Swarm science: Oral bacteria move in waves to spread and survive

New research reveals surprising ways bacteria coordinate their movements — offering fresh insights into hidden dynamics of our microbiome

By Richard Harth, ASU News
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Swarming behaviors appear everywhere in nature — from schools of fish darting in synchrony to locusts sweeping across landscapes in coordinated waves. On winter evenings, just before dusk, hundreds of thousands of starlings may gather in the sky in hypnotic, pulsing patterns known as murmuration. These vast, shifting clouds of birds move as one, responding instantly to changes in their environment to evade predators and communicate.

But swarming isn't limited to birds, insects or fish — bacteria, too, can exhibit collective movement on a microscopic scale. Some microbes use swarming to spread across surfaces, colonize new environments and outcompete rivals.

In a new study, researchers with the Biodesign Center for Fundamental and Applied Microbiomics at Arizona State University and their colleagues describe bacteria that move together like a choreographed display — expanding in waves and bursts, then settling into scattered microcolonies. The bacteria transition between different movement styles, using a strategy similar to the way plants spread seeds or fungi release spores, the study shows.

Bacteria of the genus Capnocytophaga fan out in complex, coordinated patterns, helping them to survive in changing environments. Such bacteria, which are commonly found in the human mouth and associated with gingivitis (bleeding gums) and periodontal diseases, can also accumulate to form biofilms and cause fatal septic infections in humans due to bites from canines.

The research sheds new light on microbial ecosystems, potentially opening doors for new treatments in oral and gut health.

“The human microbiome contains numerous understudied microbes. For instance, the genus Capnocytophaga — commonly found in nearly every human mouth — remains largely unexplored,” says corresponding author Abhishek Shrivastava, an assistant professor in ASU's School of Life Sciences. “Our research illuminates the developmental processes of these microbes, paving the way for deeper insights into their role in health.”

The research appears in the current issue of ISME, the Multidisciplinary Journal of Microbial Ecology. In addition to his ASU colleagues, Shrivastava is joined by researchers from the Max Planck Society in Germany.

Bacterial close-up

Bacteria of the Capnocytophaga genus occur in the healthy human oral microbiome — the diverse community of bacteria and other microorganisms living in the mouth — but imbalances of the oral microbiome can contribute to gum disease or infections in people with weakened immune systems. Also, transfer of pathogenic Capnocytophaga from the mouth of dogs to humans via simple transfer of saliva can lead to sepsis and death of humans. Understanding how Capnocytophaga move and spread could provide insights into how bacteria colonize our mouths and how biofilms — complex communities of bacteria — form on our teeth and gums and lead to pathogenesis.

Researchers used high-resolution time-lapse microscopy to track bacterial swarming, allowing them to observe movement patterns over time. After growing the bacteria on soft agar plates under oxygen-free conditions — similar to the deep layers of the human mouth — they recorded their movements over several days.

To further investigate the mechanics behind this motion, the team applied particle image velocimetry (PIV), a technique that tracks bacterial density changes over time. This allowed the researchers to measure speed, directionality and phase transitions in swarm behavior, uncovering the physical principles that drive bacterial dispersal.?

The team also created computer models to simulate the bacterial movements. By adjusting variables like speed, density and alignment, they were able to reproduce the real-world swarm patterns seen in their experiments. These models suggest that bacterial motion is not random but follows predictable rules that help microbes efficiently spread and establish themselves.

Unlike traditional swarming bacteria that spread in smooth waves, the C. ochracea bacteria observed in the study follow a three-step process.

First, bacterial groups break away from the main colony, expanding outward in punctuated bursts. These bursts create jagged, petal-shaped edges, allowing the bacteria to move in multiple directions at once.

Next, the bacteria shift to a wave-like expansion, aligning in coordinated motions that propel the swarm forward in a smoother, directed manner.

Finally, the swarm fragments into scattered microcolonies, forming new bacterial hubs millimeters or even centimeters from the original site. This scattering resembles seed dispersal in plants, ensuring colony survival even if local conditions change.

