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# Fossil Focus: Paracrinoids

by Maggie R. Limbeck*[1]

## Introduction:

The oceans of the Palaeozoic era (541 million to 252 million years ago) were full of animals that we are familiar with, such as fish, snails, and coral, but also included many organisms that look almost nothing like their living relatives. The further back in time we go, for instance to the Cambrian and Ordovician periods (541 million to 444 million years ago), the greater the difference in body plans, or morphologies, compared to modern species. Echinoderms are an excellent example of this — living members of the group, such as starfish and sea urchins, are easily recognizable, but many of their extinct, fossilized relatives from hundreds of millions of years ago look very different. Understanding these different body forms is important to palaeontologists because it helps us to learn about the history and complexity of life on Earth. A comprehensive study of these animals and where they are found can give us information on their evolutionary relationships, interactions with other organisms and responses to environmental changes in the past.

Paracrinoids are some of the most bizarre echinoderms ever to have existed. Palaeontologists have described them as 'Frankenstein creatures' because they combine features found in other echinoderm groups to create unusual and seemingly contradictory body shapes (Fig. 1). Paracrinoids were a short-lived group, known only from the Middle to Late Ordovician (470 million to 444 million years ago; for comparison, many other now-extinct fossil groups were present for more than 50 million or even 100 million years). Part of what makes this group so unusual is that for the short time paracrinoids were around, they showed an incredible diversity of body shapes. This raises a number of questions about their evolutionary history and how they lived and interacted with other organisms (their palaeoecology).

## Shape:

In addition to having unusual shapes, paracrinoid bodies are not well organized. This is very different from other echinoderms, such as blastoids and echinoids, which have an ordered body plan (that is, the number and position of the plates on the body are constant in each species). All paracrinoids have three 'basal' plates, to which a stem attached in life, and multiple 'oral' plates that surround the mouth (Fig. 1), but the rest of the plates that make up the body are added in a seemingly unpredictable way. It is possible to detect some patterns if you look at the fossils for long enough, but it is generally thought that as the organism grew, plates were added as needed, so their placement and size varies.

