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The invisible organisms that threaten to make climate change much worse

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When we think about greenhouse gas emissions, a few obvious culprits — coal-fired power plants or automobiles — come to mind. But the burning of fossils fuels isn't the only process spewing carbon into the atmosphere. A much less talked-about, but increasingly concerning source of carbon emissions is the slowly thawing permafrost, or frozen soil, in the Arctic.

We know that permafrost is a formidable threat to our changing climate, covering nearly a quarter of all the land surface in the Northern Hemisphere and containing about 1,700 gigatons of stored carbon. We also know the basic processes that can cause it to leak that carbon into the atmosphere. As permafrost thaws, microbes in the ground, including bacteria and other microorganisms, start snacking on the dead plants and other tasty organic matter contained in the soil, releasing methane and carbon dioxide.

But what we haven't clearly understood until now is how global warming can affect the microbes, themselves.

Now, a new study, published Tuesday in Proceedings of the National Academy of Sciences, tackles the question of how rising temperatures can change the activity of microorganisms in the Arctic. The study focuses on methane production, rather than carbon dioxide — an important issue to understand because of methane's potency.

Carbon dioxide may be the more famous (and abundant) greenhouse gas, but methane is the more dangerous: Some estimates rank it at about 25 times more efficient at trapping heat in the atmosphere than carbon dioxide, and the study's authors indicate that thawing permafrost may already account for up to 10 percent of global methane emissions. On top of this, Arctic temperature projections predict an increase of up to 6 degrees Celsius in the summer and up to 11 degrees Celsius in the winter by the end of the century. Knowing how these changes could affect methane-producing microbes is an important step in predicting how the Arctic landscape — and our atmosphere — might change in the coming decades.

In a worst case scenario, permafrost emissions could lead to a kind of positive feedback loop, in which warming temperatures cause more thawing, which releases more greenhouse gases, which in turn help the climate to continue warming, and then the rising temperatures cause even more thawing. So there's a definite incentive to understanding how much of an effect temperature changes will have on the microbial community's behavior.

In fact, the study's findings are a little concerning: It turns out these microbe communities are surprisingly good at adapting to rising temperatures. And the warmer it gets, the more methane they produce.

This study's authors focused on the interactions of microorganisms living in anoxic, or oxygen-poor, peat soil in the Arctic. They collected peat samples and incubated them at temperatures ranging from 1 to 30 degrees Celsius, and sure enough, the microbes' methane production rate increased steadily, and rapidly, as temperature rose.

The researchers also found that at any given temperature, methane concentration increased linearly as time passed, suggesting that the microbes were able to adapt quickly to temperature shifts and keep methane production high at all times.

"There are specific interactions at different temperatures that ensure high methane production, and there are different taxonomic units operating," said lead author Mette Marianne Svenning, a professor of arctic and marine biology at the Arctic University of

Norway. In other words, the researchers found that different types of microbes are more active at higher temperatures, and they interact with each other in different ways.

Several key findings stand out. One is that methane production may already be high in some places, even at low temperatures. The researchers observed that methane production at 4 degrees Celsius was already 25 percent of the production rate at 25 degrees — another surprising finding which "tells us that the organisms in this system are adapted to low temperature conditions, and they are able to produce a lot of methane at low temperatures," Svenning said.

Another important finding involves the rate-limiting factors in methane production, or the chemical processes that limit how fast methane can be produced. The researchers found that, below 7 degrees Celsius, the rate-limiting step was a different chemical process than the rate-limiting step above it, making 7 degrees a kind of threshold temperature. Above this threshold, the researchers also found that different types of microbes became more dominant, and they used different kinds of chemical processes to produce methane. Since the total amount of microorganisms in the soil remained the same, it was these shifts, and not an increase in microbial biomass, that helped bring about the increase in methane production.

"It's very important to understand these interactions because they will control the emission rate of methane," said Kevin Schaefer, a research scientist at the National Snow and Ice Data Center at the University of Colorado in Boulder. Right now, there aren't clear data to say whether methane emissions are currently increasing in the Arctic, specifically, Schaefer said. But understanding metabolic interactions within microbial communities can help scientists make better predictions about what the future will bring.

Schaefer also said he believes a better understanding of the microbial community can help scientists predict how much of the Arctic emissions will come out as carbon dioxide and how much will come out as methane. Carbon dioxide is the less potent when it comes to climate change, but current estimates suggest it takes the lion's share of the greenhouse gases produced through permafrost, according to Schaefer: 97 percent or more.

Since this study focused only on methane, Svenning said she can't comment on whether carbon dioxide production will also shift with temperature in similar ways. But if we assume the proportion of methane to carbon dioxide production stays the same, even in warmer temperatures, we're looking at a huge increase in carbon dioxide emissions as well.

For Svenning, the logical next step is to scale down and start looking at much smaller temperature changes, so scientists can get a better idea of how minor increases over shorter timeframes might affect microbial behavior and methane output.

In Schaefer's opinion, the most important thing is for humans to slash our carbon output enough in the coming decades to prevent the thawing permafrost from becoming a major problem at all. Cutting human-produced greenhouse gases could keep global temperatures within reasonable boundaries, slow the thawing of the permafrost and prevent even more emissions from pouring into the air.

But it's no sure thing — meaning Svenning's research and our understanding of the microbial greenhouse gas production may become important in our predictions for the future and our decisions about how to deal with them.