Internship propositions in the **Active Fluids Group** of the PMMH-ESPCI

Laboratoire de Physique et Mécanique des Milieux Hétérogènes (PMMH) – ESPCI-CNRS UMR 7636
Jussieu campus - 7, quai St Bernard, 75231 Paris CEDEX 05
Contact: Eric Clément : eric.clement@upmc.fr **WEB page : https://blog.espci.fr/eclement**

The projects currently developed, in the "*active fluids group*" of the PMMH are oriented towards applying the concepts of "*active matter*" to the dynamics and hydrodynamics of bacterial populations. Active matter is a new subject at the crossing point between hydrodynamics, statistical physics and biology. It focuses on the central role of individual motility and the nature of microscopic interactions in the emergence of collective organization and transport effects observed in nature. The final objective is to clarify important medical and bio-technological questions around contamination processes in natural environments or in biological networks. This questioning will also contribute to assess the role of bacterial transport on the many self-organization processes occurring in bacterial ecology.

Bacteria chemotaxis, developing a novel Lagrangian view point

In this context, the group is currently assessing the swimming properties of motile bacteria exploring individually or collectively, different controlled environmental situations. In the lab, we are using soft-lithography microfluidics to design micro- channels with different levels of geometrical complexity. Varying the chemical and the rheological properties of the suspending fluid, we currently seek to determine the emergent transport properties of bacterial suspensions. To this purpose, we developed an original automated Lagrangian tracking device suited to follow in 3D, selected fluorescent motile bacteria over long times and eventually visualize directly their flagellar dynamics.

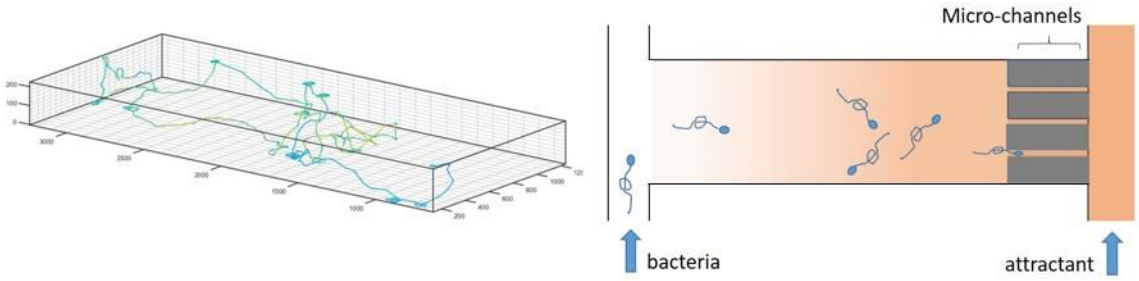

Figure – (left) *3D tracking of fluorescent bacteria in a microfluidic channels showing the swimming trajectory of a single wild-type E. coli for more than 10 minutes (Lagrangian view point). The color encodes the swimming velocity.* ***(Right)*** *Sketch of a microfluidic cell allowing the monitoring of bacteria swimming along a concentration gradient (chemotaxis).*

In this project we will build a microfluidic channel to understand the chemotactic response of a wild-type E.coli in the presence of attractant molecules. This device will shed an original light on the behavioral response at the level of an individual that can be tracked over long times. Also, another important feature will be the capacity to invade micro-channels when driven by this attractant gradient, which is a question of upmost importance in biology and physiology. Note that this system can also be extended to other micro-organisms such as algae and protists. If times allow we will investigate the possibility to extend the work to a collaboration with Florence Elias (PMMH) and Laurent Seuront a marine biologist (LOG Wimereux) and develop a general vision of the chemotactic response for a large class of microorganisms which could be the objective of a future doctoral work.

Expected skills from the candidates-The techniques developed to grow and manipulate these bacteria are safe and simple, they do not need any a priori knowledge in microbiology. This experimental project is mainly based on video-visualization under the microscope, image analysis and microfluidics techniques. According to the eventual taste of the candidate, some aspects can also be turned into more theoretical or numerical investigations.

Recent publications of the PMMH-Active fluid group

- ***Frustrated "run and tumble" of swimming, E-coli bacteria in nematic liquid crystals.*** M. Goral, Eric Clement, T. Darnige, T. Lopez-Leon, A.Lindner, Proceedings of the Royal Society: Interface Focus **12**, 20220039 (2022).

- ***Flow-dependent motility determines the dispersion of microbes in a porous medium,*** M.Dentz, A. Creppy, C. Douarche, E. Clement, H. Auradou, Journal of Fluid Mechanics , **946** , A33 (2022).
- ***Run-to-tumble variability controls the surface residence times of E. coli bacteria.*** G. Junot, T. Darnige, A. Lindner, V. A. Martinez, J. Arlt, A. Dawson, W. C. K. Poon, H. Auradou, E.Clément, Phys. Rev. Lett. **128**, 248101 (2022).
- ***Single-trajectory characterization of active swimmers in a flow*****,** G.Junot, E.Clément, H.Auradou and R. García-García, Physical Review E **103**, 032608 (2021).
- **Chirality-induced bacterial rheotaxis in bulk shear flows.** G.Jing, A. Zöttl, E. Clément, A. Lindner, Science Advances, **6**, eabb2012 (2020).
- ***3D spatial exploration by E. coli echoes motor temporal variability****.* N. Figueroa-Morales, T. Darnige, C.Douarche, V. Martinez, R. Soto, A. Lindner, E. Clément, Phys.Rev.X **10**, 021004 (2020).
- ***E.coli« super-contaminates » narrow channels fostered by broad motor switching statistics****.* N. Figueroa-Morales, A. Rivera, E. Altshuler, R. Soto, A. Lindner, E. Clément, Science Advances, **6**, eaay0155 (2020).
- ***A combined rheometry and imaging study of viscosity reduction in bacterial suspensions****,* V. Martinez, E. Clément, J. Arlt, C. Douarche, A. Dawson, J. Schwarz-Linek, A. Creppy, V. Skultéty, A. Morozov, H. Auradou and W. Poon, Proceedings of the National Academy of Sciences, **117**, 2326-2331 (2020).
- ***Vortex flow generation in magnetotactic bacteria droplets,*** B.Vincenti, G. Ramos, M.-L. Cordero, C. Douarche, R. Soto, E. Clement, Nature Comm, **10**, 5082 (2019).
- ***Oscillatory surface rheotaxis of swimming E. coli bacteria*** , A. Mathijssen, N. Figueroa-Morales, G. Junot, E. Clément, A.Lindner, A. Zöttl*,* Nature Comm. **10**, 3434 (2019).