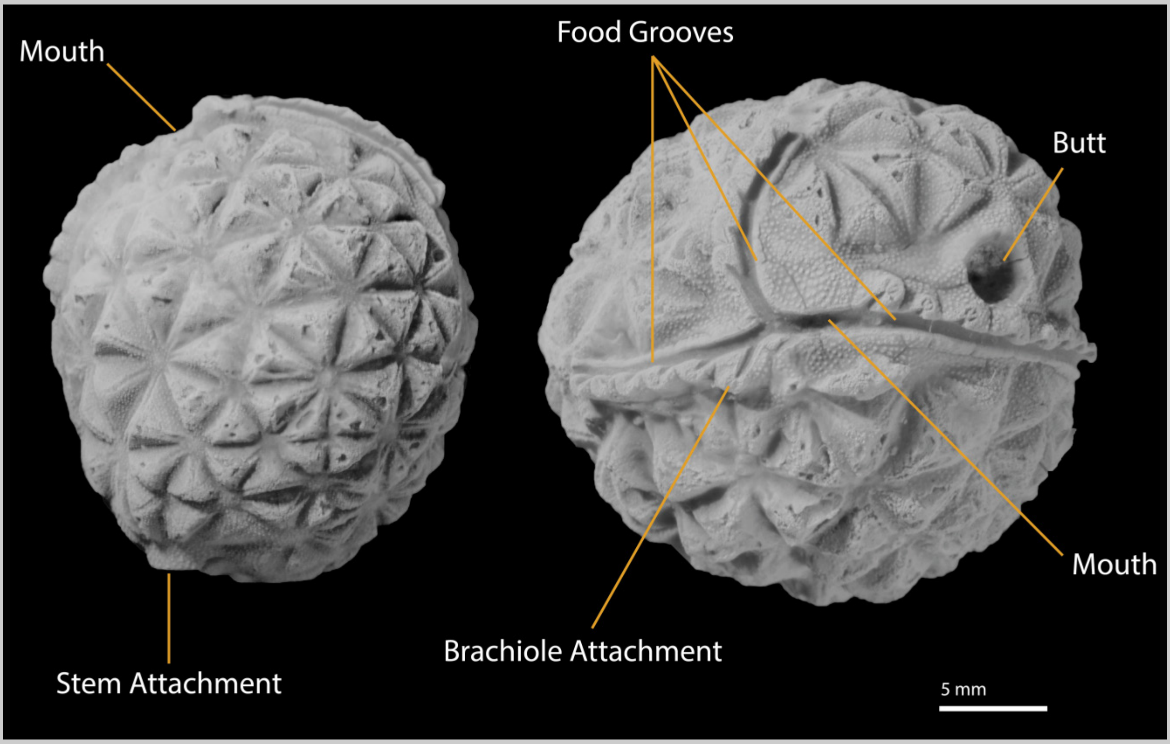


Figure 1 — Key paracrinoid features labelled on *Oklahomacystis tribrachiatus*. Credit: M. Limbeck.

Although the shapes and sizes of paracrinoids can seem completely random (Fig. 2), their overall variation gives researchers much to consider when attempting to work out how different paracrinoids were related to each other. Questions could include: how many food grooves (used for transporting food; Fig. 2A) are there around the mouth? How many mouths does the organisms have (Fig. 2B)? Are there structures for breathing (respiratory structures; Fig. 2C)? Are the plates ornamented (Fig. 2D)? This list of questions could continue for quite some time! The real challenge for understanding these different shapes is in trying to work out whether the features we are looking at are homologous (inherited from a common ancestor). If they are, they can be used to reconstruct an evolutionary tree, in a process called phylogenetic analysis. A common example of similar features that are not homologous are wings, which are present in both birds and insects, but evolved independently; this is called a convergent feature. If we treated these features as homologous, our phylogenetic analysis would have to assume that birds and insects share a more recent common ancestor than they actually do, producing an inaccurate picture of their evolutionary history.

Understanding which features are homologous in paracrinoids is very difficult. Each subgroup has very few features that are shared among all paracrinoids, so researchers must take great care when assessing these characters. However, even if features are not homologous, they can still be informative: their presence in different species could mean that these features help organisms to live in a certain environment, explaining why they evolved independently multiple times.

