PHYSICAL MATH SEMINAR

Rheotaxis: Invasion of bacteria swimming upstream into microstructured devices

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ABSTRACT:

Bacteria have the remarkable ability to swim upstream, a process called rheotaxis. This motion against flows can cause not only respiratory, gastrointestinal, and urinary tract infections, but also the contamination of medical devices and hospital equipment. However, it remains unknown how bacteria navigate upstream through these microstructured environments with narrow channels and wide cavities. Here, combining microbiology experiments with nanofabrication and mathematical modeling, we reveal how Escherichia coli bacteria invade in four stages: The (I) break-out from colonized cavities against the current, (II) propagation upstream in narrow connectors, (III) infiltration of new cavities, and (IV) colonization with biofilms under flow. Surprisingly, we find that wider channels with faster counterflows are actually more prone to invasion, but these incursions can be inhibited effectively with sharp corner designs. Next, we explore the serial invasion of multiple cavities in a row. We discover that instead of colonizing these nodes one by one slowly, the bacteria rapidly swim all the way upstream and form biofilm streamers there to take possession of the entire channel three times faster. These results shed new light on pathogen motility in host-relevant shear regimes, and they offer solutions that can be implemented directly in biomedical devices.

BIO: Arnold Mathijssen completed his undergraduate at University College London (2012), his PhD in biophysics with Julia Yeomans FRS at the University Oxford (2016), and a postdoc in bioengineering with Manu Prakash at Stanford University (2020). He is now a faculty member at the University of Pennsylvania and director of the Penn Working Group on Environmental and Biological Fluid Dynamics. Arnold was awarded the Sir Sam Edwards PhD Thesis Prize by the UK Institute of Physics, the '30 under 30' Award by Scientific American, the HFSP Cross-Disciplinary Fellowship, the Charles Kittel Award by the American Physical Society, and the Paul Sniegowski Award for Mentorship of Undergraduate Research. Arnold is also a popular science communicator known for culinary fluid mechanics and the science of pour-over coffee, with coverage in The New York Times, The Guardian, CNN, FOX, USA Today, and Food & Wine Magazine.

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