Genetic switch lets marine diatoms do less work at higher CO2

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Credit: Tiago Fioreze / Wikipedia

Diatoms in the world's oceans exhale more oxygen than all the world's rainforests. These tiny drifting algae generate about 20 percent of the oxygen produced on Earth each year and invisibly recycle gases enveloping our planet.

How diatoms will respond to the rising carbon dioxide levels is still

unknown. A new study by the University of Washington and Seattle's Institute for Systems Biology, published June 15 in *Nature Climate Change*, finds the genetic ways that a common species of diatom adjusts to sudden and long-term increases in carbon dioxide.

"There are certain genes that respond right away to a change in CO2, but the change in the metabolism doesn't actually happen until you give the diatoms some time to acclimate," said first author Gwenn Hennon, a UW doctoral student in oceanography.

Understanding the genetic machinery for how diatoms respond to rising carbon dioxide due to fossil fuel burning could help predict the future of the world's oceans, and determine what role diatoms may play in Earth's future atmosphere.

Many land plants and other photosynthetic organisms grow faster with more CO2. Surprisingly, Hennon's previous research showed that at typical nutrient levels the diatoms just kick back and relax.

"Instead of using that energy from the CO2 to grow faster, they just stopped harvesting as much energy from light through photosynthesis and carried out less respiration," Hennon said.

The new study shows how and why that happens. Hennon cultivated a common species of diatom in the lab under controlled conditions that mimic common ocean conditions, where diatom growth is limited by the availability of nitrogen. In one scenario, she gradually increased the carbon dioxide over four days. In the other scenario she tended her invisible aquarium dwellers for about a month, allowing about 15 generations of diatoms to adjust to CO2 levels as high as 800 parts per million, which Earth's atmosphere could reach by 2100.

When the CO2 suddenly spikes, as might happen during a sudden change

in ocean currents, these diatoms produce a signaling molecule that triggers a molecular cascade of events, reducing the energy-intensive processes required to concentrate the carbon dioxide.

The main enzyme for photosynthesis first evolved during the Precambrian period, almost 3 billion years ago, when CO2 was extremely high, at several thousand parts per million.

"There hasn't been another enzyme to replace it since, so plants and algae that photosynthesize have an enzyme that functions better at a higher CO2 level than we currently have," Hennon said.

When the CO2 remains high for a long time, however, the diatoms make a more radical metabolic shift. They decrease photosynthesis and respiration to balance the cell's energy budget. In other words, the diatoms use less energy to grow at the same rate. Diatoms could use the existing light energy to grow faster, but only if there are no other limitations on their growth.

"It really depends on where it is," Hennon said. "There are a lot of situations in the oceans where the diatoms can't grow faster, because they're limited by nutrients such as iron or nitrogen."

Senior author Ginger Armbrust, a UW professor of oceanography, sequenced the full genome of the Thalassiosira pseudonana diatom used in this study in 2004. The new paper builds on that work, as well as the growing genetic knowledge of other diatoms.

"We leveraged results from nearly 100 different publicly available experiments to identify these genetic 'needles in a haystack' and gain our first hints as to how diatoms detect and respond to increasing CO2 concentrations," Armbrust said.

This same genetic machinery exists in distantly related diatoms, Hennon said, suggesting that the same response could occur in many species that live in the real oceans.

"It's really exciting when you find something in a lab strain that you think you might be able to generalize to other diatoms in the field, and maybe even other phytoplankton," Hennon said.

Future research may look at how the genetic shuffle works for other species and under different environmental conditions, as well as how it ties in with the much slower process of genetic evolution.

"We want to understand how these tiny photosynthetic workhorses will respond to the increasing CO2 concentrations of our future oceans," Armbrust said.

More information: Diatom acclimation to elevated CO2 via cAMP signalling and coordinated gene expression, *Nature Climate Change*, DOI: 10.1038/nclimate2683

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