Proposal for a Master 2 internship

The air-flow rush: How do bacteria navigate complex oxygen-flow environments?

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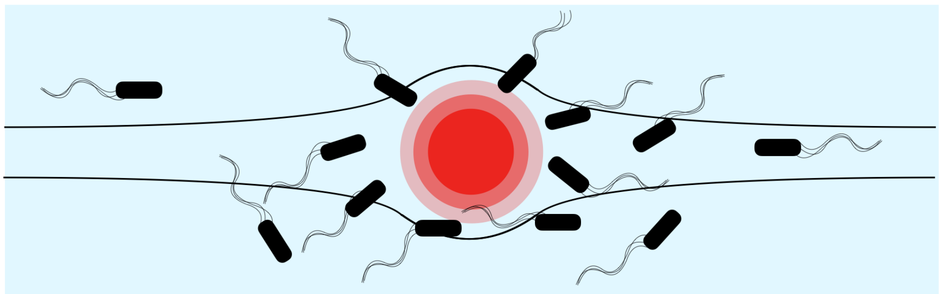
To promote the repair and recolonization of degraded soils, it is essential to understand how microorganisms navigate and establish themselves sustainably in these environments. Some soil bacteria require a fluid medium containing nutrients and oxygen. However, these environmental conditions are inherently complex: fluids circulate through a porous matrix where oxygen and nutrients are distributed heterogeneously. Bacteria detect these gradients and bias their swimming to find the most favorable environment. The question then arises: how do swimming, gradients, and flows couple together? How do fluid flows alter oxygen gradients, and thus the navigation of a single bacterium? Of an entire population? What are the feedback loops of oxygen consumption in these complex environments?

To address these questions, the objective of the internship is to develop an innovative microfluidic device to study bacterial behavior in an oxygen gradient, with or without flow. A pore created in a Hele-Shaw cell will allow oxygen diffusion, forming a two-dimensional Gaussian gradient in a bacterial suspension. Using a fluorescent oxygen marker, a map of the gradient will be recorded simultaneously with bacterial dynamics via video microscopy.



In parallel, we will conduct mathematical modeling of the active suspension within the heterogeneous medium. Approaches at different scales will be considered. The microscopic description will be based on solving the Stokes equations, with bacteria modeled as hydrodynamic dipoles. Combined with convection-diffusion equations for oxygen, this approach will capture individual interactions and emergent behaviors. As for the macroscopic approach, it will be useful for describing the global properties of the suspension at large scales. A Darcy-type model for flow in the porous medium will be coupled with a Keller-Segel-type equation to describe bacterial swimming in the oxygen gradient. These models will complementarily study the collective dynamics observed experimentally, and the influence of various system parameters such as bacterial volume fraction or oxygen gradient profile.

References:
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