeobiology are debated by scientists.

## Morphology:

Cinctan fossils range from a few millimetres to a few centimetres long. Like all echinoderms, they have a skeleton made of many interlocking calcite plates, which are organized into a flattened body (theca) and a stiff appendage (stele; Fig. 1). The theca is made of an outer ring of stout marginal plates (the cinctus) surrounding numerous small central plates (the upper and lower integuments). One narrow groove or an asymmetrical pair of such grooves (covered by many tiny plates) runs along the front of the theca, ending at a circular opening that is thought to be the mouth. Next to this, there is a large opening at the midline of the theca (called the porta), which is enclosed by a large spoon-shaped plate (the operculum). In at least some species, a pyramid of small plates pierces the upper surface of the theca. The stele is a short, rigid structure at the back of the cinctus.

Cinctan thecae come in many different shapes, from circular to oval and boot-shaped. Some are nearly symmetrical down the centre; others are completely asymmetrical (Fig. 2). There are other notable differences, including the number of plates in the cinctus and the stele, the size and position of protuberances on the marginal plates, and the relative length of the grooves along the front of the theca. All these features are important for recognizing cinctan species.

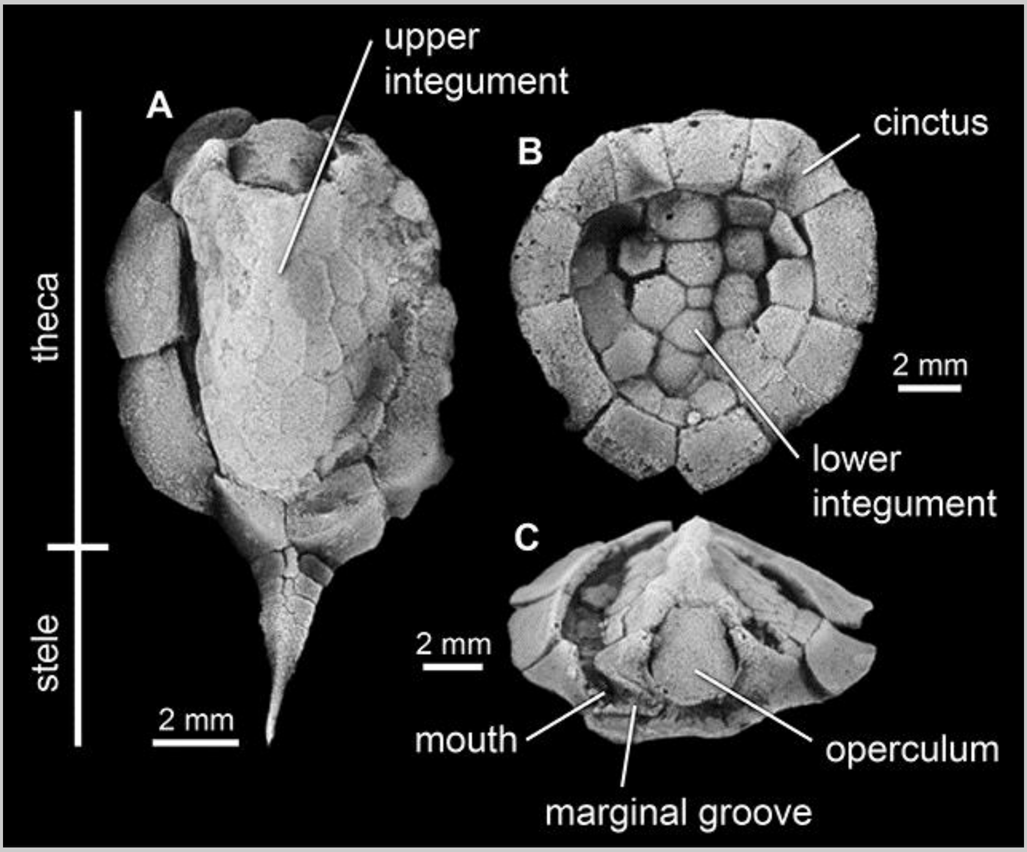


Figure 1 — The key characteristics of a typical cinctan. (A) Upper view. (B) Lower view. (C) Front view. Modified from Zamora & Álvaro (2014).

