Modern microbes provide window into ancient ocean

January 6 2021

An image of Cyanobacteria, Tolypothrix. Credit: Wikipedia / CC BY-SA 3.0

Step into your new, microscopic time machine. Scientists at the University of Colorado Boulder have discovered that a type of single-celled organism living in modern-day oceans may have a lot in common with life forms that existed billions of years ago—and that fundamentally transformed the planet.

The new research, which will appear Jan. 6 in the journal *Science Advances*, is the latest to probe the lives of what may be nature's hardest working microbes: cyanobacteria.

These single-celled, photosynthetic organisms, also known as "blue-green algae," can be found in almost any large body of water today. But more than 2 billion years ago, they took on an extra important role in the history of life on Earth: During a period known as the "Great Oxygenation Event," ancient cyanobacteria produced a sudden, and dramatic, surge in oxygen gas.

"We see this total shift in the chemistry of the oceans and the atmosphere, which changed the evolution of life, as well," said study lead author Sarah Hurley, a postdoctoral research associate in the departments of Geological Sciences and Biochemistry. "Today, all higher animals need oxygen to survive."

To date, scientists still don't know what these foundational microbes might have looked like, where they lived or what triggered their transformation of the globe.

But Hurley and her colleagues think they might have gotten closer to an answer by drawing on studies of naturally-occurring and genetically-engineered cyanobacteria. The team reports that these ancient microbes may have floated freely in an open ocean and resembled a modern form of life called beta-cyanobacteria.

Studying them, the researchers said, offers a window into a time when single-celled organisms ruled the Earth.

"This research gave us the unique opportunity to form and test hypotheses of what the ancient Earth might have looked like, and what these ancient organisms could have been," said co-author Jeffrey

Cameron, an assistant professor of biochemistry.

Take a breath

You can still make the case that cyanobacteria rule the planet. Hurley noted that these organisms currently produce about a quarter of the oxygen that comes from the world's oceans.

One secret to their success may lie in carboxysomes—or tiny, protein-lined compartments that float inside all living cyanobacteria. These pockets are critical to the lives of these organisms, allowing them to concentrate molecules of carbon dioxide within their cells.

"Being able to concentrate carbon allows cyanobacteria to live at what are, in the context of Earth's history, really low carbon dioxide concentrations," Hurley said.

Before the Great Oxidation Event, it was a different story. Carbon dioxide levels in the atmosphere may have been as much as 100 times what they are today, and oxygen was almost nonexistent. For that reason, many scientists long assumed that ancient microorganisms didn't need carboxysomes for concentrating carbon dioxide.

"Cyanobacteria have persisted in some form over two billion years of Earth's history," she said. "They could have been really different than today's cyanobacteria."

To find out how similar they were, the researchers cultured jars filled with bright-green cyanobacteria under conditions resembling those on Earth 2 billion years ago.

Hurley explained that different types of cyanobacteria prefer to digest different forms, or "isotopes," of carbon atoms. As a result, when they grow, die and decompose, the organisms leave behind varying chemical signatures in ancient sedimentary rocks.

"We think that cyanobacteria were around billions of years ago," she said. "Now, we can get at what they were doing and where they were living at that time because we have a record of their metabolism."

Resurrecting zombie microbes

In particular, the team studied two different types of cyanobacteria. They included beta-cyanobacteria, which are common in the oceans today. But the researchers also added a new twist to the study. They attempted to bring an ancient cyanobacterium back from the dead. Hurley and her colleagues used genetic engineering to design a special type of microorganism that didn't have any carboxysomes. Think of it like a zombie cyanobacterium.

"We had the ability to do what was essentially a physiological resurrection in the lab," said Boswell Wing, a study coauthor and associate professor of geological sciences.

But when the researchers studied the metabolism of their cultures, they found something surprising: Their zombie cyanobacterium didn't seem to produce a chemical signature that aligned with the carbon isotope signatures that scientists had previously seen in the rock record. In fact, the best fit for those ancient signals were likely beta-cyanobacteria—still very much alive today.

The team, in other words, appears to have stumbled on a living fossil that was hiding in plain sight. And, they said, it's clear that cyanobacteria living around the time of the Great Oxygenation Event did have a structure akin to a carboxysome. This structure may have helped cells to protect themselves from growing concentrations of oxygen in the air.

"That modern organisms could resemble these ancient cyanobacteria—that was really counterintuitive," Wing said.

Scientists, they note, now have a much better idea of what ancient cyanobacteria looked like and where they lived. And that means that they can begin running experiments to dig deeper into what life was like in the 2 billion-year-old ocean.

"Here is hard evidence from the geological record and a model organism that can shed new light on life on ancient Earth," Cameron said.

More information: "Carbon isotope evidence for the global physiology of Proterozoic cyanobacteria" *Science Advances* (2021). advances.sciencemag.org/lookup … .1126/sciadv.abc8998

Provided by University of Colorado at Boulder