New gene-based model suggests, for microbes, it's not who you are but what you do

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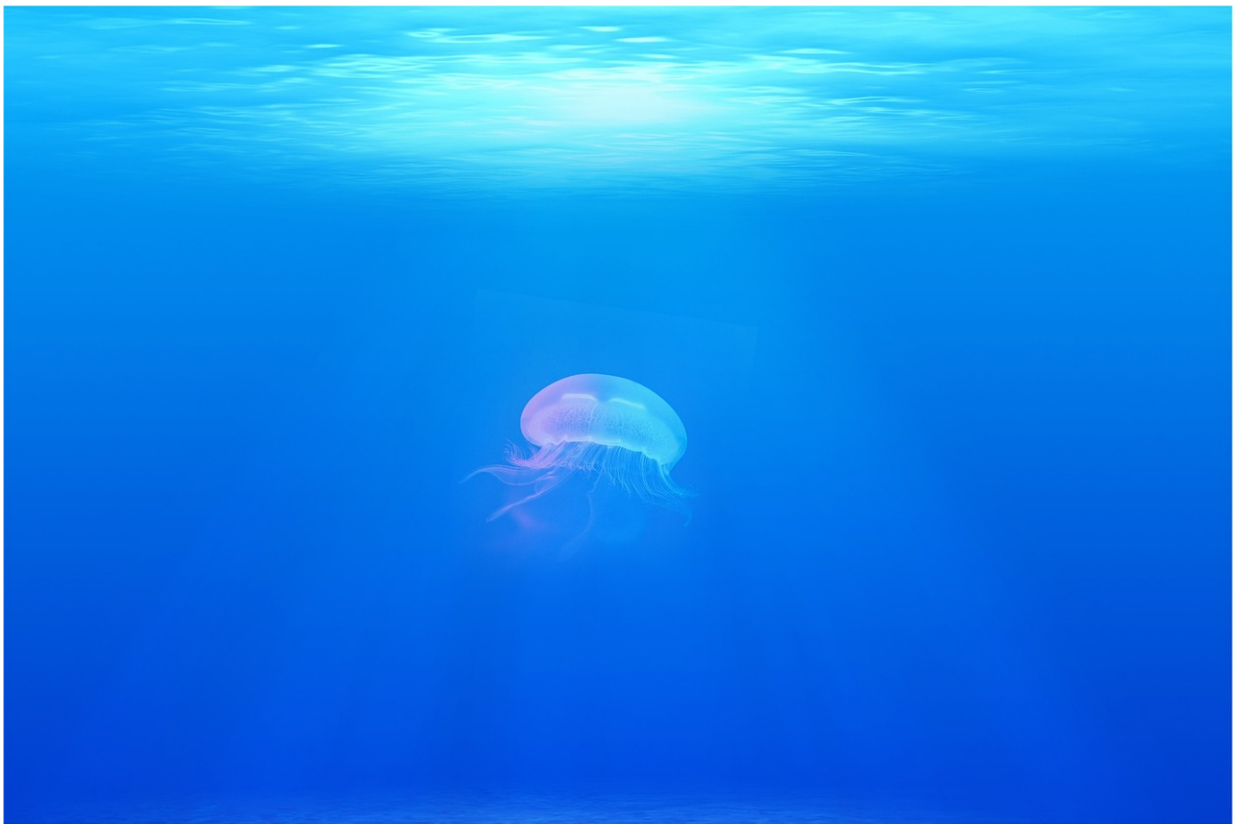

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Amazing diversity hides beneath the surface of the ocean where tiny microbes work busily; transforming carbon dioxide from the atmosphere into oxygen, converting sunlight into energy, and breaking down nitrogen gas to serve as food. University of Maryland Center for Environmental Science researcher Victoria Coles and her team have developed a new tool that advances our understanding of how these microbes maintain this complex ocean chemistry.

The new model, published today in *Science*, simulates the impact of microbial activities on the chemistry in the North Atlantic and suggests that the evolution of a metabolic function rather than the evolution of an individual species shapes the ocean as we know it. It is the first model that actually predicts genes and transcription throughout the ocean.

"The model suggests that it's not the evolution of species but rather the evolution of microbial metabolisms that sets our present-day ocean chemistry," said Victoria Coles, associate professor at the University of Maryland Center for Environmental Science's Horn Point Laboratory.

Microbes are like invisible machines that together perform the biochemical transformations that maintain the ocean's balance and function. The ocean may be inhabited by as many as 170,000 different microbial species, but we know next to nothing about the functions of most. Yet they all work together to make the ocean work the way we know it.

"Most microbes we can't bring into the lab and learn about because we don't know how to grow them," said Coles. "How does a model capture species we don't yet know and can't grow? We decided to begin with the smaller number of different metabolic processes that microbes can perform. We make synthetic model organisms with different functions and throw them all into the model ocean. Then we watch to see how they sort it out and compare the predicted community genes and transcripts to direct observations."

It's kind of like a SIM City build-your-own-world, but for microbes. Throw a wide diversity of characters into a pool together and the attributes you want them to have, and see what happens.

"They either win or lose. Some don't work. If one dies off we add in another," she said. "This gives us the ability in our model to adapt to environmental conditions like nutrient pollution or changing climate."

Coles said that the researchers ran this new model many times with different microbes, and each time they established the same basic patterns of biochemistry in the ocean. They discovered that gene function, influenced by local environmental conditions rather than the species of microbe, drives the biochemical reactions and processes in the model. In other words, the library of gene functions available to the community, rather than the distribution of functions among specific organisms, influences ocean biogeochemistry.

"All of the model oceans that we make give us something that looks like today's ocean," she said. "Each community is really different at the end of the model, but they are doing the same thing. It's not about the specific species as much as the process. All the microbes operate together to get to the environment we observe."

For instance, the process of nitrogen fixation, taking nitrogen gas that has been dissolved in the ocean and turning it into fertilizer, can be done by plants such as diatoms working together with cyanobacteria or by cyanobacteria alone, but also by bacteria that aren't plants and derive energy from organic compounds. Each of these are totally different organisms with different lineages that perform the same metabolic function.

"The models we use today to understand climate change are all fundamentally based on common microbes in the present-day ocean.

They don't include rare microbes that might become common in the future," she said. "If the ocean environments changes, this model has the ability to shift and adapt so we might get better predictions about how ocean biogeochemistry could change."

The study "Ocean biogeochemistry modeled with emergent trait-based genomics," was published in the December 1 issue of Science.

More information: V. J. Coles et al. Ocean biogeochemistry modeled with emergent trait-based genomics, *Science* (2017). DOI: 10.1126/science.aan5712

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