Going Backward to Move Faster: Diatom-Inspired Sliding Uncovers Novel Efficient Locomotion Modes

Julien Le Dreff*[1], Gabriel Amselem[1], and Blaise Delmotte[1]

[1]Laboratoire d'hydrodynamique – Ecole Polytechnique, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UMR7646 – France

Résumé

Across biological scales, from sperm cells to whales, locomotion often relies on undulatory gaits. In these systems, traveling deformation waves interact with the surrounding fluid to generate thrust. At the microscopic scale, flagellar propulsion results from bending waves propagating along a filament. This motion occurs in the direction opposite to wave propagation, and energetic efficiency is maximized when the wavelength is comparable to the flagellum length.

Here, we show that sliding-based actuation, inspired by chains of rod-shaped diatom cells, gives rise to a previously unexplored swimming mechanism. In this mechanism, propulsion direction, speed, and efficiency depend sensitively on the number of oscillations along the chain. In contrast to classical flagellar locomotion, relative sliding between adjacent rods introduces an additional degree of freedom. This coupling produces two competing propulsion modes: a forward-swimming mode driven by traveling-wave–like centerline deformations and a backward-swimming mode, where the colony moves in the same direction as the traveling wave, generated by sliding-induced shear.

Strikingly, the backward mode is both faster and more energetically efficient than the classical forward mode. Its optimal wavelength is nearly five times larger than the chain length. Through a systematic parametric analysis of chain geometry, we identify an optimal rod aspect ratio that maximizes propulsion performance, in agreement with measurements of diatom cells in chains.

*Intervenant