Microscopic biological motors using magnetotactic bacteria

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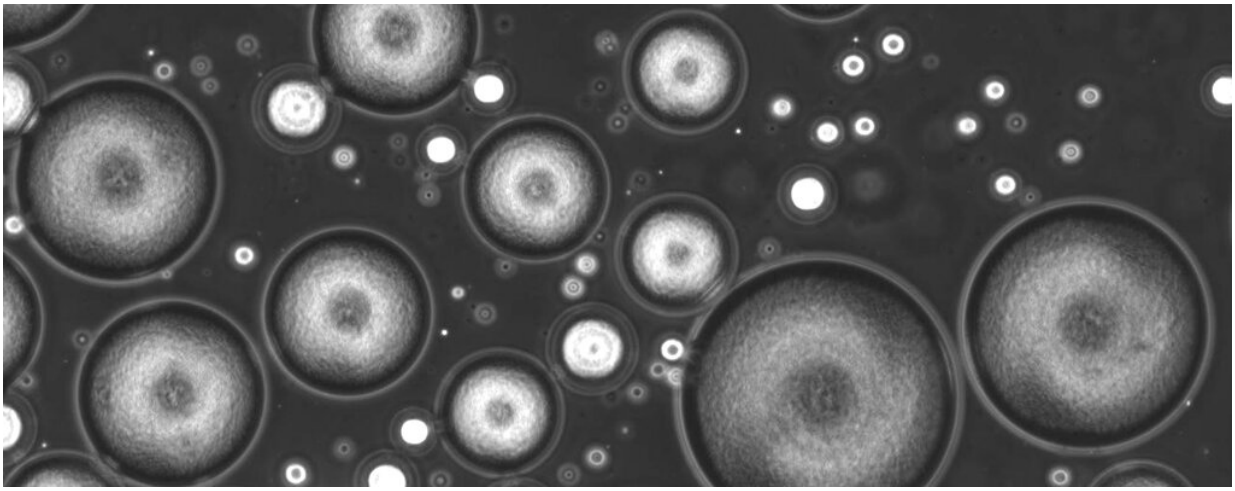

An active suspension of water droplets, in an oil bath. Droplets are filled with magnetotactic bacteria, which are rotating through the action of an electromagnetic field. the whole system acts as a self assemble rotor engine. Credit: PMMH Lab -ESPCI Paris

Since their discovery in the 1970s, scientists have developed a strong interested for magnetotactic bacteria, an intriguing microorganism that moves along the magnetic field lines due the magnetite particles they grow in their body. How this property can be used to induce collective behavior and create a microscopic engine? This is the work done by a team of researchers from the PMMH Laboratory (ESPCI Paris -PSL, Sorbonne University, CNRS) in collaboration with researchers from the

FAST laboratory in Orsay and the University of Chile. In their study, published in the journal *Nature Communications*, they managed to create reversible vortices in drops filled with these bacteria when subjected to a magnetic field.

Whether one considers proteins inside the cells or large-scale animal motion (bird flocks, schools of fish ...), the physical concepts that govern self-organization phenomena are still mysterious. However, in the context of magnetotactic bacteria, researchers know that their motion is influenced by the presence of micron scale magnet in their body, which allows these micro-organisms to align with the magnetic field lines and in a natural context, move along these lines to find their ecological niche. Is it then possible to consider creating a suspension of these bacteria, which flow properties could be controlled?

To study this phenomenon, scientists from the PMMH laboratory and their colleagues prepared an emulsion of water droplet dispersed in oil, the droplets being filled with a large amount of these bacteria. When a constant magnetic field was applied, the bacteria spontaneously formed a vortex inside the droplets and set in motion the oil outside of the drop. Then the team played with the parameters of the experiment, showing that it was possible to reverse the direction of rotation by inverting the magnetic field, or change the rotation speed by varying the intensity of the field. Hence the scientist demonstrated that magnetotactic bacteria can be driven collectively to organize into a controllable microscopic rotary motor

In the end, the physical approach developed by the team combining hydrodynamics and magnetic response, made possible to reach some level of understanding on the possibility to create such controlled and organized microscopic flows, which was as priori not obvious with such small living systems.

Benoit Vincenti, first author who was a Ph.D. student at PMMH Lab adds: "We do not yet understand all the physical mechanisms leading to this collective motion, but its complexity will undoubtedly attract curiosity. In any case, it is an original example of controllable active matter system, meaning that the bacteria suspension was able to perform a task on demand and in non-intrusive way thanks to the action if the magnetic field. Potential applications in this area are numerous!"

More information: B. Vincenti et al., Magnetotactic bacteria in a droplet self-assemble into a rotary, motor, *Nature Communications*, 2019, DOI: 10.1038/s41467-019-13031-6 , www.nature.com/articles/s41467-019-13031-6

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