The study also suggests that C. ochracea plays a role in microbial transport, as it can carry non-motile bacteria and even viruses known as bacteriophages as it moves. This could have significant implications for how different microbes interact and compete within the oral microbiome.

Such research highlights the remarkable adaptability of bacteria and their ability to reorganize in response to environmental changes. By better understanding these behaviors, scientists may develop new strategies for managing bacterial infections, improving oral health and advancing microbiome-based therapies.

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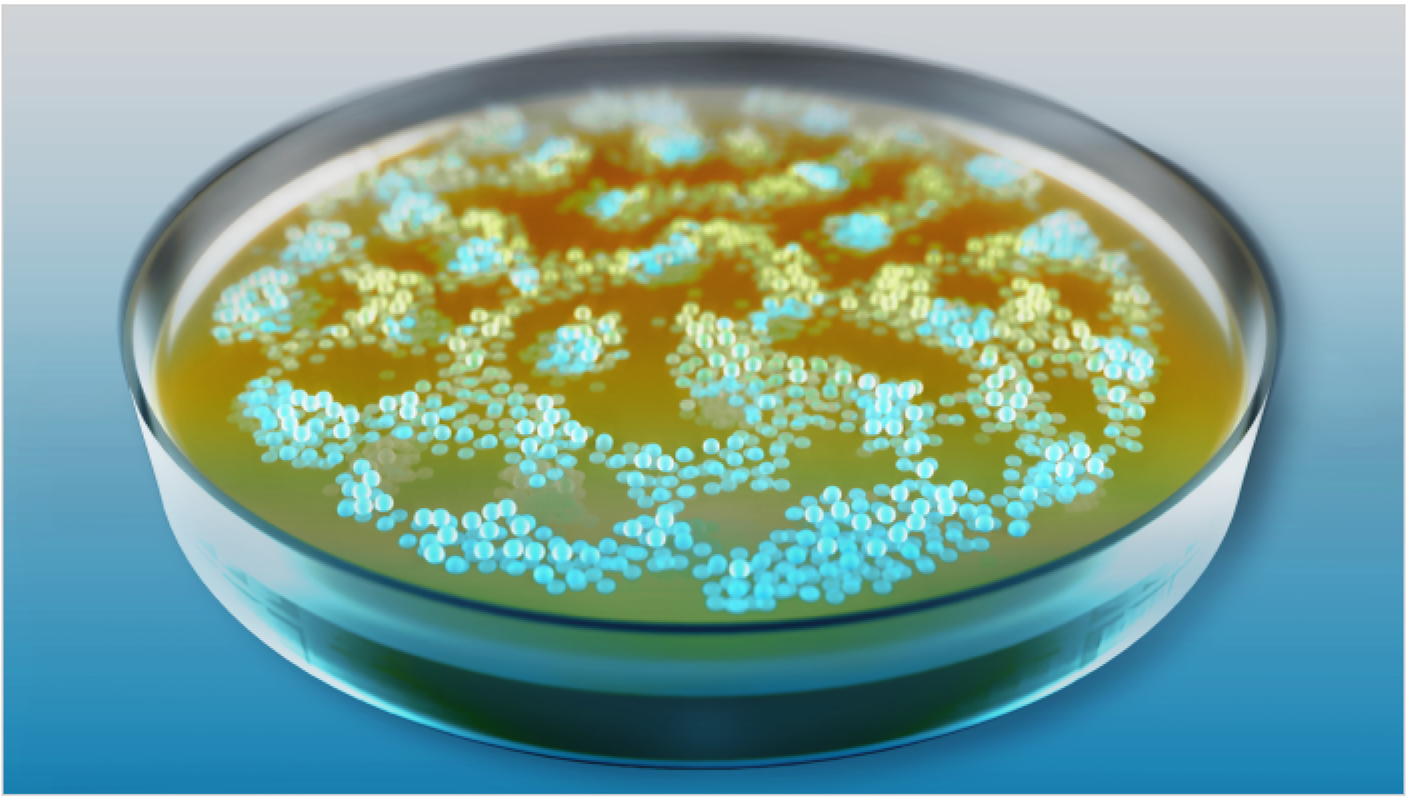
Main image



