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Flow-induced symmetry breaking in growing bacterial biofilms

PHILIP PEARCE, Harvard Medical School, BOYA SONG, DOMINIC SKINNER, RACHEL MOK, Massachusetts Institute of Technology, RAIMO HARTMANN, PRAVEEN SINGH, Max Planck Institute for Terrestrial Microbiology, JEFFREY OISHI, Bates College, KNUT DRESCHER, Max Planck Institute for Terrestrial Microbiology, JORN DUNKEL, Massachusetts Institute of Technology — Bacterial biofilms are matrix-bound multicellular communities. Biofilms represent a major form of microbial life on Earth and serve as a model active nematic system, in which activity results from growth of the rod-shaped bacterial cells. In their natural environments, from human organs to industrial pipelines, biofilms have evolved to grow robustly under significant fluid shear. Despite intense practical and theoretical interest, it is unclear how strong fluid flow alters the local and global architectures of biofilms. Here, we combine highly time-resolved single-cell live imaging with 3D multi-scale modeling to investigate the effects of flow on the dynamics of all individual cells in growing biofilms. Our experiments and cell-based simulations reveal that, in the initial stages of development, the flow induces a downstream gradient in cell orientation, causing asymmetrical droplet-like biofilm shapes. In the later stages, when the majority of cells are sheltered from the flow by the surrounding extracellular matrix, buckling-induced cell verticalization in the biofilm core restores radially symmetric biofilm growth, in agreement with predictions from a 3D continuum model.

Philip Pearce
Harvard Medical School

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