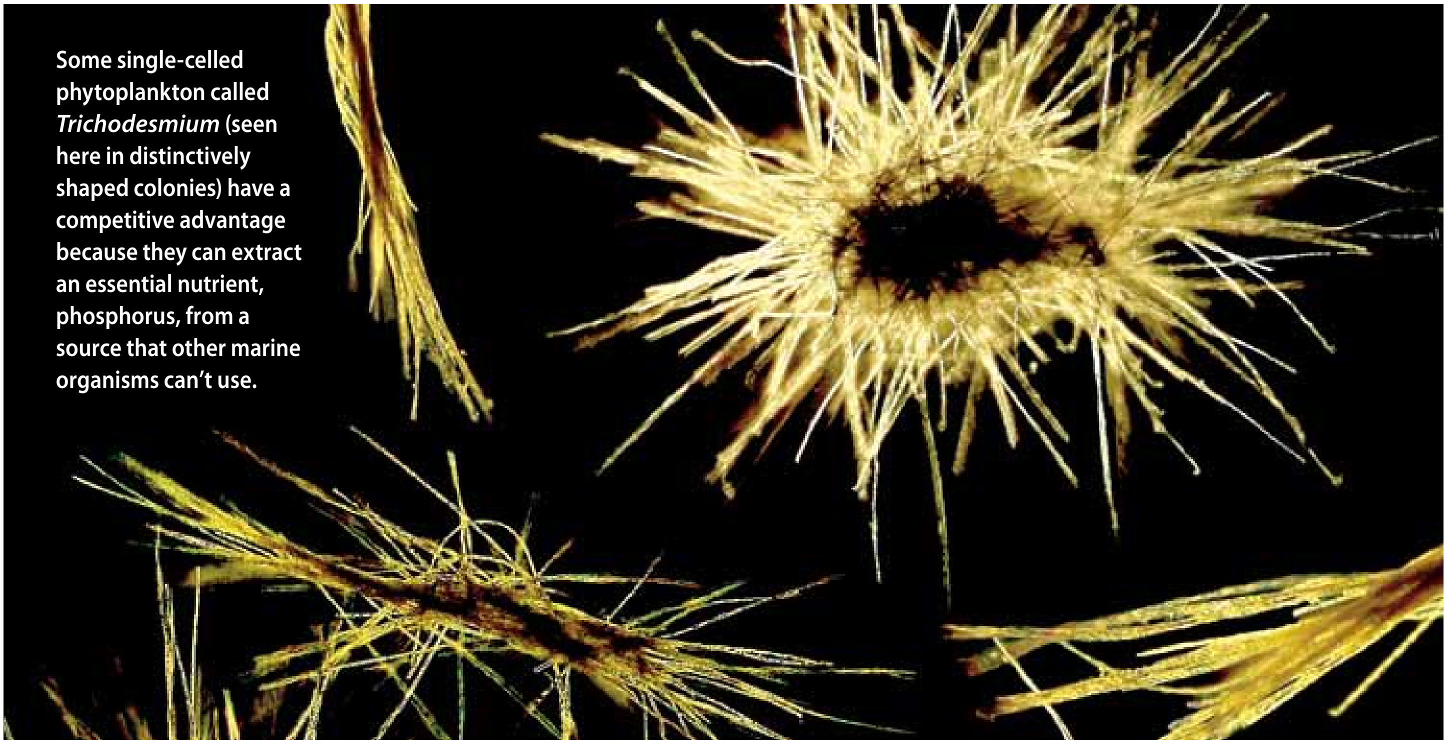

Some single-celled phytoplankton called *Trichodesmium* (seen here in distinctively shaped colonies) have a competitive advantage because they can extract an essential nutrient, phosphorus, from a source that other marine organisms can't use.

Abby Heithoff, WHOI

Having their phosphorus and eating it too

Try naming the nutrients you need to be strong and healthy. Chances are phosphorus will be pretty far down the list, if it's there at all.

And yet you and every other organism on Earth—including those in the ocean—need phosphorus. It's an essential chemical brick in DNA's double-helical scaffold, and it's the "P" in ATP, or adenosine triphosphate, the basic molecule that most cells use for energy.

"Phosphorus is a critical macronutrient required for all life in the sea, and especially for phytoplankton," the tiny marine plants at the base of the food chain, said Sonya Dyhrman, a biologist at Woods Hole Oceanographic Institution (WHOI). Half of all the photosynthesis on the planet occurs in the ocean (mostly by phytoplankton), and since the process requires phosphorus, the nutrient's importance is obvious.

But until recently, little attention was paid to oceanic phosphorus, partly because it was so hard to get reliable measurements of phosphorus in seawater.

When new techniques for detecting minute amounts of the nutrient became available about 15 years ago, they revealed that the ocean contains far less phosphorus than most ecosystems on land. Dyhrman

The bottom of the food web at the bottom of the world

For all its ice, cold, and six months of annual darkness, the oceans around Antarctica are teeming with life. Penguins, whales, and seals inhabit the area where sea ice meets open ocean. And occasionally, so do scientists.

