Uncovering the tricks of nature's ice-seeding bacteria

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Like the Marvel Comics superhero Iceman, some bacteria have harnessed frozen water as a weapon. Species such as *Pseudomonas syringae* have special proteins embedded in their outer membranes that help ice crystals form, and they use them to trigger frost formation at warmer than normal temperatures on plants, later invading through the damaged tissue. When the bacteria die, many of the proteins are wafted up into the atmosphere, where they can alter the weather by seeding clouds and precipitation.

Now scientists from Germany have observed for the first time the step-by-step, microscopic-level action of *P. syringae*'s ice-nucleating proteins locking water molecules in place to form ice. The team will present their findings at the AVS 60th International Symposium and Exhibition, held Oct. 27 – Nov. 1 in Long Beach, Calif.

"Ice nucleating proteins are the most effective ice nucleators known," said Tobias Weidner, leader of the surface protein group at the Max Planck Institute for Polymer Research. The proteins jump-start the process of ice crystal formation so well that dried ice-nucleating bacteria are often used as additives in snowmakers.

Although scientists discovered ice-nucleating proteins decades ago, little is known about how they actually work. Weidner and his team tackled the mystery with a powerful tool called spectroscopy that can decipher patterns in the interaction between light and matter to visualize the freezing process in layers of materials only a few molecules thick.

The researchers prepared a sample of fragments of *P. syringae* bacteria that they spread over water to form a surface film. As the temperature was lowered from room temperature to near freezing levels the scientists probed the interface between the bacterial proteins and the water with two laser beams. The beams combined within the sample and a single beam was emitted back, carrying with it information about how the protein and water molecules move and interact.

By analyzing the returning light beam's frequency components, Weidner and his colleagues found a surprisingly dramatic result: as the temperature approached zero degrees Celcius the water molecules at the ice-nucleating protein surface suddenly became more ordered and the molecular motions become sluggish. They also found that thermal energy was very efficiently removed from the surrounding water. The results indicate that ice nucleating proteins might have a specific mechanism for heat removal and ordering water that is activated at low temperatures, Weidner said.

"We were very surprised by these results," Weidner added. "When we first saw the dramatic increase of water order with lower temperatures we believed it was an artifact." The movements of the water molecules near the ice-nucleating protein was very different than the way water had interacted with the many other proteins, lipids, carbohydrates, and other biomolecules the team had studied.

Recent studies have shown that large numbers of bacterial ice-nucleating proteins become airborne over areas like the Amazon rainforest and can spread around the globe. The proteins are among the most effective promoters of ice particle formation in the atmosphere, and have the potential to significantly influence weather patterns. Learning how *P. syringae* triggers frost could help teach researchers how ice particle formation occurs in the upper atmosphere.

"Understanding at the microscopic level – down to the interaction of specific protein sites with water molecules – the mechanism of protein-induced atmospheric ice formation will help us understand biogenic impacts on atmospheric processes and the climate," Weidner said. For a more detailed picture of protein-water interactions it will also be important to combine their spectroscopic results with computer models, he said.

More information: Presentation BA+AI+AS+BI+IS+NL-MoM10, "A Molecular View of Water Interacting with Climate-active Ice Nucleating Proteins," is at 11:20 a.m. Pacific Time on Monday, Oct. 28, 2013.

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