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# Propelling bacteria ease liquid flow

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The combined action of swimming bacteria can reduce the viscosity of a liquid by up to a factor of seven, according to a pair of researchers in the US. This surprising discovery could lead to new microfluidic applications such as extremely well controlled and efficient mixing devices.

Bioscientists and physicists alike are interested in how tiny biological entities such as bacteria and sperm cells can propel themselves. Observations and models have revealed that a variety of non-trivial mechanics may lie at the heart of these propulsion systems. One interesting feature, hinted at by models, is that the viscosity of a liquid – that is, its resistance to flow – could be significantly reduced by the presence of swimming bacteria.

Now, Andrey Sokolov and Igor Aranson of Argonne National Laboratory in the US have tested this theory and confirmed it to be the case – to a much larger extent than anyone had predicted. The researchers carried out two complementary experiments using *Bacillus subtilis*, the rod-shaped bacteria chosen for its swimming ability. In both cases, the bacteria – which are approximately 5 µm long and 0.7 µm in diameter – were suspended in a nutrient-rich medium to a concentration of approximately $2 \times 10^{10}$ $cm^{-3}$.

## Oxygen feed

The researchers found that they could control the mobility of *Bacillus subtilis* by varying the amount of available oxygen dissolved in the fluid. Therefore, the swimming speed of bacteria was controlled by steadily replacing the air in the experimental chambers with nitrogen, and tracking the bacteria using fluorescent markers. After approximately two minutes, the bacteria had reached a complete standstill.

In the first experiment, the researchers triggered a miniature vortex using a magnetically controlled probe. They then inferred the viscosity of each suspension from the time it took each vortex to decay. In the second experiment, they calculated the viscosities more directly by measuring the torque generated by a rotating magnetic microparticle also suspended in the fluid.



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In both experiments, the viscosity of the bacterial solution was reduced by up to a factor of seven, so long as there was sufficient oxygen to keep the bacteria moving.

## Organic industry

While the researchers do not offer a full physical description of why the viscosity varies in this way, they attribute the reducing viscosity to the conversion of oxygen and nutrients into mechanical energy. "The bacteria are effectively absorbing energy and injecting it directly into the liquid," explained Aranson. The researcher told *physicsworld.com* that he can imagine this mechanism finding a role in industry, for example to enhance mixing processes in microscopic systems.

Roberto Di Leonardo, a microfluidics researcher at Rome University, can also see the potential of this research for industry. "Bacterial suspensions could play a more interesting role as advanced, 'active' lubricants for micro-machines," he says. Di Leonardo notes, however, that the "contamination" with organic microfluid could be problematic in some applications.

One of the new directions that Aranson hopes to pursue is the development of a bacterial micromotor that is self-starting. "These micromotors are asymmetric with 200–400 µm miniature gears immersed into the suspensions of swimming bacteria and energized due to collisions with bacteria," he says.

This research has been published in *Physical Review Letters*.

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