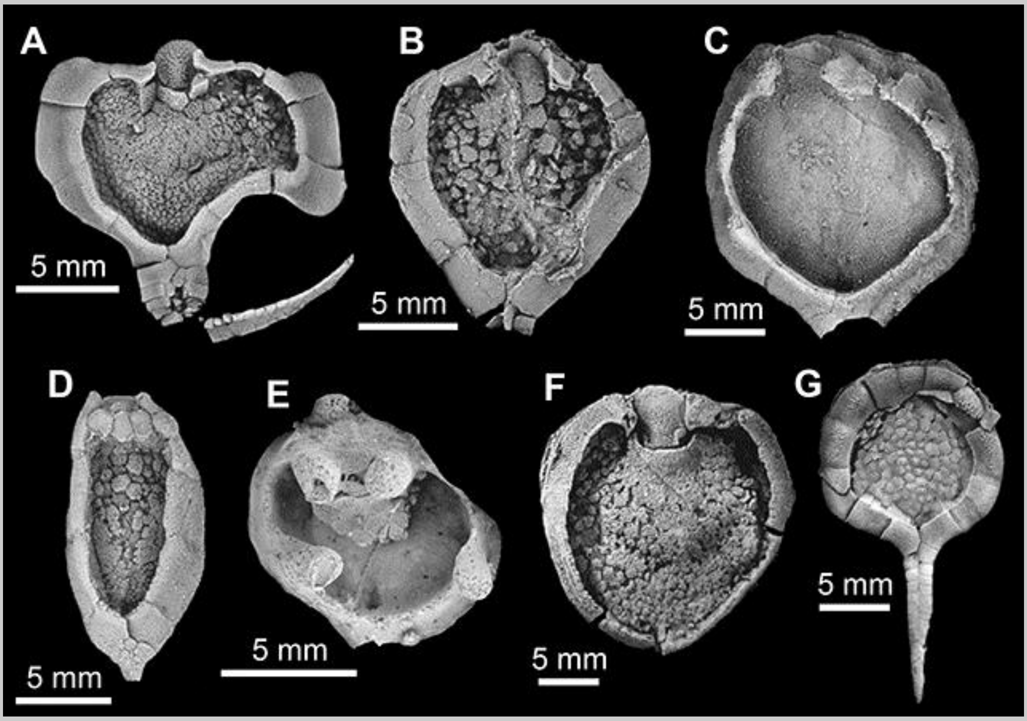


Figure 2 — Different cinctan species. (A) *Lignanicystis barriosensis*. (B) *Asturicystis jaekeli*. (C) *Sucocystis undata*. (D) *Gyrocystis badulesiensis*. (E) *Sucocystis quadricornuta*. (F) *Trochocystites bohemicus*. (G) *Trochocystites bohemicus*. Modified from Smith & Zamora (2009).

State-of-the-art imaging techniques have allowed palaeontologists to describe the morphology of select species in exceptional detail. For example, X-ray computed tomography (CT) scanning was used to study the Spanish cinctan *Protocinctus mansillaensis*, allowing researchers to create a computer model in which they could separate the fossil from the surrounding rock without having to destroy the fossil. The resulting 3D reconstruction revealed previously hidden aspects of the fossil's anatomy (Model 1). Such approaches are becoming increasingly common in palaeontological research.

Model 1 — 3D reconstruction of *Protocinctus mansillaensis*. Modified from Rahman & Zamora (2009).

## Phylogeny:

To date, around 16 genera and 26 species of cinctans have been formally described, with fossils recovered from parts of the Czech Republic, France, Germany, Morocco, Siberia, Spain and the United Kingdom. Determining how these groups are related to each other (their phylogenetic relationships) has proved especially challenging because cinctans do not share many characters with other echinoderm groups, so it was not clear how to define their most recent common ancestor (i.e. root the tree). However, a recent study that used several different rooting approaches found that they all produced similar results. Based on this agreement, we can be increasingly confident that we now have a fairly accurate picture of the relationships within this enigmatic group (Fig. 3), although the discovery of new fossils could change this.

