The dynamics of active suspensions: effects of confinement and of concentration

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We use a kinetic theory and continuum simulations to study the emergence of coherent structures, large-scale flows, and collective dynamics in suspensions of motile particles such as swimming microorganisms or artificial microswimmers, focusing specifically on the effects of oxytaxis in confinement and of concentration.

First, we extend the previous kinetic model of Saintillan & Shelley [1] to account for oxytaxis using a run-and-tumble model, in which the swimmers change their tumbling frequency based on the temporal changes in the oxygen field they sample. Using three-dimensional numerical simulations, we study the behavior of such suspensions in thin liquid films surrounded by oxygen baths on both sides. As the microorganisms consume the dissolved oxygen, gradients form causing them to swim towards the free surfaces where the oxygen concentration is higher. We demonstrate the existence of a transition from one-dimensional dynamics (in the direction normal to the interfaces) in thin films to chaotic three-dimensional dynamics and pattern formation as film thickness increases. This transition, which is consistent with experimental observations, is shown to be associated with an enhancement of oxygen mixing and transport into the liquid.

Next, we investigate the effects of increasing concentration by including in the model a steric alignment potential in the spirit of the classic Doi & Edwards theory [2] for passive rod suspensions. We first present results from linear stability analyses, for both a uniform isotropic suspension and a uniform aligned suspension, and show that steric interactions lead to new modes of instability, including in suspensions of pullers (head-actuated swimmers), which are stable in the dilute limit. The linear predictions are then compared to fully non-linear three-dimensional simulations, and we characterize the long-time dynamics in suspensions of both pushers and pullers.

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References

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[2] Doi, M. & Edwards, S. F. "Dynamics of rod-like macromolecules in concentrated solution," *J. Chem. Soc. Faraday Transactions II* **74**, 560 (1978).

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