Knowing why bacteria are great upstream swimmers may prevent serious infections

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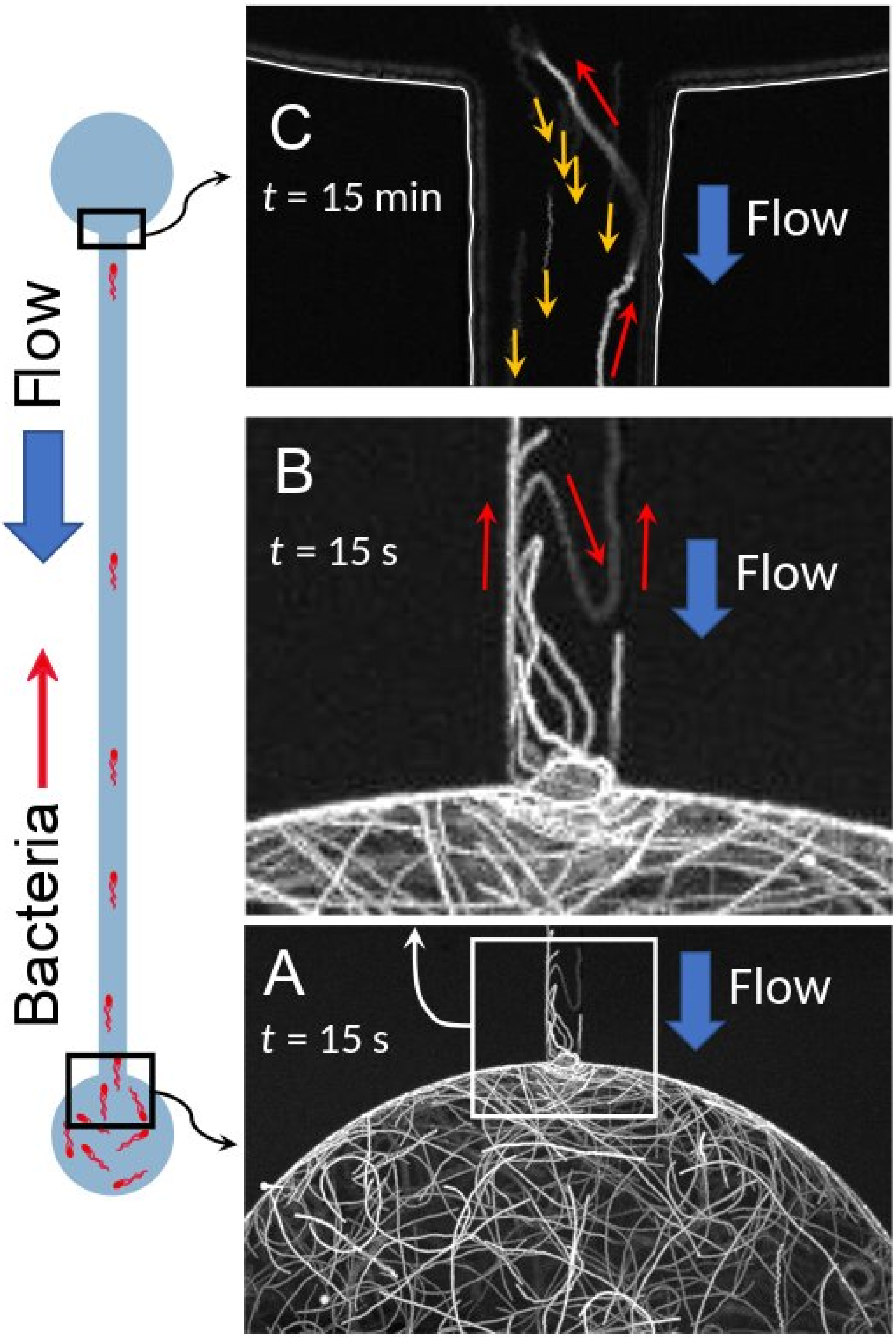

Bacterial paths represented by the superposition of photograms. A bacterium reaches a clean area of the microchannel by swimming upstream over 15mm in 15 minutes. Credit: Nuris Figueroa-Morales

New findings on how bacteria can maintain persistent and fast upstream swimming motion over distances comparable with many human organs, may help prevent life-threatening infections, according to a team of international researchers.

Upstream bacterial migrations often occur where liquids flow in one direction, such as the human urinary tract and intravenous and urinary catheters. How far and how fast bacteria can swim upstream has long been poorly understood. This is mainly due to uncertainty of how bacteria maintain persistent upstream motion despite also demonstrating run-and-tumble dynamics—moving forward, tumbling randomly, then moving again in another direction.

In a paper published in *Science Advances*, the researchers have demonstrated just how far upstream bacteria can travel despite what appears to be erratic movement. The team designed an experiment with E. coli bacteria swimming against fluid flow in microfluidic channels, which they filmed. They examined to what extent the confinement was important in the macroscopic transport of the bacteria.

"Our measurements suggest that upstream-swimming bacteria can overcome distances comparable to the sizes of human organs, tens of millimeters in some tens of minutes under conditions of high confinement," said Nuris Figueroa-Morales, Penn State bioengineering postdoctoral researcher and lead author of the publication. "In the human urinary tract, for example, ureters are tubes with muscular walls that undergo successive waves of active muscular contraction to move liquid from the kidney to the bladder. When totally contracted, they collapse to a slit-shaped, very confined cross section, possibly favorable to upstream bacterial migration."

The flow's confinement is an essential ingredient for upstream contamination. Bacteria move forward in upstream paths but are interrupted by downstream transport, when they are carried by fast flows near the center of the channel. The wider the channel, the further bacteria are transported back before restarting their motion upstream close to walls. In a narrow channel, the bacteria move much quicker and more consistently upstream—an effect the researchers named "super-contamination." Their findings could explain why some infections rapidly become life-threatening medical emergencies.

"It's a physical mechanism. Like a weathervane on a windy day, the bacteria's geometry causes them to point upstream," Figueroa-Morales said. "Very confined channels make this upstream migration more drastic. In the experiments, we made the channels so narrow that most of the bacteria swam close to the walls and they swam upstream for a long time. The edges of the microchannel and the flow just help guide bacteria straight upstream, resulting in a fast contamination."

The study's findings have implications for prevention of medical emergencies due to blood infections and other contaminations. For example, to avoid bacterial contamination of intravenous and urinary catheters, hospital procedures require periodic replacement of these devices. This procedure is painful, and involves a high risk of additional complications. According to Figueroa-Morales, the findings could help design novel flow geometries or surface treatments of catheters to limit upstream bacterial migration.

"Our research could also be relevant to new emerging technologies seeking to improve targeted drug delivery, use of bacteria for environmental depollution and understanding the spreading of biocontaminants in soils," Figueroa-Morales said.

More information: Nuris Figueroa-Morales et al. E. coli "super-contaminates" narrow ducts fostered by broad run-time distribution, *Science Advances* (2020). DOI: 10.1126/sciadv.aay0155

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