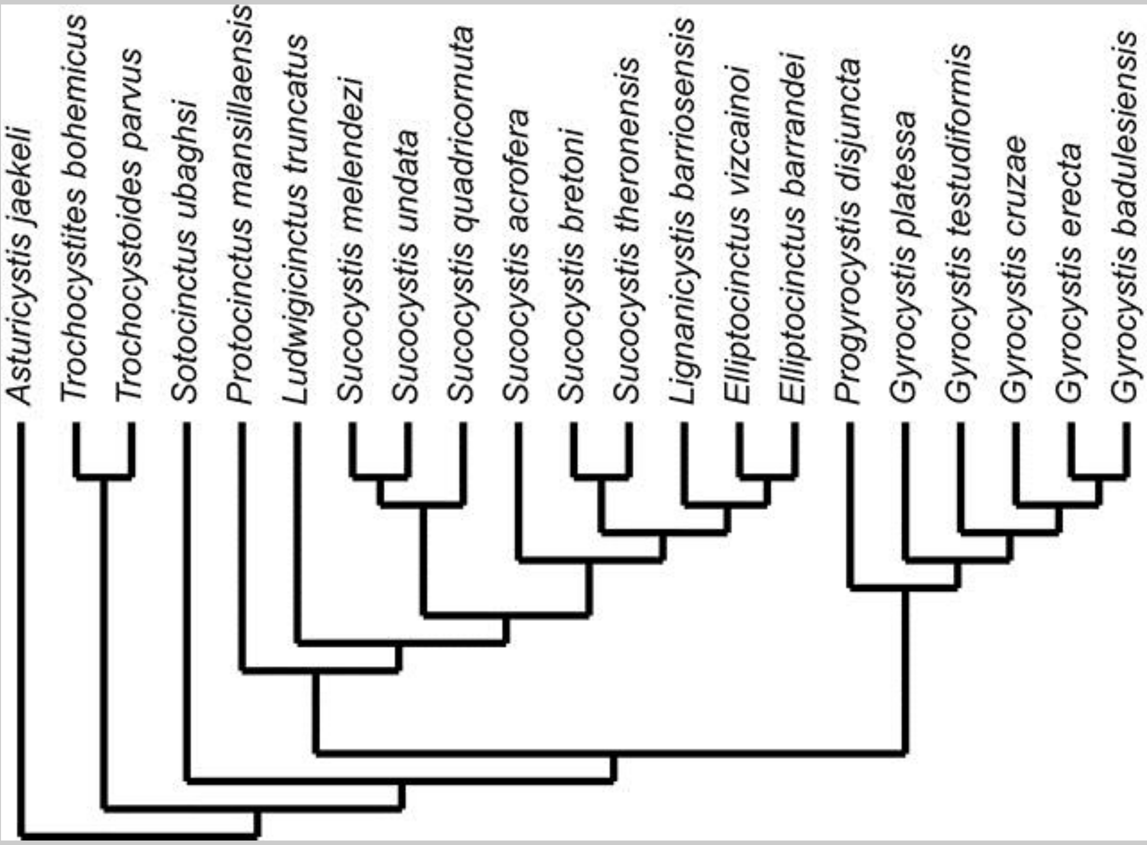


Figure 3 — Phylogenetic relationships of different cinctans. Modified from Smith & Zamora (2009).

## Mode of life:

Cinctans were restricted to marine environments and are thought to have lived on the sea floor. They were probably mostly sessile, meaning that they could not move about freely. The grooves at the front of the theca were probably involved in feeding, perhaps channelling food to the mouth. Parts of the stele and the theca were buried, and this presumably helped to keep the animal stable on the sediment surface. Figure 4 shows a reconstruction of this lifestyle.

Figure 4 — Reconstruction of *Protocinctus mansillaensis* in life position. Image credit: O. Sanisidro.

Other aspects of cinctan mode of life are less well understood, for example how they fed. One idea is that they were passive suspension feeders, relying on currents in the water to bring nutrients to the mouth and associated grooves. This mode of feeding is common among modern echinoderms. Alternatively, it has been suggested that cinctans were active suspension feeders that generated their own currents to drive water to the mouth. This strategy is not seen in other echinoderms, but is a feature of some modern acorn worms and sea squirts.

Computer simulations of water flow around a 3D model of a cinctan were used to test these hypotheses. The results demonstrated that there would have been almost no flow of water to the mouth if cinctans were passive suspension feeders. Simulations of active suspension feeding showed much greater flow to the mouth (Fig. 5), indicating that this would have been more effective for gathering nutrients. This suggests that cinctans fed by actively drawing water into their mouths, rather than passively waiting for food to come to them. The large opening adjacent to the mouth was probably used to eject waste water.

