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Bacterial Swimming and Accumulation at the Fluid Boundaries

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Micro-organisms often reside and thrive at the fluid boundaries. The tendency of accumulation is particularly strong for flagellated bacteria such as *Escherichia coli*, *Vibro alginolyticus*, and *Caulobacter crescentus*. We measured the distribution of a forward swimming strain of *Caulobacter crescentus* near a solid surface using a three-dimensional tracking technique based on darkfield microscopy and found that the swimming bacteria accumulate heavily within micrometers from the surface, even though individual swimmers are not trapped long enough to display circular trajectories. We attributed this accumulation to frequent collisions of the swimming cells with the surface, causing them to align parallel to the surface as they continually move forward. The extent of accumulation at the steady state is accounted for by balancing alignment caused by these collisions with the rotational Brownian motion of the micrometer-sized bacteria. We performed simulations based on this model, which reproduces the measured results. Additional simulations demonstrate the dependence of accumulation on swimming speed and cell size, showing that longer and faster cells accumulate more near a surface than shorter and slower ones do. Our ongoing experimental effort also includes observation of similar phenomena at the interfaces of either water-oil or water-air, noting even stronger trapping of the swimming bacteria than near a solid surface. These studies reveal a rich range of fluid physics for further analysis.