Microbiologists reveal unexpected properties of methane-producing microbe

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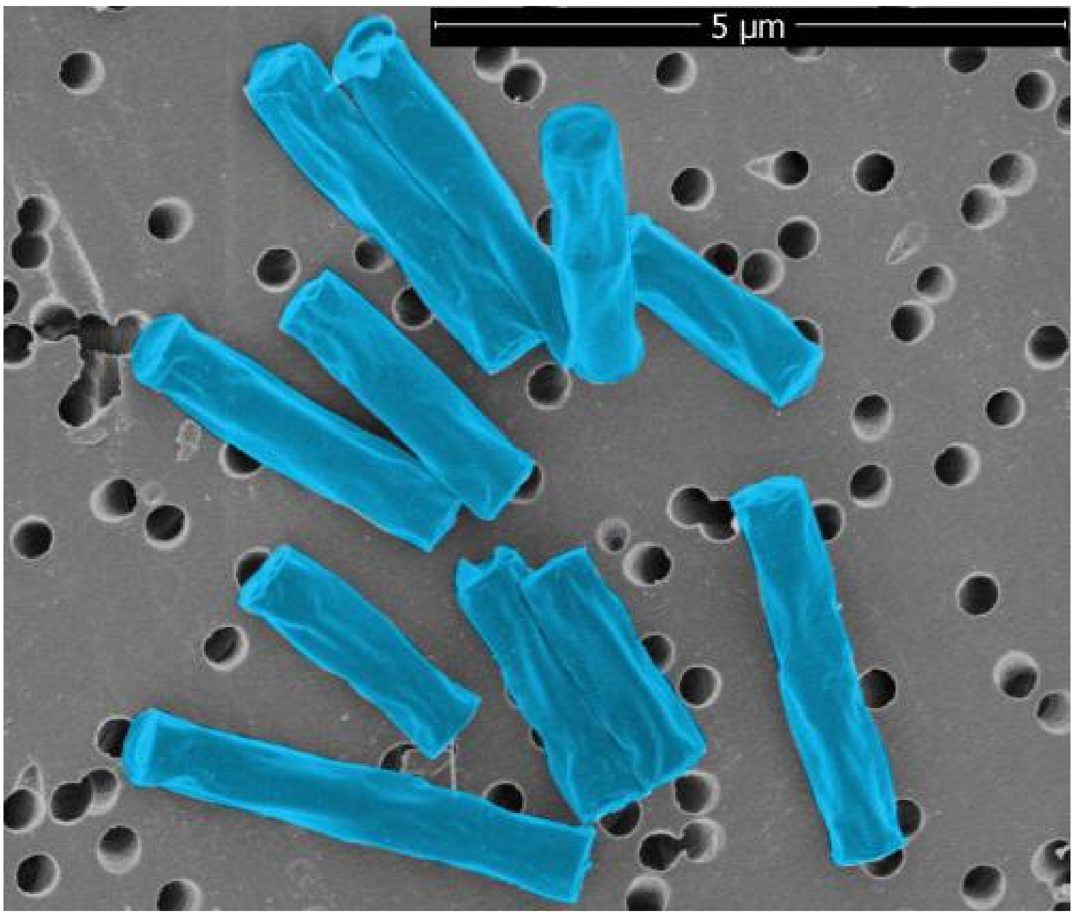

UMass Amherst microbiologists discovered that *Methanosaeta* have the ability to reduce carbon dioxide to methane by a remarkable mechanism in which they make electrical connections with other microorganisms, something methanogens have never been known to do before. Credit: Dale Callahan and Amelia-Elena Rotaru

For 40 years, scientists thought they understood how certain bacteria work together to anaerobically digest biomass to produce methane gas, important in bioenergy and the major source of greenhouse gas. But now microbiologists in Derek Lovley's lab at the University of Massachusetts Amherst show for the first time that one of the most abundant methane-producing microorganisms on earth makes direct electrical connections with another species to produce the gas in a completely unexpected way.