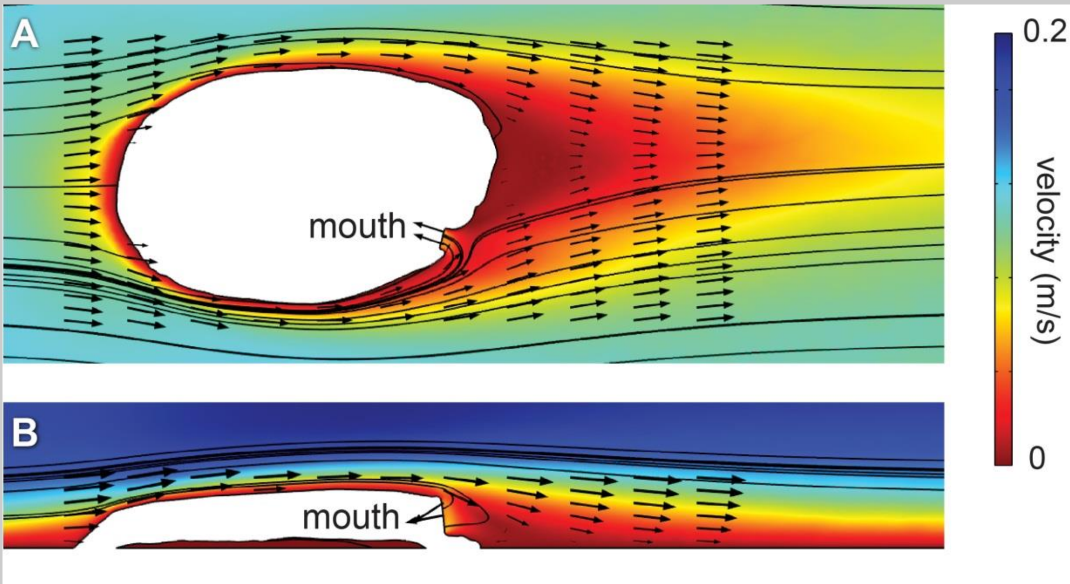


Figure 5 — Computer simulation of feeding in *Protocinctus mansillaensis*. Arrows and lines show the movement of water flow. (A) Top-down cross-section. (B) Side-on cross-section. Modified from Rahman *et al.* (2015).

## Evolutionary significance:

Because they lack certain characters of modern echinoderms, cinctans could be important for understanding the early evolution of the phylum. Unfortunately, there has long been disagreement over how they are related to other groups. Some researchers place cinctans close to the base of the echinoderm tree, in which case they might provide information on the order in which key characters of living echinoderms evolved. Others see cinctans as a relatively derived fossil group, which evolved from earlier echinoderms and has lost characters (such as five-fold symmetry) that are seen in most members of the group.

Distinguishing between these hypotheses is difficult because, as mentioned above, cinctans are very distinctive and it is not clear how to relate their characters to those of other groups. However, the recent discovery of a fossil echinoderm called *Ctenoimbricata*, which has near-perfect bilateral symmetry, has helped to resolve this. *Ctenoimbricata* shares features with the hypothetical ancestor of all echinoderms and so is an excellent candidate for the earliest known echinoderm. An analysis that used *Ctenoimbricata* as the outgroup put cinctans close to the base of the echinoderm evolutionary tree (Fig. 6). This indicates that echinoderms passed through bilateral and asymmetrical phases before they gained three-fold or five-fold radial symmetry.

## Summary:

Cinctans are a strange group of fossil echinoderms. They are very different to all living species, and this has made it difficult to reach a consensus on important details such as their mode of life and evolutionary relationships. Recent research has helped to clarify some of these details, and we now have a much more complete picture of the palaeobiology and evolution of cinctans. Future work, including the discovery of new species, will hopefully fill in the remaining blanks.

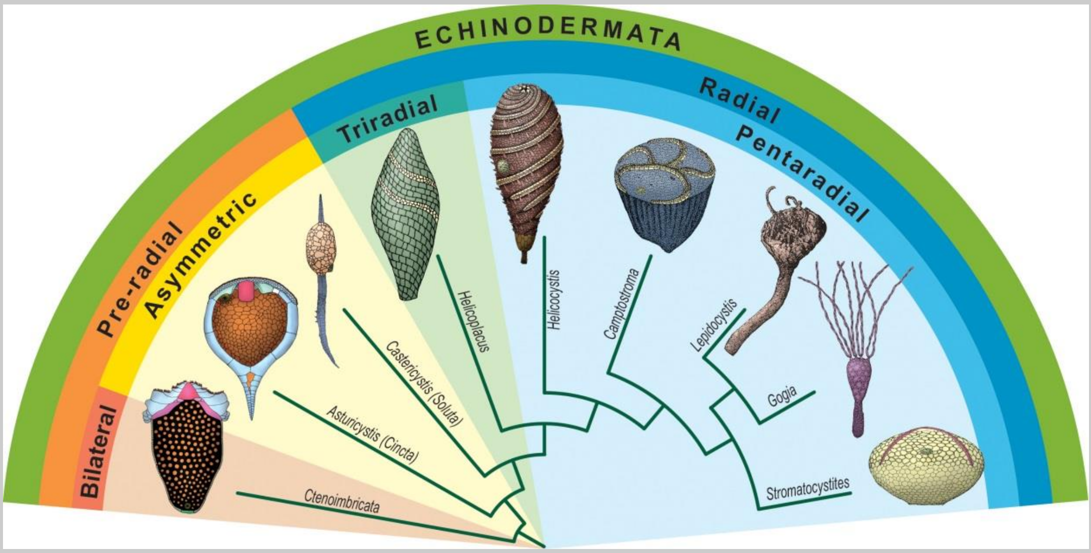


Figure 6 — Phylogenetic relationships of early echinoderms. Taken from Zamora & Rahman (2014).

## Suggestions for further reading:

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