
Light-controlled transport: from single microswimmers to active suspensions

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Résumé

Biological microswimmers employ diverse strategies to efficiently navigate complex fluid environments at microscopic scales. They are a prototypical example of out-of-equilibrium systems, converting internal energy into persistent motion and generating flows at low Reynolds number.

Their interactions with the surrounding fluid can lead to enhanced transport and mixing, both at the level of individual swimmers and through collective phenomena such as bioconvection (1). Biological microswimmers have also drawn significant attention for their potential applications in biomedicine, particularly for cargo transport and drug delivery tasks (2).

In this work, we investigate light-controlled transport induced by the microswimmer *Chlamydomonas reinhardtii*, a quasi-spherical, 10- μm -long unicellular alga exhibiting phototaxis. The sensitivity of its swimming direction to external illumination provides a non-invasive means to control swimmer distributions and the flows they generate. We explore transport mechanisms across two distinct scales: a population of *C. reinhardtii*, and a single microswimmer.

At the population scale, dense suspensions of *C. reinhardtii* undergo bioconvective instabilities that produce macroscopic flow structures and significantly alter tracer transport (3,4). By exploiting phototactic responses, we steer these collective flows into directed transport (Figure 1, left).

At the individual scale, we introduce a novel active particle in an aqueous two-phase system: a droplet propelled by an encapsulated, motile, light-sensitive microalga. The confined swimming activity generates self-propulsion of the droplet, enabling light-controlled transport of volumetric loads (Figure 1, right).

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