Over the past two years, WHOI marine biogeochemist Mak Saito and colleagues have briefly shared the ice edge to sample the seawater chemistry and the diversity of life at the bottom of the food chain: hordes of phytoplankton, the microscopic plants of the sea, which, in turn, depend on essential, elemental nutrients: nitrogen, carbon, iron, zinc, and others.

"We still have many questions about how elements get into the ocean and how different phytoplankton use them as nutrients," Saito said. "These are critical questions for how marine ecosystems work. And one place in particular where we have little information is Antarctica, because it's so hard to access."

Helicoptering to the ice edge and setting up camp there, the researchers collected samples from both seawater and the ice itself. Collaborators at the J. Craig Venter Institute use genomics to study the phytoplankton's genes, while Saito and colleagues use proteomics, the study of the proteins encoded by the genes and the functions that the proteins perform. The studies will provide new biotech tools to study the health of phytoplankton, and the biochemical mechanisms they use to thrive in cold temperatures, lack of light, and sparse nutrients. It will also provide clues to how the Antarctic ecosystem will be affected by climate change.

and other scientists began to wonder: Does the availability of phosphorus in the ocean help determine where marine life can flourish? Could a shortage of phosphorus account for regions in the North Atlantic and North Pacific that are relatively barren?

Furthermore, scientists found that a fairly high proportion of oceanic phosphorus is in the form of phosphonates. That was surprising, because the phosphorus in phosphonates is bonded so strongly to carbon atoms that few organisms can break the bonds to free up the phosphorus. So scientists presumed phosphonates didn't contribute much to food webs.

Can any marine organisms use phosphonates? Dyhrman asked. In 2006, a team of scientists including Dyhrman and former WHOI biologist Eric Webb found that several species of a phytoplankton called *Trichodesmium* have a special set of genes encoding the machinery that enables them to break the phosphonate bond and get the phosphorus out. The researchers found that *Trichodesmium* uses more accessible forms of phosphorus if they're available; but if those forms are scarce, whether in a lab culture or in a nutrient-poor region of the North Atlantic, *Trichodesmium* turns on the genes that allow it to acquire phosphorus from phosphonate.

Dyhrman said that ability likely gives *Trichodesmium* an advantage over its competitors in areas of the ocean where phosphorus is in very short supply. But it raises another question: Where are the phosphonates coming from? Levels of phosphonates are the same in nutrient-rich and nutrient-poor regions of the ocean; if *Trichodesmium* in nutrient-poor areas is breaking down phosphonates, what is renewing the supply?

Dyhrman and marine geochemist Claudia Benitez-Nelson of the University of South Carolina thought the most likely source was one or more species of plankton. To find out if any common marine microbes make phosphonates, the scientists used nuclear magnetic resonance spectroscopy to measure various chemical forms of phosphorus, including phosphonates, in dozens of single-celled species. In test after test, they detected little or no phosphonates in the cells—"until we started looking at *Trichodesmium*," Dyhrman said.

In a study published in the October 2009 issue of *Nature Geoscience*, she and her colleagues reported that in one species, *Trichodesmium erythraeum*, from 8 to 17 percent of the phosphorus was in the form of phosphonates. "That is more phosphonate than anyone has found in any kind of microbe, and it's certainly the first significant detection of phosphonate in a marine microbe," she said.

The results were astounding: The same species can not only *use* phosphonates, it can also *produce* them.

"It is a little confounding, but it could be a clever strategy," Dyhrman said. Not too many other microbes can use phosphonate, "so the *Trichodesmium* are basically creating an environment where they're self-selecting for themselves. You can imagine this scenario would give *Trichodesmium* a competitive advantage."

That advantage is likely to come into play even more in years to come, as climate change affects the marine environment, Dyhrman said. "In the future ocean, we expect *Trichodesmium erythraeum* to grow really well. It likes warm temperatures, and it does well under high CO_2 [carbon dioxide] levels. That suggests it's potentially going to be producing more phosphonate in the future."

Which would be good news for the few other organisms that can use phosphonates, including other species of *Trichodesmium*. It could also be good news for the oceans' productivity and their ability to store carbon, because all the *Trichodesmium* species have yet another special chemical ability: They can convert atmospheric nitrogen into compounds that other organisms can use, much as legume plants do on land. In effect, *Trichodesmium* provides nitrogen "fertilizer" that boosts the ability of other phytoplankton to photosynthesize and take up more CO_2.

Dyhrman cautioned that the news may not be all good, depending on the specific phosphonate compounds that *T. erythraeum* makes. If those compounds are methylated—that is, if they contain a methyl, or CH_3, group—then when they are broken down to release their phosphorus, they will also release methane—an even more potent greenhouse gas than CO_2.

—Cherie Winner

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See audio slideshow at whoi.edu/oceanus/antarctica

Mak Saito, WHOI