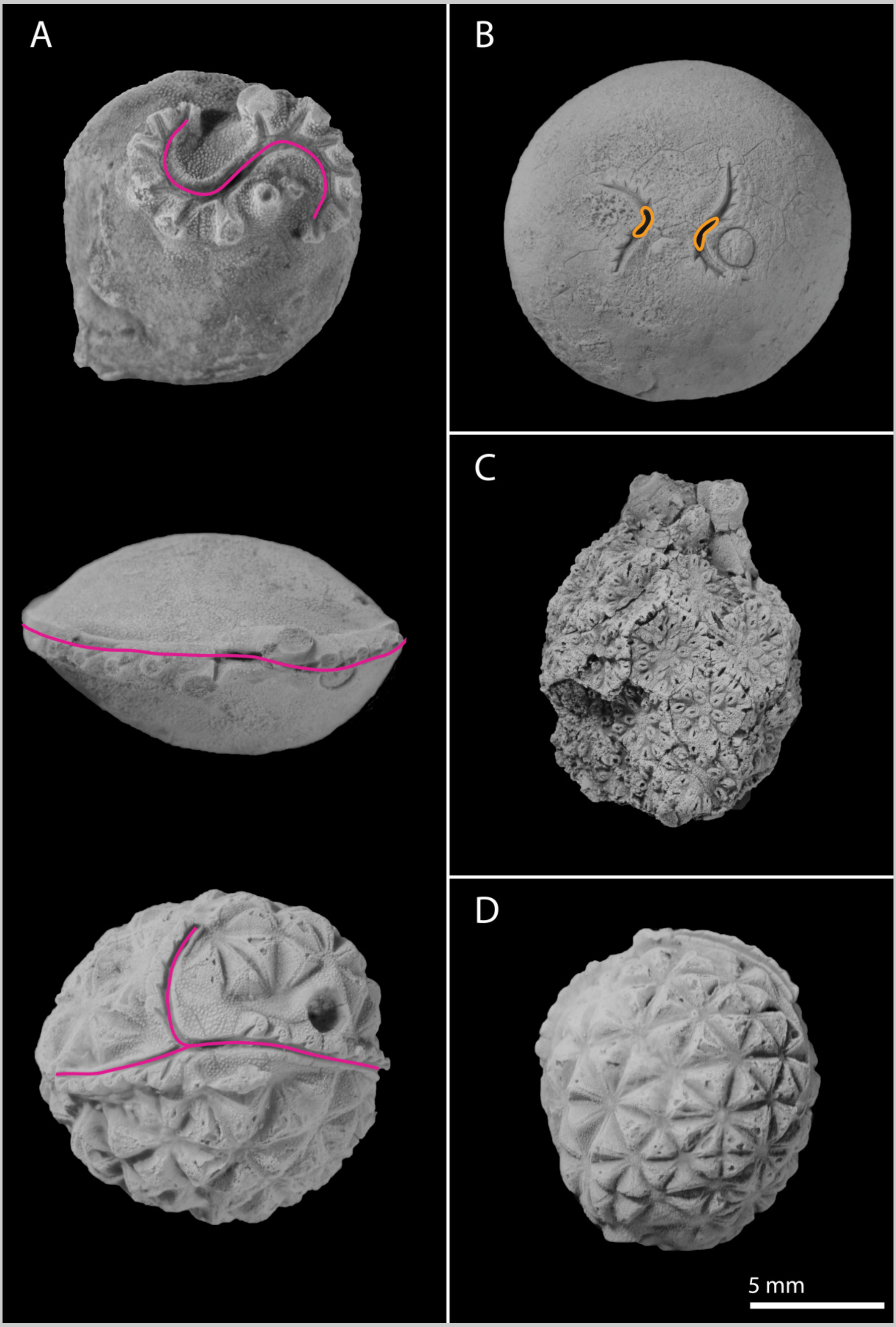


Figure 2 — Unusual morphologies found in paracrinoids. (A) Differences in the shape and number of food grooves (outlined in pink): top, *Canadocystis tennesseensis*; middle, *Globulocystites cristatus*; bottom, *Oklahomacystis tribrachiatus*. (B) Two species of paracrinoid have two mouths (outlined in orange), whereas all other species have only one mouth. Pictured: *Bistomiacystis globosa*. (C) Some paracrinoids have respiratory structures. Pictured: *Implicatycystis symmetricus*, in which the respiratory structures are holes on the plates that make up the body. (D) Other paracrinoids have distinct plate ornamentation. Pictured: *Oklahomacystis tribrachiatus*, which has 3D triangles on body plates that give the appearance of flowers. Credit: M. Limbeck.