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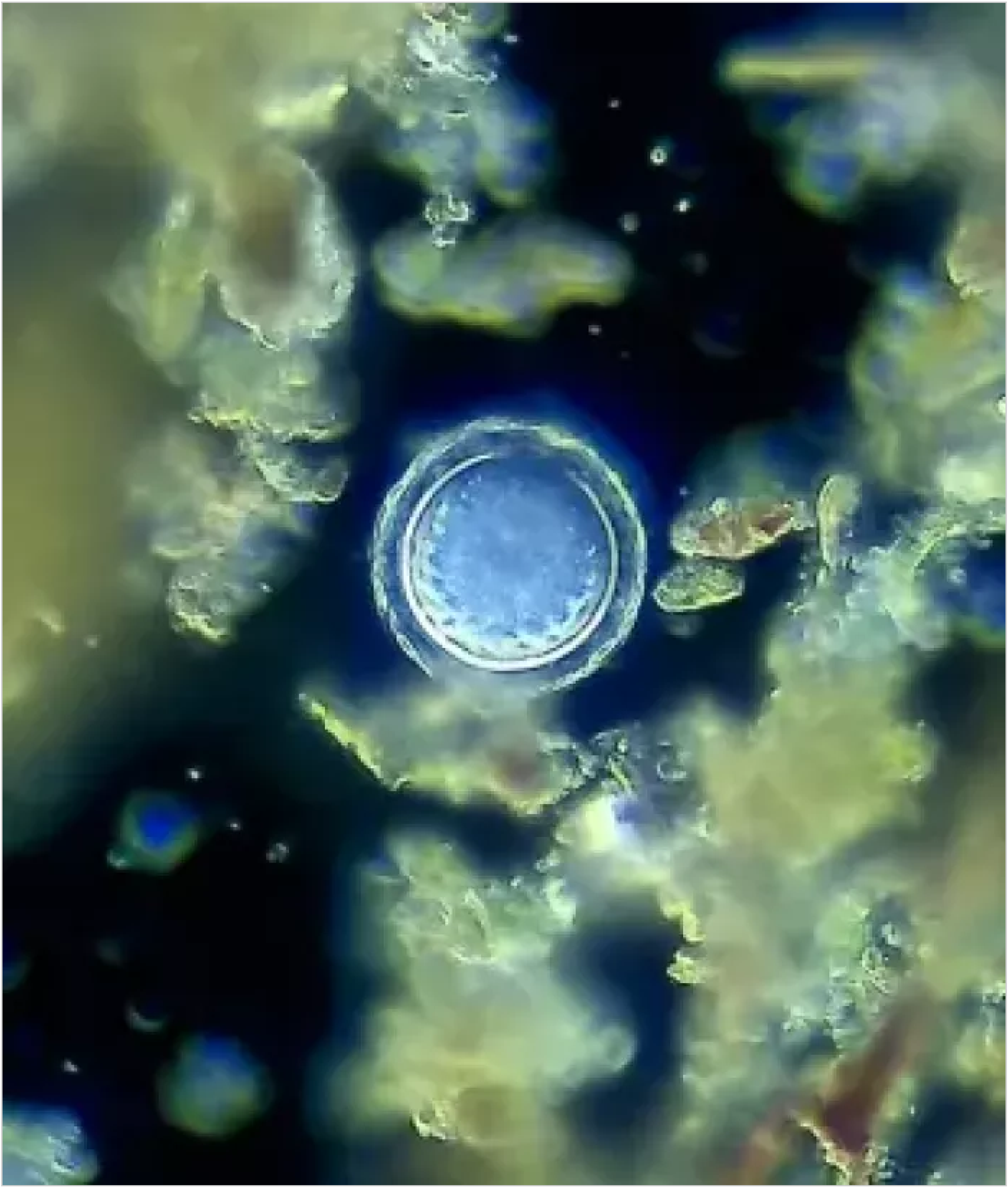
Text image(s)

Abhishek Shrivastava



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