Lovley and colleagues, including former postdoctoral researcher and first author Amelia-Elena Rotaru, describe the newly discovered properties of the methane-producing bacterium *Methanosaeta* in the current issue of the British Royal Society of Chemistry journal, *Energy and Environmental Science*.

"We discovered that *Methanosaeta* have the ability to reduce carbon dioxide (CO_2) to methane," Lovley explains. "They do this by a remarkable mechanism in which they make electrical connections with other microorganisms, something methanogens have never been known to do before."

Methanosaeta species are important for a couple of reasons, Lovley and his co-authors point out. They are so active in methanogenic wetlands that they are considered the most prodigious methane producers on the planet. This is a concern because atmospheric methane is 20 times more effective at retaining heat than CO_2, and as tundra soils warm due to climate change even greater methane releases are expected. Also, methane produced in anaerobic biomass digesters is economically important as "one of the few proven, economical, large-scale bioenergy strategies" in use today, they say.

Methane-producing microbial communities have been studied for decades, Lovley notes, "but all this time we were missing a major pathway of methane production." His group's study of *Methanosaeta* started when they found that digesters converting brewery wastes to methane contained large quantities of the microorganism *Geobacter*. *Geobacter* cannot produce methane, but it does break down more complex substrates to compounds that methane-producing bacteria can use.

The UMass Amherst teams knew from previous studies that *Geobacter* grow electrically conductive filaments known as microbial nanowires, which can transport electrons outside the cell to make electrical connections with minerals, electrodes or other cells. *Methanosaeta* were the dominant methane-producing microorganisms in the digesters and known to convert acetate to methane, but analysis of the gene expression in the digester revealed that *Methanosaeta* were also highly expressing genes for converting carbon dioxide to methane. The researchers speculated that *Geobacter* were feeding *Methanosaeta* electrons through their nanowires to promote *Methanosaeta*'s methane production from CO_2.

Further studies in which individual *Geobacter* and a *Methanosaeta* species were cultured together confirmed these suspicions, Lovley says. He and colleagues used radioactive tags to demonstrate that CO_2 was being reduced to methane. They dubbed this transfer via microbial nanowire "direct interspecies electron transfer," or DIET. It was confirmed when they used a strain of *Geobacter* genetically altered to prevent it from producing nanowires, and the process did not work.

Lovely says the discovery of DIET challenges the concept held for decades that natural methane-producing microbial communities primarily exchange electrons through the production and consumption of hydrogen gas. DIET is a much more direct, and potentially more efficient mechanism for feeding electrons to methane-producing bacteria. "Now we need to improve predictions of how methane-producing microbial communities will respond to climate change.

Microbial communities using DIET may react much differently than those that rely on hydrogen exchange," he says.

There are also short-term practical implications. "Once you realize that there are methane producers that can directly feed on electrons, you start thinking differently about how to optimize methane production from wastes," the microbiologist notes. "Although generating methane from wastes is one of the oldest bioenergy strategies and is practiced even in small villages in developing countries, its application on a large scale has been limited because it is slow." Trying to speed methane production in large-scale operations can disrupt the microbes' highly coordinated activity and systems can fail.

These communities evolved over billions of years to slowly convert organic matter to methane, Lovley explains. "Electrical circuitry that evolved for microbes to make methane from organic matter in swamps at their own leisurely pace may not match our wish for a faster process in waste digesters. Just as you need to upgrade electrical service in your house when you add more appliances, we made need to use synthetic biology or other engineering approaches to increase the capacity to move current through methanogenic microbial communities in digesters."

With the Massachusetts Department of Environmental Protection planning to begin in January 2014 phasing in a requirement that large-scale food service operations such as grocery stores, universities and correctional facilities compost food waste to increase diversion from landfills by 350,000 tons per year by 2020, anaerobic biodigesters may soon be very important to the state's business community. The new advances from UMass Amherst research could help to significantly improve their design and efficiency, Lovley notes.

More information: pubs.rsc.org/en/Content/Articl … E42189A#!divAbstract

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