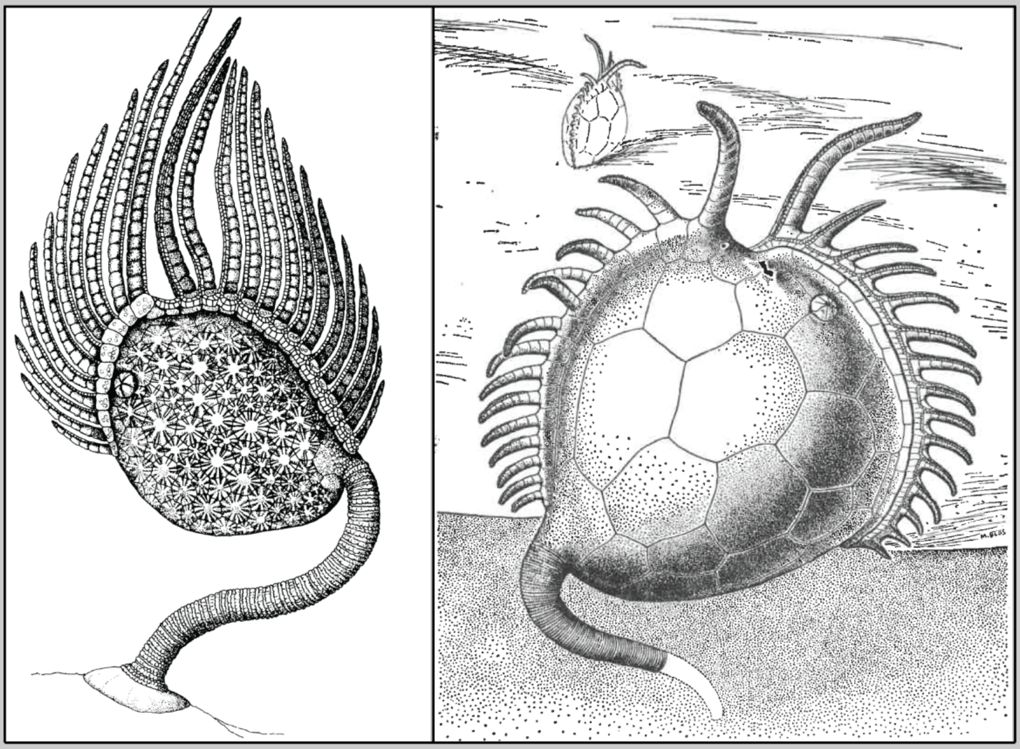

Figure 3 — Comparison of how two different paracrinoids are inferred to have lived. Left: *Amygdalocystites florealis* had a stem that raised the body of the animal off the sea floor. Modified from Guensburg (1991). Right: *Platycystites* had a small, short stem that was buried in the sediment. Modified from Parsley and Mintz (1975). Both images show the brachioles (arm-like structures) that aided feeding.

## Mode of life:

As adults, paracrinoids were sessile, meaning that they did not move around. Some species had long stems that attached to the sea floor, whereas others are thought to have had a short stem that anchored the paracrinoid into the sea floor (Fig. 3). One of the main challenges for understanding the mode of life of fossil echinoderms is that after an echinoderm dies, its skeleton breaks apart rapidly. This is problematic because individual echinoderms can be made up of anywhere from tens to millions of different pieces! Paracrinoids are no different. Typically, only the main body is found fossilized (Fig. 2), because the stem and brachioles (arm-like structures seen in Fig. 3) are the easiest to break apart and so are lost readily after death.

Very little is known about how paracrinoids lived in their environments or how their different shapes could have benefitted them. One of the questions that I and others are interested in is: how did these animals function in life? Paracrinoid bodies are asymmetrical, with the mouth and the stem both on the left side of the body (Fig. 4). By contrast, most other fossil echinoderms (and living crinoids, a type of echinoderm also known as a 'sea lily') have their moth and stem aligned with the central axis of the body. Paracrinoids are also unusual in that their feeing appendages only grew from the left side of the food grooves (Fig. 1), as opposed to most other fossil echinoderms whose feeding appendages grew along both sides of the food grooves. The general body shape of paracrinoids is extremely varied and can range from almost perfect spheres to flattened ovals and even crescent-moon shapes. The function of these varied body shapes and how they many have been beneficial in the Ordovician seas is still unclear.

