

BIOCHEMISTRY

High-Tech Lures Hook Into New Marine Microbes

Two groups of researchers have identified large populations of bacteria that convert sunlight hitting the sea surface into energy

Two scientific teams have found an entirely unexpected phenomenon: new kinds of ocean bacteria that convert light to energy. What's more, combined, these two previously undetected microbial groups may account for a whopping 20% of bacterial life on the ocean surface, says Edward DeLong, a marine microbiologist at the Monterey Bay Aquarium Research Institute in Moss Landing, California, and head of one of the teams who report their findings this week in *Science* (p. 1902) and *Nature*. The other team was led by biological oceanographer Paul Falkowski of Rutgers University in New Brunswick, New Jersey. "These two papers are going to have a major impact on the way oceanographers think about the ecology of the ocean surface," comments Stephen Giovannoni, a microbiologist at Oregon State University in Corvallis.

These two groups of bacteria, which harness light to move electrons and power cellular processes, likely help bring energy into the food chain. And that could help to explain a puzzle that has confounded researchers trying to understand marine ecosystems: how so many bacteria can survive in the open ocean, where there seems to be relatively little for them to eat.

The bacteria DeLong discovered have light-harnessing abilities previously known to exist in a fungus and in nonbacterial microbes called archaea that hang out in the most hostile salty environments, such as salt ponds, where sustenance is scarce. They are equipped with a protein, known as bacteriorhodopsin, that enables them to thrive by harnessing light to generate ATP—the source of energy needed to power cellular processes. The bacteria Falkowski found use a type of bacterial chlorophyll that, until now, no one had found in bacteria in the open ocean.

DeLong and Falkowski both discovered their bacteria somewhat serendipitously, using novel and distinct techniques for tracking down new species. Traditionally, biologists have assessed microbial diversity by growing environmental samples in the laboratory. But researchers have come to realize that the technique misses many organisms that don't survive long enough to be count-

ed, so they are trying new approaches. "DeLong went fishing using a molecular biology tool; we went fishing with a biophysical technique," notes Falkowski.

DeLong's group collects DNA directly from seawater samples, without first isolating the individual organisms. In one 130-kilobase DNA fragment they fished out this way, the team found a gene that encoded the small ribosomal subunit RNA belonging to a group of marine bacteria called SAR86, discovered by Giovannoni about a decade ago. No one had ever been able to grow the bacteria in the lab, so it was known only by this one ribosomal gene.

But the DeLong team had that gene and more in their fragment. When they compared the rest of the sequence—which included some 120 genes—to other genes on file in the public archives, most looked unexceptional for this type of bacterium. But one stood out: a gene for bacteriorhodopsin, a rhodopsin protein that, contrary to what the name implies, had never before been found in bacteria. "It's a mechanism of photosynthesis that's totally unknown in bacteria," says Norman Pace, a microbial biologist at the University of Colorado, Boulder.

DeLong's team dubbed this new protein proteorhodopsin and tested its function by putting it into *Escherichia coli*. As they hoped, the modified bacteria not only made the protein, but they reacted to light by moving protons out of the cell and into the surrounding medium. That's characteristic of bacteriorhodopsin, whose proton-pumping activity helps set up a gradient whereby energy is generated by protons flowing back into the cell. "It's a really strong finding," says Kenneth Nealson, a

microbiologist at the California Institute of Technology in Pasadena. "And I don't think you could have ever discovered this without genomics."

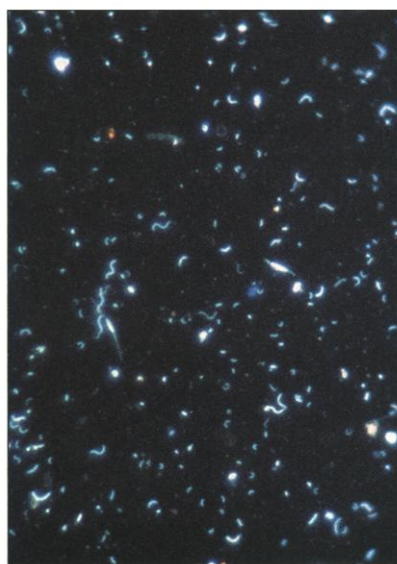
Falkowski's team, in contrast, was not after genes. They were searching for new types of photosynthesizing organisms that might use dim infrared light emitted from deep-sea vents. For almost a decade, researchers had postulated that such microbes might exist in those extreme environments, "but there was no solid proof," says Falkowski. So he and his Rutgers colleague Zbigniew Kolber built a fluorometer designed to detect any changes in the electromagnetic radiation that would be caused by microbes using light energy to move electrons.

They found no organisms by the deep-sea vents. But, to their surprise, when they scanned surface waters they picked up many positive signals in samples taken along a 1000-km line in the eastern tropical Pacific and later off the coast of New Jersey. Because only bacterial—as opposed to plant—chlorophyll makes use of light at the wavelengths detected by the fluorometer, the team is certain that they have found a new home for phototrophic bacteria—the sea surface. Based on the strength of the signals, they estimate that these aerobic phototrophic bacteria

represent about 1% of the surface phytoplankton. These bacteria and DeLong's bacteria use different mechanisms to harness light, but they both use that light to generate ATP. This gives them a leg up in environments where food is sparse, says DeLong, and they in turn become nourishment for organisms higher up the food chain. Neither Falkowski nor DeLong knows whether their light-loving organisms also use light to fix carbon the way plants do; if they do, they would enrich the ocean surface further.

Few microbiologists have imagined that aerobic phototrophic bacteria could live on the ocean's surface, because they usually thrive where the water's oxygen content is low. And even fewer suspected that some bacteria might have a bacteriorhodopsin. Says Giovannoni: "Most people are going to do a double take when they encounter these papers."

—ELIZABETH PENNISI



Plethora of bacteria. White specks and squiggles reveal the diverse bacteria floating in the ocean, some of which harness light energy.