Genetic maps of ocean algae show bacteria-like flexibility

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This is a coccolithophore bloom off Brittany, France. Credit: Jacques Descloitres, NASA

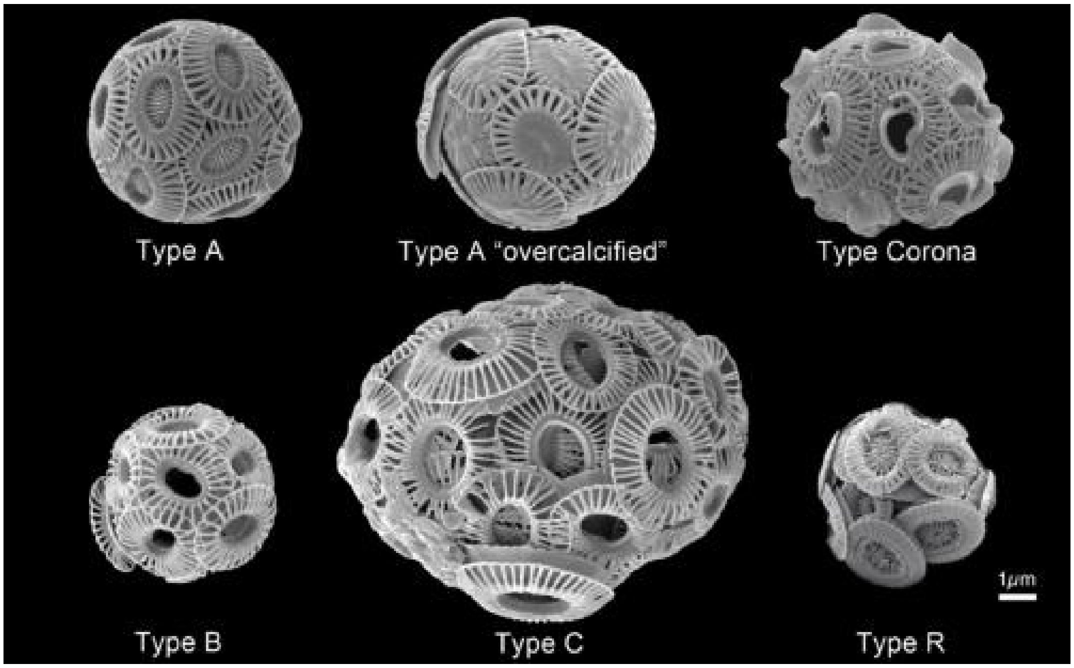
Smaller than a speck of dust, *Emiliania huxleyi* plays an outsized role in the world's seas. Ranging from the polar oceans to the tropics, these free-floating photosynthetic algae remove carbon dioxide from the air, help supply the oxygen that we breathe, and form the base of marine food chains. When they proliferate, their massive turquoise blooms are visible from space.

Now scientists have discovered one of the keys to *E. huxleyi*'s success. A seven-year effort by 75 researchers from 12 countries to map its genome has revealed a set of core genes that mix and match with a set of variable genes that likely allows *E. huxleyi*, or Ehux, to adapt to different environments. Their results are described in the latest issue of *Nature*.

Over generations, the exchange of material within Ehux's so-called "pan-genome" has allowed it to evolve in far-flung places. "In the sea, we thought that only bacteria were shuffling around their genes in this way so it was a real shock to see that Ehux was doing the same thing," said senior co-author of the study Sonya Dyhrman, a microbial oceanographer at Columbia University's Lamont-Doherty Earth Observatory.

Like all phytoplankton, Ehux harvests sunlight from the upper layer of the world's oceans. But it sets itself apart by building armor-like plates of chalk, or coccoliths. It lives mostly in cold, nutrient-rich waters but also thrives at the warm, nutrient-poor equator. Its variety of shapes and sizes, and the diverse places it calls home, hint at its extreme versatility.

Two-thirds of Ehux's genes are shared among all strains. This core genome allows Ehux to thrive under low levels of phosphorus and iron, elements key to life but in short supply in the ocean. The remaining third of its genes are present in one but not all strains. In this variable gene pool are those that allow Ehux to use varying forms of nitrogen, another relatively scarce element in the sea. This flexibility likely allows it to adapt to changing environmental conditions.



Emiliania huxleyi's shapes are as varied as the ocean environments it lives in. Credit: Nature Publishing Group

A pan-genome has previously been seen only in some marine bacteria, organisms lacking enclosed nuclei. Ehux is a eukaryote—an organism with an enclosed nucleus, like all plants and animals. This is the first description of a pan-genome in eukaryotic marine algae.

"We're starting to get a window into the variations that allow the oceans to function the way they do," said Tatiana Rynearson, an oceanographer at University of Rhode Island who was not involved in the study. "Will this pan genome trend hold for other microalgae in the ocean?"

Understanding what makes Ehux so easygoing may help scientists understand how rising industrial carbon emissions will affect climate and ocean health in the future. Industrial carbon is warming Earth's atmosphere but also acidifying its oceans. Coccolithophores play an important role in removing carbon from both places.

They combine it with calcium to build their coccoliths—for each ton, removing 320 pounds of carbon. They also convert it into biomass during photosynthesis, producing oxygen as a byproduct. What's more, their blooms release dimethyl sulfide into the air, creating clouds, which reflect sunlight into space and cool the planet.

Depending on where they are and what they're doing, coccolithophores can also release carbon dioxide, making it difficult for scientists to say for sure whether they take up or release more carbon over time. This question becomes important as increasing levels of carbon in the atmosphere change the ocean's chemistry. As seawater acidifies, the form of carbon that Ehux and other calcifying organisms need to build their coccoliths become scarcer. If seawater grows acidic enough, it could dissolve them entirely.

Ehux may adapt, and even grow better under more acidic conditions, but its contribution to the carbon cycle could change dramatically. The genome allows researchers to study how the pan-genome is expressed, and potentially predict Ehux's response. "Where will it be?" said Dyhrman. "What will it be doing? These seem like simple questions but they could have a big impact on the net result of how carbon in the ocean is cycled."

On the eukaryotic tree of life, Ehux belongs to the haptophytes, which are important for understanding how eukaryotes, and especially land plants, evolved. The genome brings scientists closer to understanding the evolution of life on Earth as well as how organisms evolve to exploit diverse environments. "It gives you the code to decipher the signals you see in the sea," said Dyhrman.

The Ehux genome revealed other surprises that could lead to practical benefits. Some of its metabolites, known as polyketides, have anti-microbial, anti-fungal, anti-parasitic and anti-tumor properties that could be used to treat disease. Identifying the genes and proteins used in the coccolith-building process could also lead to the design of new materials for bone replacement, sensing systems and optoelectronic devices.

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