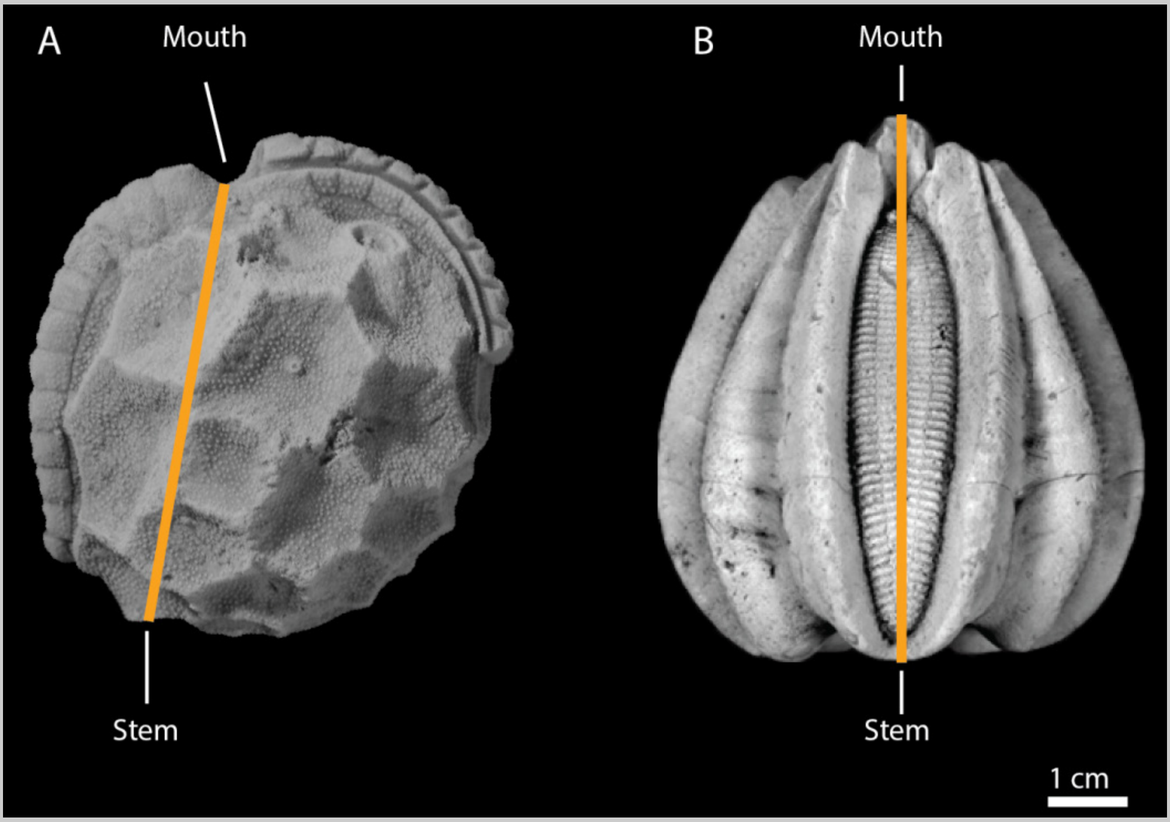


Figure 4 — Comparison of main body axes between a paracrinoid and a blastoid. A: The paracrinoid *Sinclairocystis praedicta*, with offset axis connecting the mouth to the stem, giving the body a distinct asymmetry. Credit: M. Limbeck. B: The blastoid *Deltoblastus*, with a perfectly straight axis connecting the mouth to the stem. Credit: W. Atwood.

To learn more about paracrinoid lifestyles, we must keep studying their anatomy. This can be achieved by examining fossils, or by using modern techniques to simulate on a computer how their varied body shapes responded to different conditions.

## Phylogeny:

The evolutionary relationships of early echinoderms are important for researchers trying to assemble the echinoderm tree of life and understand how this diverse and successful group of animals evolved. To assess these relationships, researchers study features such as the number of oral plates, the shape and placement of the food grooves, and they types of respiratory structures to determine if they are homologous. Until recently, our poor understanding of paracrinoid features prevented researcher from completing a phylogenetic analysis of this puzzling group.

Previous studies had separated paracrinoids into two groups. However, a recent phylogenetic analysis indicates that there are actually four subgroups within Paracrinoidea (Fig. 5). These subgroups are largely defined by whether or not the paracrinoid has respiratory structures, and by what shape the food grooves are. This is different from previous studies, which suggested that only one feature defined the division of Paracrinoidea into two subgroups: either the presence or absence of respiratory structures or the shape of the food grooves, but not both.

