Physicists discover simple propulsion mechanism for bodies in dense fluids

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A team of researchers from Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), the University of Liège and the Helmholtz Institute Erlangen-Nürnberg for Renewable Energy have developed a micro-swimmer that appears to defy the laws of fluid dynamics: Their model, consisting of two beads connected by a linear spring, is propelled by completely symmetrical oscillations. The scallop theorem states that this cannot be achieved in fluid microsystems. The findings have now been published in the academic journal *Physical Review Letters*.

Scallops can swim in water by quickly clapping their shells together. They are large enough to still be able to move forwards through the moment of inertia while the scallop is opening its shell for the next stroke. However, the Scallop theorem applies more or less depending on the density and viscosity of the fluid: A swimmer that makes symmetrical or reciprocal forward or backward motions similar to the opening and closing of the scallop shell will not move an inch. "Swimming through water is as tough for microscopic organisms as swimming through tar would be for humans," says Dr. Maxime Hubert. "This is why single-cell organisms have comparatively complex means of propulsion such as vibrating hairs or rotating flagella."

Swimming at the mesoscale

Dr. Hubert is a postdoctoral researcher in Prof. Dr. Ana-Suncana Smith's group at the Institute of Theoretical Physics at FAU. Together with researchers at the University of Liège and the Helmholtz Institute Erlangen-Nürnberg for Renewable Energy, the FAU team has developed a swimmer that does not seem to be limited by the Scallop theorem: The simple model consists of a linear spring that connects two beads of

different sizes. Although the spring expands and contracts symmetrically under time reversal, the microswimmer is still able to move through the fluid.ü

"We originally tested this principle using computer simulations," says Maxime Hubert. "We then built a functioning model." In the practical experiment, the scientists placed two steel beads measuring just a few hundred micrometers in diameter on the surface of water contained in a Petri dish. The surface tension of the water represented the contraction of the spring and expansion in the opposite direction was achieved with a magnetic field which caused the microbeads to periodically repel other.

Vision: Swimming robots for transporting drugs

The swimmer is able to propel itself because the beads are of different sizes. Maxime Hubert says, "The smaller bead reacts much faster to the spring force than the larger bead. This causes asymmetrical motion and the larger bead is pulled along with the smaller bead. We are therefore using the principle of inertia, with the difference that here we are concerned with the interaction between the bodies rather than the interaction between the bodies and water."

Although the system won't win any prizes for speed—it moves forwards about a thousandth of its body length during each oscillation cycle—the sheer simplicity of its construction and mechanism is an important development. "The principle that we have discovered could help us to construct tiny swimming robots," says Maxime Hubert. "One day they might be used to transport drugs through the blood to a precise location."