Bacteria change behavior to tackle tiny obstacle course

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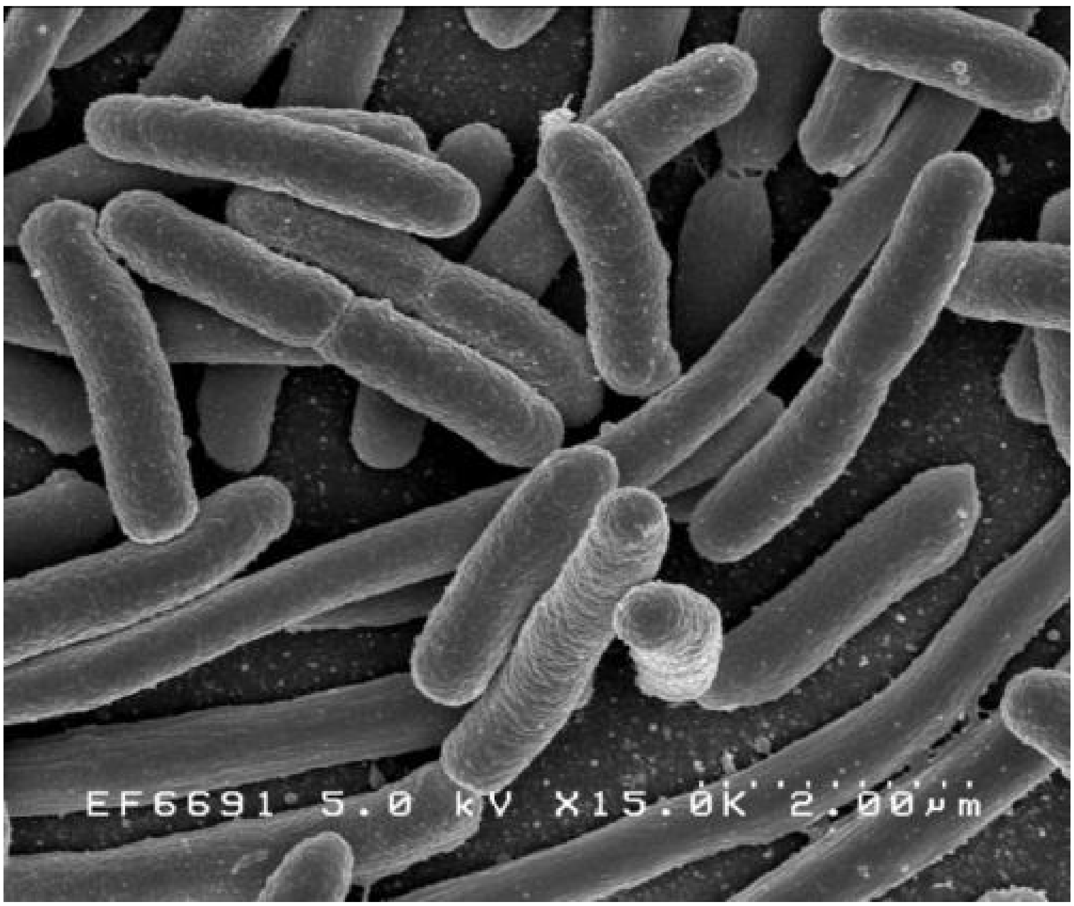

Escherichia coli. Credit: Rocky Mountain Laboratories, NIAID, NIH

It's not exactly the set of TV's "American Ninja Warrior," but a tiny obstacle course for bacteria has shown researchers how *E. coli* changes its behavior to rapidly clear obstructions to food. Their work holds implications for not only biology and medicine, but also robotic search-and-rescue tactics.

Scientists at Carnegie Mellon University, the University of Pittsburgh and the Salk Institute for Biological Studies report today in the *Proceedings of the National Academy of Sciences* that the well-known "swim and tumble" behavior that bacteria use to move toward food or away from poisons changes when bacteria encounter obstacles.

"In the real world, they always encounter lots of obstacles," said Ziv Bar-Joseph, a professor in CMU's Computational Biology and Machine Learning departments. *E. coli*, for instance, inhabits the complicated terrain of the gastrointestinal tract. Yet previous studies of chemotaxis—the way bacteria move toward a higher concentration of food or away from concentrations of poisons—generally have been done in unobstructed chambers.

Existing models of chemotaxis predict that obstacles will slow the progress of bacteria. So the researchers designed microfluidic chambers—just 10 micrometers high, one millimeter wide and one millimeter long—and placed evenly distributed square and round obstacles in them. When they tested *E. coli* inside these tiny obstacle courses, they were surprised at the speed at which the bacteria found a food source.

"Almost regardless of the obstacles, they got to the food almost as quickly as they did without obstacles," said Sabrina Rashid, a CMU Ph.D. student in computational biology and the lead author on the study. "The obstacles were not affecting the time they needed to reach food, as the previous models predicted."

Bacteria are known to communicate with each other by secreting chemicals, and this sort of communication no doubt informs bacteria as they try to get around an obstacle, she said. But a closer look at the bacteria also showed a change in behavior.

Normally, bacteria swim a bit, then perform a circular dance, called tumbling, to reorient themselves regarding food concentrations. The tumbling slows progress toward food, but importantly enables bacteria to make course corrections.

The researchers suspected that a key reason for the improvement in speed when facing obstacles is the bacteria's ability to tumble less and swim more until they are in the clear. So they designed additional experiments that tracked individual bacteria cells and confirmed these predictions.

Given the importance of cell movement in biology, the new findings could have implications for how malignant cells spread through the body or how infections might be treated, Bar-Joseph said.

Based on these findings the researchers have developed their own chemotaxis model to account for this new behavior and better predict the performance of bacteria. Applying the model to simulations of teams, or swarms, of robots performing searches for trapped victims in emergencies has shown that this approach can reduce their search time as well.

"Any type of insight we can get from biology to improve computation is important to us," Bar-Joseph added.

In addition to Bar-Joseph and Rashid, the research team at CMU included Shashank Singh, a Ph.D. student in machine learning and statistics. At Pitt, Hanna Salman, associate professor of physics and astronomy, and Zoltan Oltvai, associate professor of pathology, were joined by Zicheng Long, a post-doctoral researcher in Salman's lab, and

Maryam Kohram and Harsh Vashistha, both Ph.D. students in physics. Saket Navlakha, an associate professor at the Salk Institute, completes the team.

More information: Sabrina Rashid el al., "Adjustment in tumbling rates improves bacterial chemotaxis on obstacle-laden terrains," *PNAS* (2019). www.pnas.org/cgi/doi/10.1073/pnas.1816315116

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