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When was the first time life began to prey on each other?

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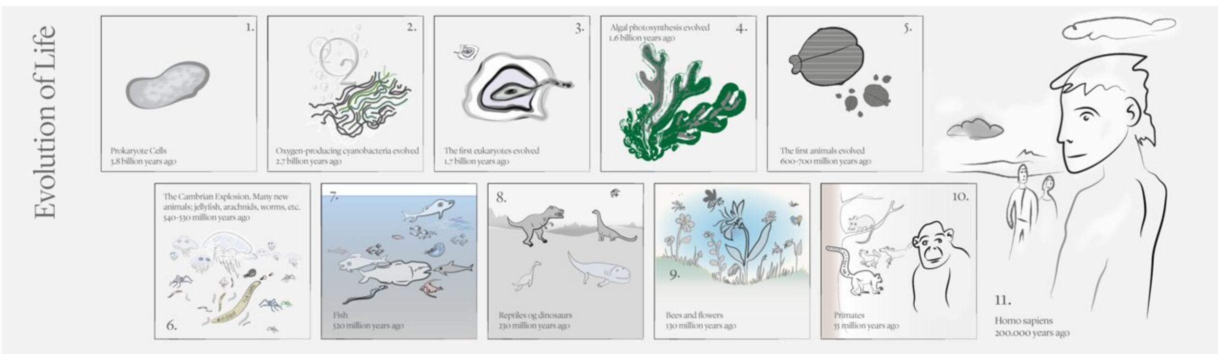

Credit: Mikkel Larris, University of Southern Denmark

Using the word predation may seem surprising when we talk about the first organisms that set out to eat other organisms, for they were not deadly predators with sharp teeth and claws, but small single-celled life forms that swam around in the primordial sea. They had neither a mouth nor a gut system; all they had was a cell membrane so soft that they could engulf another, smaller organism, that they encountered on their way.

Thus, the prey was not eaten in the way we usually think about; instead it was rather encapsulated—but nevertheless, it provided its predator with nutrients and energy. After this happened there was no going back to a world without predators. But when did it happen?

First primitive life

The question occupies Professor in ecology at Department of Biology, University of Southern Denmark, Donald E. Canfield, who has spent much of his career studying how life evolved on Earth. He is interested in which biological, chemical and geological conditions allowed life to rise on Earth.

"That question is inextricably linked to the question of when and how the evolution of life changed the ecosystems of the oceans," he said.

Canfield adds that an answer will not only satisfy our curiosity about our primordial origin:

"It is also about understanding how chemistry and biology interact to control modern marine ecosystems so that we can better predict how the oceans will react to man-made activities and global climate change."

Let's start in the peaceful primordial sea, where organisms had not yet begun to feed on each other. The dominant life forms were the primitive prokaryotes. They got this name because they have no cell nucleus (pro means before, and karyot is a derivation of the Greek word for nucleus; karyon).

Then, a new player entered the field. The eukaryotes. Unlike the prokaryotes, eukaryotes have a nucleus and organelles with specialized functions. Their name is created from the two Greek words for genuine (eu) and karyon (core). The eukaryotes changed everything:

"They could feed on other organisms. And when you introduce eating of other organisms into an ecosystem, it radically changes the dynamics of the system," said Don Canfield.

The eukaryotes today include the life forms that we call advanced: plants and animals (including humans), but back then, in the primeval sea, they were still single-celled organisms.

"But they had this trick; they could engulf organisms that were smaller than themselves. The prey attaches to the cell of the eukaryote after which a small sac forms around the prey cell. In this way the single-celled eukaryote predator absorbs its prey," Canfield said.

"They could gain more energy by this process, and what happens when you get more energy? You can grow in size, and that's what happened to the eukaryotes."

So, when did eukaryotes start to feed on other organisms and what were the consequences for marine ecosystems? These are some big questions in understanding the history of life on Earth.

Large 1.7 billion year old fossils

Some clues come from fossils; tangible proof that some form of life actually existed, but what form of life do ancient eukaryote fossils represent?

"In truth, it is very difficult to unravel what type of lifestyle an ancient eukaryote fossil represents, but one thing we can be sure about is their size, and beginning about 1700 million years ago, ancient eukaryotes fossils were large. Well, maybe not large compared to what you might consider large, but at 100 to 400 microns in size (a human hair is about 70 microns thick), they are big by the standards of single-celled organisms. Consider that most prokaryotes in the ocean are less than 1 micron in size," said Don Canfield.

Still, the size of these fossils can tell us something about the nature of the ancient ecosystems where these organisms lived.

Not a friendly ocean

Using an ecosystem model (developed by Ken Andersen from the Danish Technological University), SDU marine biologist Lisa Eckford-Soper, together with Don Canfield, Trine Frisbæk Hansen and Ken Andersen, found that an ecosystem containing large organisms as found in the fossil record must also have contained eukaryote predators.

Even more, modeling suggests that eukaryotes were likely abundant in the ancient ecosystems where the large eukaryotes are found. So, a combination of new biomarker work (see below) and modeling shows that active eukaryote ecosystems containing algae, but also predators, populated the oceans as far back as 1700 million years ago.

"This is a billion years earlier than previously thought," said Lisa K. Eckford-Soper. "A billion years where marine organisms could feed on each other and therefore, the oceans were not as friendly as we previously imagined."

How the researchers found the hidden clues in rock

Sedimentary rocks often contain remains of dead marine organisms. If you have an old rock and use the right techniques, you can even extract some of the ancient organic material.

This organic material in old rocks has revealed chemical traces of eukaryotic organisms in samples up to 780 million years old—but not older than that. Therefore, it is reasonable to conclude that eukaryotes became dominant in marine ecosystems by 780 million years ago. But what about before this time? What if the organic material in rocks loses its resolution over time and doesn't tell the whole story?

According to Professor Donald Canfield, it is possible that the organic matter record is not revealing the real importance of eukaryote marine ecosystems before 780 million years ago.

What you typically look for in old rocks to reveal the presence of eukaryotes are sterane biomarkers, where steranes are chemical remnants of ancient eukaryote organisms. These steranes are typically extracted from the rocks along with other organic molecules using chemical solvents. These extracts are called bitumen.

This technique has revealed eukaryotes in rocks up to a maximum of 780 million years ago. The organic matter not removed by organic solvents and left in the rocks is known as kerogen. The kerogen may contain important information as to the nature of organisms in the ancient environment where the sediments first deposited, but they are more difficult to access.

Nevertheless, Donald Canfield and his colleagues from Petrochina in Beijing analyzed some 1.4-billion-year-old sedimentary rocks from the Xiamaling Formation in China , focusing on the kerogen. To do this they dissolved all the rock with acid, so that in the end only organic material remained.

After extracting with organic solvent, and revealing no steranes, the remaining kerogen was transferred to a gold tube which was heated, breaking down the kerogen into components that could then be further removed in organic solvents. These extracts revealed steranes from algae that were not found in the bitumen extracts indicating that eukaryotic algae were part of the ancient marine ecosystem 1.4 billion years ago.

The findings are published in the journal *Proceedings of the National*

Academy of Sciences.

More information: Lisa K. Eckford-Soper et al, A case for an active eukaryotic marine biosphere during the Proterozoic era, *Proceedings of the National Academy of Sciences* (2022). DOI: 10.1073/pnas.2122042119

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