Internship

Modeling Bacterial Navigation in Complex Porous Environments: Chemotaxis and Quorum Sensing

Context: Many natural systems, including biological tissues like the gut, are composed of complex porous environments that are strongly heterogeneous at the microscale. This heterogeneity arises from a wide distribution of pore sizes and distinct features such as dead-end pores (DEPs)—closed structures that do not transmit flow. These DEPs play a crucial role in microbial ecology. For example, in the gut, when bacteria enter such confined zones, they release a communication molecule known as Autoinducer-2 (AI-2). Since these molecules are trapped in dead ends, local gradients form. Certain bacteria can sense these gradients via a process called chemotaxis, allowing them to swim toward areas of higher concentration. Using microfluidic experiments, we have shown that such microstructural features create hotspots of bacterial accumulation, influencing the global organization of bacterial colonies in the gut.

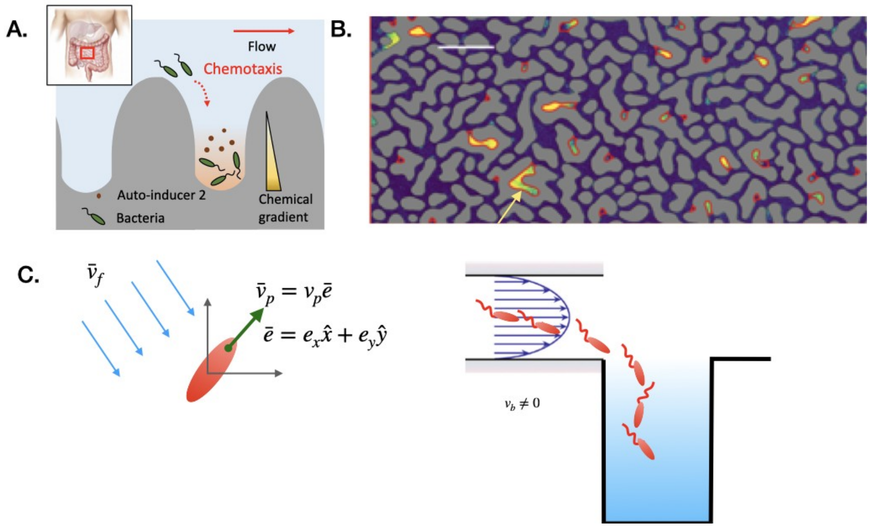

Figure: (A) Bacteria in the gut enter dead-end pores, where they release the signaling molecule AI-2, forming local chemical gradients. (B) Experimental visualization of bacteria accumulating in dead-end regions within a porous microfluidic network. (C) Modeling approach: COMSOL simulations provide background velocity and concentration fields, which are used to simulate run-and-tumble particle trajectories with chemotaxis in structured environments.

Project: In this project, the student will develop numerical tools to model bacterial swimming and chemotaxis in complex porous environments, inspired by gut-like microstructures. Using COMSOL Multiphysics, we will first compute fluid velocity and time-dependent chemical concentration fields within heterogeneous networks. These fields will serve as the background upon which Lagrangian particle-based simulations of run-and-tumble bacteria will be implemented. The goal is to capture how local gradients and microstructure guide bacterial trajectories and collective accumulation.

Required Qualifications:

- Background in physics, applied mathematics, or computational biology
- Experience with coding (Python or MATLAB preferred)
- Interest in active matter, microbial behavior, or porous media

Duration: 5-6 months
Grant: 600 euros per month
Degree: M2, Starting from February 2026.
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References:

- Scheidweiler, D., Bordoloi, A.D., et al. Nature Communications 15, 191, 2024
- Bordoloi, A.D., Scheidweiler, et al, Nature Communications 13, 3820, 2022