Large-Scale Coherence in Bacterial Dynamics

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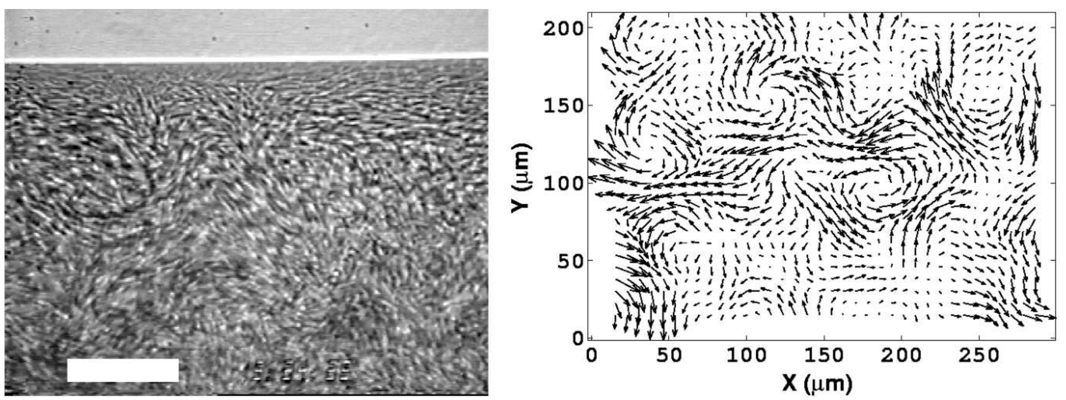
In many biological contexts, and particularly in bacterial systems, the processes of intercellular communication, chemotaxis, and metabolite uptake take place in a fluid environment in which dissipation dominates inertia, and diffusion would appear to dominate advection. Indeed, on the few-micron scale ℓ of an individual bacterium, at typical fluid velocities u achieved by self-propulsion, the Peclet number $Pe = u\ell/D \ll 1$. Yet, recent theoretical and experimental studies have shown that large-scale cooperative behavior can drastically modify this picture. This involves coherent swimming (left figure) at high volume fractions, with transient, recurring vortex streets straddling high-speed jets and



Swirling bacterial flows (left) in a concentrated suspension near a contact line. Vector field of bacterial swimming (right), showing vortex street generation.

greatly enhanced velocities and scales (right) so that $Pe \gg 1$. These and earlier observations involving anomalous diffusion of passive scalars in dense suspensions help define a whole set of challenging problems at the interface of physics and biology:

• How do we construct a many-body dynamical theory (coarse-grained) for a suspension of hydrodynamically-interacting cells, each with stochastic internal dynamics, responding to and secreting chemical signals?

• What are the proper experimental model systems and measurements to quantify such collective behavior?

• What are the implications for biological processes, including micro-ecology, quorum sensing, and biofilm formation?