Yellowstone microbes fueled by hydrogen

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Microbes living in the brilliantly colored hot springs of Yellowstone National Park use primarily hydrogen for fuel, a discovery University of Colorado at Boulder researchers say bodes well for life in extreme environments on other planets and could add to understanding of bacteria inside the human body.

A team of CU-Boulder biologists led by Professor Norman Pace, one of the world's leading experts on molecular evolution and microbiology, published their report "Hydrogen and bioenergetics in the Yellowstone geothermal system" this week in the online edition of the Proceedings of the National Academy of Sciences.

The team's findings, based on several years of research at the park, refute the popular idea that sulfur is the main source of energy for tiny organisms living in thermal features.

"It was a surprise to find hydrogen was the main energy source for microbes in the hot springs," Pace said. "This project is also interesting in the context of microbiology because it's one of the few times we've been able to study microbes to get information on an entire ecosystem. That's never before been possible."

The study was specifically designed to determine the main source of metabolic energy that drives microbial communities in park features with temperatures above 158 degrees Fahrenheit. Photosynthesis is not known to occur above that temperature.

A combination of three different clues led researchers to conclude that hydrogen was the main source of energy. Genetic analysis of the varieties of microbes living in the hot springs communities revealed that they all prefer hydrogen as an energy source. They also observed ubiquitous H2 in all the hot springs at concentrations sufficient for microbial bioenergetics.

Thermodynamic models based on field data confirmed that hydrogen metabolism was the most likely fuel source in these environments.

"This work presents some interesting associated questions," said John Spear, lead author of the report. "Hydrogen is the most abundant element in the universe. If there is life elsewhere, it could be that hydrogen is its fuel," Spear said. "We've seen evidence of water on Mars, and we know that on Earth, hydrogen can be produced biogenetically by photosynthesis and fermentation or non-biogenetically by water reacting with iron-bearing rock. It's possible that non-biogenic processes produce hydrogen on Mars and that some microbial life form could be using that," he said.

There are many examples of bacteria living in extreme environments -- including the human body -- using hydrogen as fuel, according to Spear. "Recent studies have shown that Helicobacter pylori bacteria, which cause ulcers, live on hydrogen inside the stomach," said Spear. "Salmonella metabolizes hydrogen in the gut. It makes me wonder how many different kinds of microbes out there are metabolizing hydrogen in extreme environments."

Instead of relying on traditional techniques of microbiology that utilize cultures grown in the lab, the CU-Boulder team used methodology developed by Pace to genetically analyze the composition of the microbial community as it appeared in the field. "We didn't look at what grows in a culture dish, we looked at the RNA of samples directly from the field," Spear said.

"We've never before known what microbes were living in Yellowstone hot springs, and now we do," Pace said.

A novel suite of instruments was used to gather data, some of which had never before been collected. "No one had measured the concentration of hydrogen in the hot springs before because the technology didn't exist until about seven years ago. Now we can detect very low-level concentrations of hydrogen in water," Spear explained.

"We found lots of hydrogen in the hot springs -- an endless supply for bacteria," he said. Measurements of the amount of H2 in water were recorded in Yellowstone hot springs, streams and geothermal vents in different parts of the park and during different seasons. All of the environments had concentrations appropriate for energy metabolism.

The team used computer-generated thermodynamic models to find out if hydrogen was indeed the principle source of energy. "You can smell sulfide in the air at Yellowstone, and the accepted idea was that sulfur was the energy source for life in the hot springs," Spear said. Not so, according to the team's computer models built on field measurements of hydrogen, sulfide, dissolved oxygen concentration and other factors.

Spear said it was difficult to explore a microbial ecosystem. "We have a hard enough time explaining what's going on in a forest, for example, with all the interlacing systems. We can't even see a microbial system."

Sample extraction was a dangerous and delicate operation. In order to accurately analyze a hot spring's entire microbial community, Spear needed to collect only about as much material as a pencil eraser. Sediment samples were scooped into special sample vials and immediately frozen in liquid nitrogen canisters to preserve the microbial community.

In springs where there was no sediment, Spear collected samples of planktonic organisms by hanging a glass slide in the water and allowing the microbes to accumulate. "Bacteria are just like us. They like to be together, they like to be attached to a surface and they like to have their food - dissolved hydrogen, in this case -- brought to them."

Spear explained that the hot springs' colors are the result of interactions between minerals and the microbes living in the pools. Hotter water usually shows colors from minerals, and cooler water plays host to photosynthetic pigments.

"Based on what I've seen in this analysis, I think hydrogen probably drives a lot of life in a lot of environments," Spear said. "It's part speculation, but given the number and kinds of bacteria that are metabolizing hydrogen, it's probably a very old form of metabolism.

That's important because it tells us about the history of life on Earth," he said. "And if it works this way on Earth, it's likely to happen elsewhere. When you look up at the stars, there is a lot of hydrogen in the universe."

Source: University of Colorado at Boulder

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