Researchers make major photosynthesis discovery

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CARBONDALE, Ill. -- Of all the processes on earth, photosynthesis is perhaps the most important to sustaining life. This means by which organisms convert sunlight into energy is a well-understood system. Scientists know what goes in, what goes on and what comes out. But two researchers at Southern Illinois University Carbondale were part of a team that recently proved science still has a lot to learn about this critical, ubiquitous process. Their discovery was startling enough that the leading journal Science has published the findings this month.

Michael T. Madigan, a professor and distinguished scholar in the Department of Microbiology at SIUC, along with SIUC doctoral student Marie Asao, worked on a multi-disciplinary team examining a microorganism found in an alkaline lake in California. The team also included aquatic microbiologists from the University of Georgia and geochemists from the U.S. Geological Survey.

The study involved a type of bacteria found in Mono Lake that appeared to use a different substance to achieve photosynthesis. Within a year, Madigan and Asao showed that what the USGS had discovered was actually an ancient form of photosynthesis, yet one not previously discovered.

The USGS called Madigan because of his more than 30 years of studying organisms that live in extreme environments, such as the Antarctic or in hot springs. Mono Lake contains several hot springs and has a high pH level.

“Last summer, the USGS scientists had found this hot spring that contained a microbial mat, which is a thin structure containing various bacteria. These bacteria appeared to be photosynthetic,” Madigan said.

More than that, however, the bacteria appeared to be onto something new in the photosynthesis area.

To carry out photosynthesis, an organism must “fix” carbon dioxide -- that is, take it in and mix it with something else. In green plants, this additional substance is water. Plants split the water molecules, take some electrons and mix them with the carbon dioxide to make cell material. Chemically, this process is called a reduction.

Water, in this instance, is known as a “donor” because it donates electrons during the reduction. But considering how widespread photosynthesis is on earth, the list of such known electron donors is almost comically small. Green plants use water only, producing oxygen as a byproduct, while photosynthetic bacteria, which cannot split water, use a few reduced sulfur compounds or reduced iron.

Madigan’s team, however, was able to expand this list, proving that these bacteria from Mono Lake were actually using a form of arsenic as an electron donor to achieve photosynthesis. The finding will have a great impact on further research, as it opens an entirely new vein for exploring photosynthesis.

“The significance comes when you look at how widespread arsenic is in nature,” Madigan said. “It’s present in a lot of ground water and a lot of other things, so it could be driving photosynthesis that we’ve never been aware of until this discovery.

“Arsenic isn’t as common as water, which green plants use as an electron donor, but our findings reveal a much greater diversity in photosynthesis, which is the most important

process on earth. We're all dependent on it for life," he said.
The USGS team had suspected this to be the case and had conducted some simple field experiments on site that appeared to confirm their hypothesis. Madigan and Asao set out to prove it.
"When you do field studies like this they're not absolutely controlled and unequivocal experiments because you don't know everything that's in there," Madigan said.
Back in Madigan's laboratory at SIUC, Asao isolated the organism by growing a culture from one single cell. They then subjected the culture to a series of tests, injecting substances such as hydrogen sulfide (a common electron donor for photosynthetic bacteria) and arsenite, a form of arsenic, and exposing it to light.
"We demonstrated the organism could grow in culture with just carbon dioxide and arsenite, which proved the process seen back at the lake," Madigan said.
They also conducted molecular characterization of the organism's genes, which gave them a strong idea about its family tree. They could tell, for instance, the organism was related to a genus of bacteria already known to exist in such alkaline environments.
"Where it got its ability to use arsenite for photosynthesis, we don't know," Madigan said.
Proving the theory was one thing. Getting published in Science, considered by many researchers to be the top scientific journal in the world, was another. They submitted the paper in April and found a receptive audience. Peer review followed, and the journal published the paper Aug. 14.
"We thought it was a significant discovery, but you never know when you submit it to Science," Madigan said. "We thought it was important because it added to that very short list of electron donors and really opens up new possibilities for photosynthesis and expands its diversity, and I think that's what caught Science's eye."
While the discovery is new to researchers, it certainly isn't a "new" process. To the contrary, Madigan said there is evidence in the geologic record that points to this type of anaerobic photosynthesis existing billions of years before oxygen existed on earth. Finding the Mono Lake organism was sort of like discovering a living dinosaur -- at the microbiological level.
"Photosynthesis was invented by bacteria and only picked up by green plants and algae later on, where it was expanded and made more complex," Madigan said. "This is an ancient form of photosynthesis. There are still little habitats on earth where these organisms can survive and we kind of stumbled into one."
Madigan has spent much of his career studying photosynthetic bacteria, and much of what scientists know about green plant photosynthesis they learned by studying the simpler processes involved with such organisms. This discovery will have a lasting impact, Madigan said.
"It expands our knowledge of the diversity of photosynthesis and the kinds of organisms and types of processes that can be driven by light energy," he said.

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