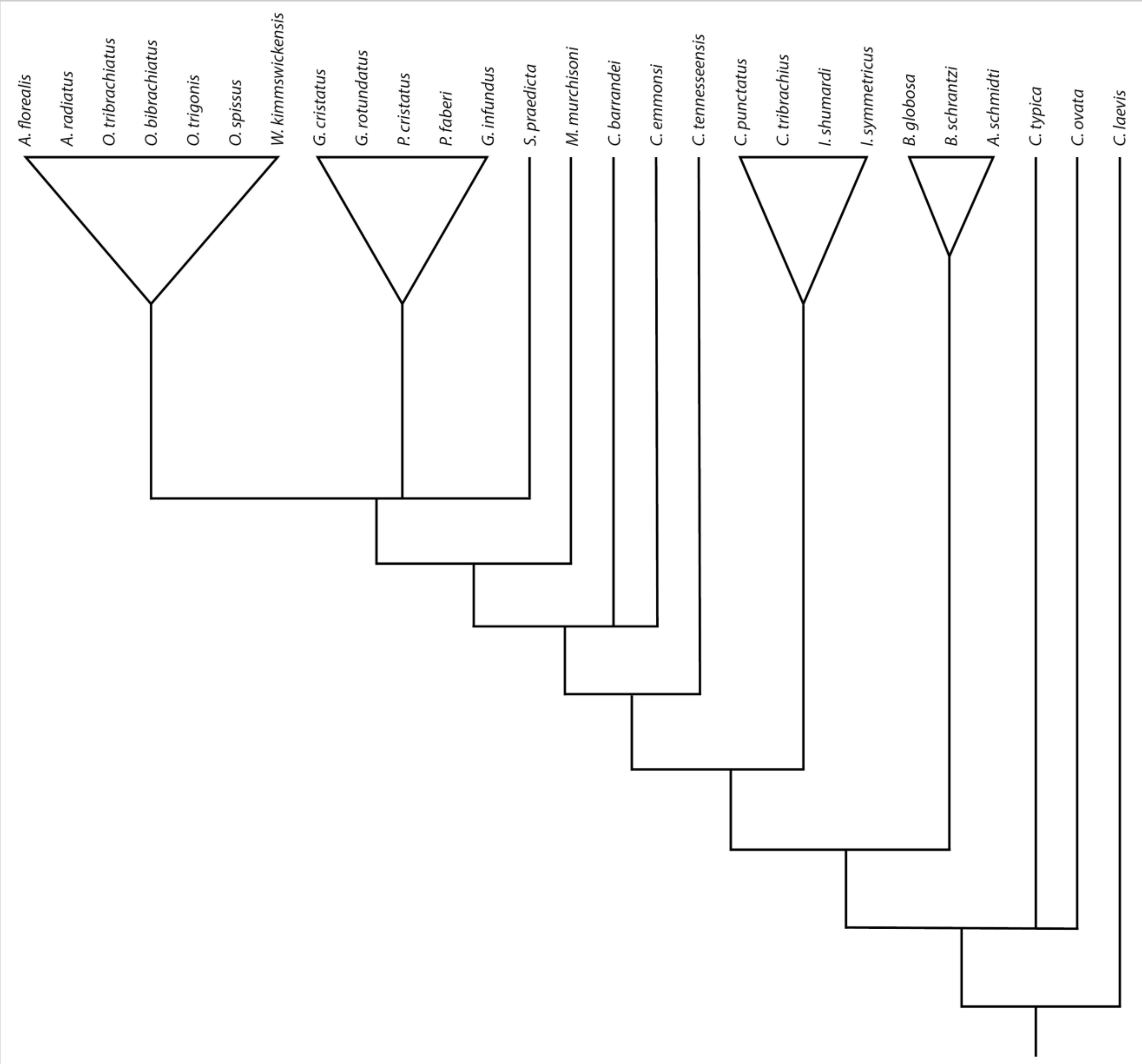


Figure 5 — Simplified evolutionary relationships of paracrinoids. Species grouped by triangles form small subgroups in the larger grouping Paracrinoidea. Others that are not in these distinct groups require further study to fully understand their relationships to these existing groups. Modified from Limbeck *et al.* (in preparation).

## Evolutionary significance:

Paracrinoids are an especially interesting group of echinoderms because of their unusual morphologies that evolved in a relatively short amount of time. By contrast, blastoids, a Palaeozoic echinoderm group that lived for about 200 million years, had plenty of time for dramatic environmental changes, changing community interactions, and the evolution of new features. Many species of different groups (echinoderms and other animals) look very similar in the same time period, but as time goes on, changes in body shape happen, and over a period of hundreds of millions of years, those animals look very different from when they first appeared. Paracrinoids are unusual because they lived for such a short time period, but had a diversity in body plans that researchers would expect to see of a group that had been around for a longer amount of time. Some paracrinoids do have features that we can recognize from other echinoderms, and knowledge of these other groups can improve our understanding of paracrinoids. To learn more about paracrinoid features, then, researchers must undertake large-scale phylogenetic analyses with multiple echinoderm groups, including paracrinoids.

## Summary:

Paracrinoids, echinoderms that thrived for a fairly short period of time hundreds of millions of years ago, had highly unusual body shapes compared with other fossil echinoderms from the same time. This has often hindered our understanding of these organisms, but advances in our knowledge of echinoderm features and phylogenetic methods have allowed researchers to begin to examine relationships in this group. Future work aims to digitally reconstruct selected paracrinoid species to begin to learn how these animals lived. These reconstructions, along with the evolutionary analyses discussed here, will be used to investigate rates of evolutionary change and functional morphology, shedding light on the palaeobiology of this puzzling fossil group.

## Suggestions for further reading:

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