ASU researchers zero in on how sudden stress drains bacterial energy

Rapid changes in a cell’s environment can disrupt its power supply

By Richard Harth, ASU News
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When bacteria are suddenly hit with a salty or sugary shock, they do not just shrivel slightly and carry on. According to new research from Arizona State University, they also suffer a rapid drop in a core energy system that helps keep the cell alive and functioning.

This is important because bacteria live in constantly changing environments, from soil and water to the human body. Learning how they respond to sudden stress could help researchers better explain how microbes survive harsh conditions, with possible long-term implications for both controlling harmful bacteria and making use of beneficial ones.

The study focused on Escherichia coli, a bacterium commonly found in human and animal guts. The researchers found that a sudden increase in the concentration of dissolved substances outside the cell, known as hyperosmotic shock, causes an almost immediate drop in part of the bacterium’s membrane-based energy. That effect happens within seconds and is reversible, suggesting that abrupt changes in a microbe’s surroundings can briefly throw its internal power supply off balance.

“All living things, from tiny bacteria to mighty whales, constantly contend with imbalances in water and osmolytes,” says Navish Wadhwa, who led the study. “What we’ve found is that in bacteria, sudden osmotic stress doesn’t just disrupt that balance, it briefly shuts down the proton motive force, the cell’s primary energy source. That raises a fundamental question about how life continues, even briefly, when that energy supply collapses.”

Wadhwa is a researcher with the Biodesign Center for Mechanisms of Evolution and an assistant professor in the Department of Physics and the Center for Biological Physics at ASU. The research appears in the advanced online edition of the Biophysical Journal.

Scientists have long known that bacteria must cope with osmotic stress. If the environment outside a cell suddenly becomes more concentrated, water rushes out, the cell shrinks and its membrane can deform. But the new work suggests the effects go deeper than changes in shape and water balance. It shows that osmotic stress also disrupts the bacterium’s energetic state — the membrane-based electrical gradient that powers many of the cell’s most basic activities.

That energy system, called the proton motive force, is central to bacterial life. It helps power movement, energy production, cell division and the formation of bacterial communities.

To observe this process in real time, the researchers used an unusual built-in sensor: the bacterium’s flagellar motor, the tiny rotary machine that spins its screw-like tail that propels the cell through fluids. Because the speed of that motor depends on the cell’s proton motive force, it can serve as a live readout of what is happening across the membrane.

The team showed that after an osmotic shock, motor speed dropped sharply, indicating a loss of membrane energy. They then confirmed the result with a fluorescent dye that tracks the cell’s electrical state. Both methods showed that osmotic shock quickly drains part of the membrane-based energy the bacterium uses to function.

The stronger the osmotic shock, the bigger the drop. But the effect was not permanent. When conditions returned to normal, motor speed quickly recovered. In longer experiments, the bacteria partially regained their energy over several minutes, suggesting they can adapt and restore much of what was lost.

The researchers also tested whether the effect depended on the exact substance used to create the osmotic stress. The researchers found that different compounds produced similar results, suggesting the response is a general one rather than a quirk of a particular chemical. Taken together, the findings suggest that osmotic stress is not only a problem of water balance, but also a rapid challenge to the cell’s internal energy system.

"For me, this work shows not just how osmotic shock affects a cell’s energy, but how we can now watch those changes as they happen,” says first author Luis Meneses, a graduate student in Wadhwa's lab. “It opens the door to studying how other environmental and mechanical stresses shape a cell’s energy state, helping us connect what a cell experiences to how it powers itself.”

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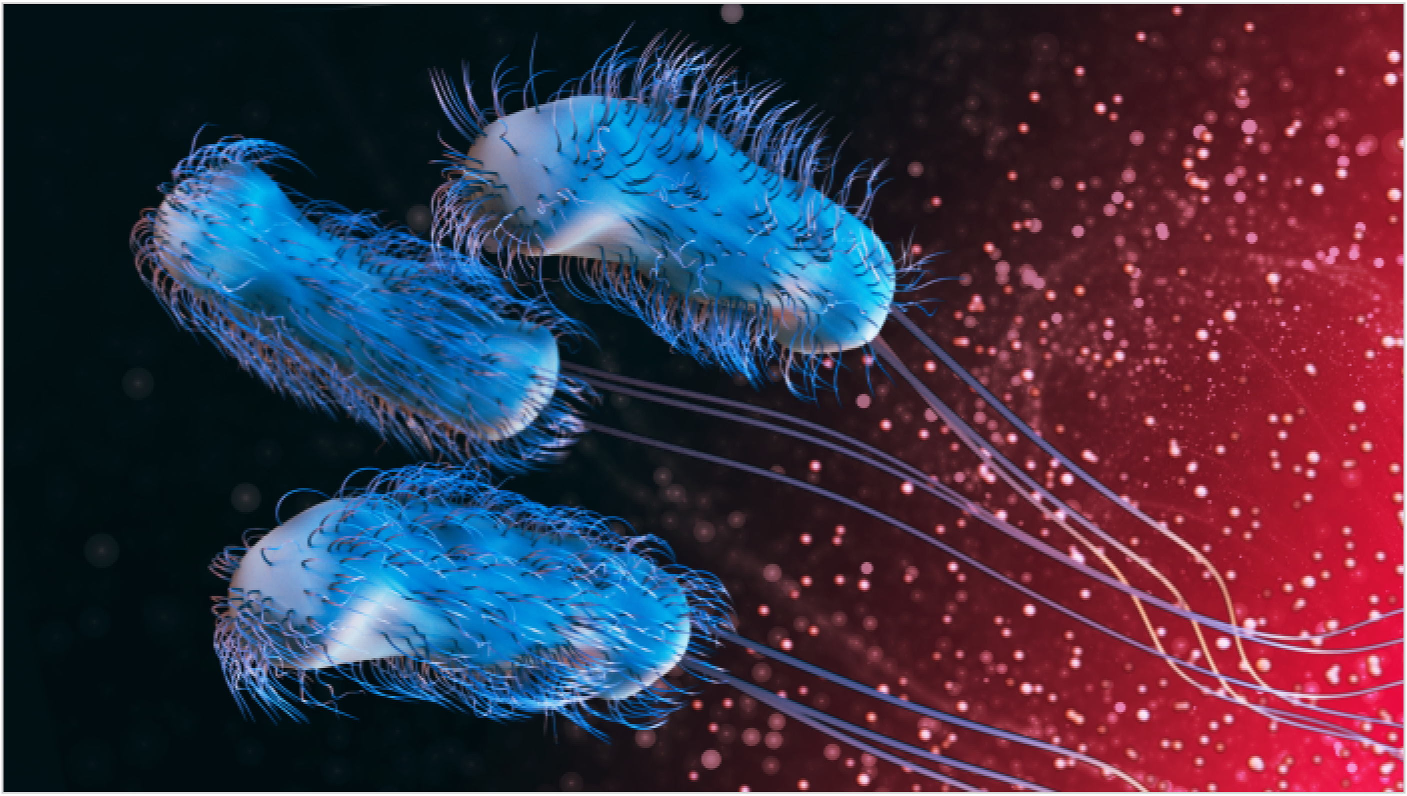
Main image



Graphic by Jason Drees/ASU

Text image(s)

ASU graduate student Luis Meneses (left), first author on the study, and corresponding author Navish Wadhwa.