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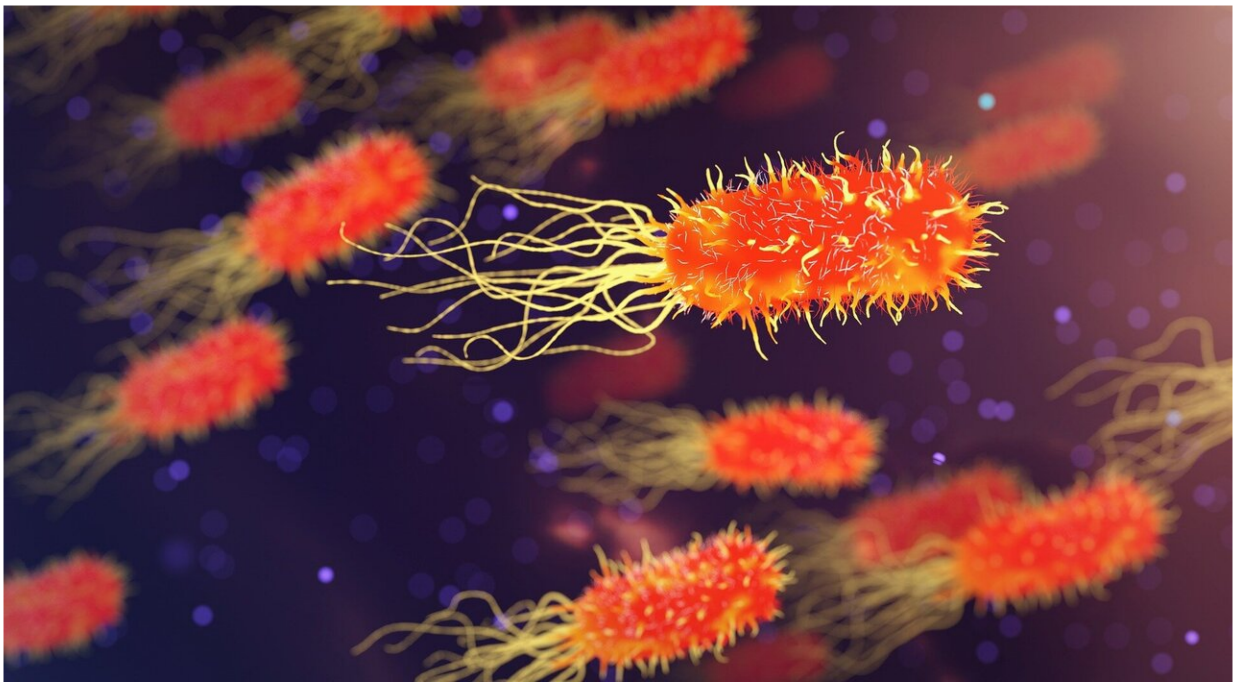
# Jets of bacteria carry microscopic cargo

March 24 2020



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It is a longstanding challenge to be able to control biological systems to perform specific tasks. In a paper published in *Nature Physics*, researchers at the Niels Bohr Institute, University of Copenhagen, in collaboration with groups in U.S. and U.K., have now reported doing just that. They have found a way to control bacteria to transport microscopic cargo. Bacteria form the largest biomass in the world, larger than all the animals and plants combined, and they are constantly moving, but their movement is chaotic. The researchers pursued the idea that if this motion could be controlled, they might be able to develop it into a biological tool. They used a liquid crystal to dictate the direction of the bacterial movement, and added a microscopic cargo for the bacteria to carry, more than five times the size of the bacteria.

## Bacteria-scale railroad construction

Assistant Professor Amin Doostmohammadi at the Niels Bohr Institute explains that in the past, there have been attempts to control the behavior of bacteria. But he and his colleagues adopted a novel approach: "We thought to ourselves, how about we create a track for the bacteria? The way we do that experimentally is to put the bacteria inside a liquid crystal. The trick is that a liquid crystal is not like a crystal, nor is it a liquid, it is somewhere in between. Each molecule in the crystal has an orientation, but doesn't have a positional order. This means that the molecules can flow like a liquid, but they can also align like a crystal at the same time. This is exactly the physics underlying liquid crystal displays (LCDs) for televisions, monitors and mobile phones We can prepare the underlying liquid crystal such that it takes a well-defined pattern. And the bacteria will orientate in the same direction. It doesn't restrict the bacterial movement, it just orientates them in the direction we want them."

### Pattern design and model building

Strong jets of bacteria moving in a designated direction without fluctuations is the great outcome of the experiment, according to Amin Doostmohammadi. What usually happens if the jets of bacteria are strong enough to be useful, the concentration of bacteria has to be high, and instabilities typically start to appear. The jet becomes unstable and chaotic. But in the liquid crystal pattern, the instabilities can be largely suppressed and prevent the bacterial jets from becoming chaotic. The pattern dictates the direction. This means it is possible to create jets of bacteria strong enough to carry strings of microscopic cargo, each piece of cargo five times the size of the bacteria themselves.

## An expanding scientific field

Over the last 10 years or so the scientific field has expanded. Presently, it is possible to control bacteria to a rather large extent and the so called "active matter"—the bacteria, can be made to rotate or form different patterns. Now, with this approach, bacterial jets can be stabilized in space such that they can even carry microscopic cargo.

"We are still at an experimental level, and there is not yet a designated area of use for this technique. At the moment, the main motivation is medical applications. But really, when we think about it, we are actually talking about a completely new type of material. We know the liquid crystal from before, but now we are dealing with a living liquid crystal," Amin Doostmohammadi says. "You can imagine all sorts of material science opportunities with this research. Perhaps it could apply to other systems, to cellular behavior or sperm behavior and so on. As a theoretical physicist, I think about the fundamental implications in terms of the science, but this capability of the drug delivery by bacteria, this is something new. One thing worth noting is that when you deliver a drug this way, you don't need any external force. The bacteria are doing it by themselves. It is like a fluid pumping itself. It is a self pumping fluid, so to speak."

## Theory and experiment are inextricably linked

The results have been obtained in a collaboration with other research groups. Two collaborators in the U.S., Oleg Lavrentovich at Kent State University and Igor Aranson at Penn State University—started this branch of research in 2014. Now teamed up with Amin Doostmohammadi at the Niels Bohr Institute and Julia Yeomans at the University of Oxford, experiments and theory have come together to design and control strong bacterial jets. "We may have a theoretical idea, but it is the coupling of theory and experiment that actually leads to these promising results," says Amin Doostmohammadi.

**More information:** Taras Turiv et al, Polar jets of swimming bacteria condensed by a patterned liquid crystal, *Nature Physics* (2020). DOI: 10.1038/s41567-020-0793-0

Provided by University of Copenhagen