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Food supply affects bacteria's response to temperature

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As a population of bacteria grows, it can become desperate. When their food supply dwindles, bacteria must either forage for new sources of nutrients or slow their metabolism. That's why, at a critical bacterial concentration, Escherichia coli use a chemical signal to collectively swim from warm areas to cooler ones where they can conserve energy.

New research from Rockefeller University shows that at high concentrations, when nutrients are nearly depleted, these bacteria do not rely on chemical signals alone. They remain in cooler temperatures by reversing their expression of two key receptors that sense temperature.

Co-author Albert Libchaber, head of the Laboratory of Experimental Soft Matter Physics, and lead author Hanna Salman, a postdoc in his lab, first observed that bacteria are drawn to either warm or cold temperatures depending on how tightly they are packed together. At low concentrations, they are attracted to warm climates, and at high concentrations to cooler ones. Until now, however, nobody has looked at how bacteria respond to temperature as they continue to multiply in real time.

When the bacteria grew to a specific concentration they reversed their response to temperature: They started swimming away from the middle of the microscope slide, where a laser beam had heated it to 30 degrees Celsius, and started swimming toward the slide's outer edges where it was 12 degrees cooler.

"This switch is very sharp," says Salman, whose findings appear in the August 12 issue of *Nature Cell Biology*.

Two receptors allow bacteria to detect temperature changes in their environment. Tsr mainly senses two chemicals, glycine and serine, and is responsible for bacteria's attraction to warmth. Tar mainly senses the chemical aspartate and is responsible for bacteria's attraction to cold. Under normal conditions, Tsr is more abundant than Tar.

As bacteria multiply, they secrete glycine. Then, at a critical concentration — approximately 200 million bacteria in a cubic centimeter — they produce enough glycine to methylate Tsr, a process that chemically modifies the receptor and makes it insensitive to temperature changes. At this point, Tar takes control and the bacteria begin to swim toward cooler temperatures. When Salman and Libchaber deleted Tar, the bacteria remained at the heated center of the microscope slide even as they continued to multiply.

When the duo added high levels of glycine to wildtype strains, the bacteria swam to cooler regions even at lower concentrations. The added glycine made Tsr insensitive before the bacteria reached their critical concentration. Salman and Libchaber observed the same result when they deleted Tsr, suggesting that glycine mediates this switch through the methylation of Tsr receptors.

Salman then grew the bacteria to higher concentrations and placed them in a fresh microscope slide after he diluted the bacteria to concentrations at which they are attracted to warm regions. "But we observed a long recovery time before the bacteria began swimming toward the center of the dish," says Salman. "And this could not be explained by methylation."

The scientists tracked the levels of Tar and Tsr as the bacteria multiplied, and found that the expression of Tar became more abundant than that of Tsr when bacteria hit a very specific concentration — approximately 300 million per cubic centimeter. This observation explains why it took so long for the bacteria to start swimming toward the warm region: The two receptors needed to reverse back to their original expression levels.

“This additional change in the ratio of the two receptors strengthens and sustains a bacteria’s response to temperature,” says Salman. “When they need to, bacteria have the ability to ramp up their survival mode.”

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