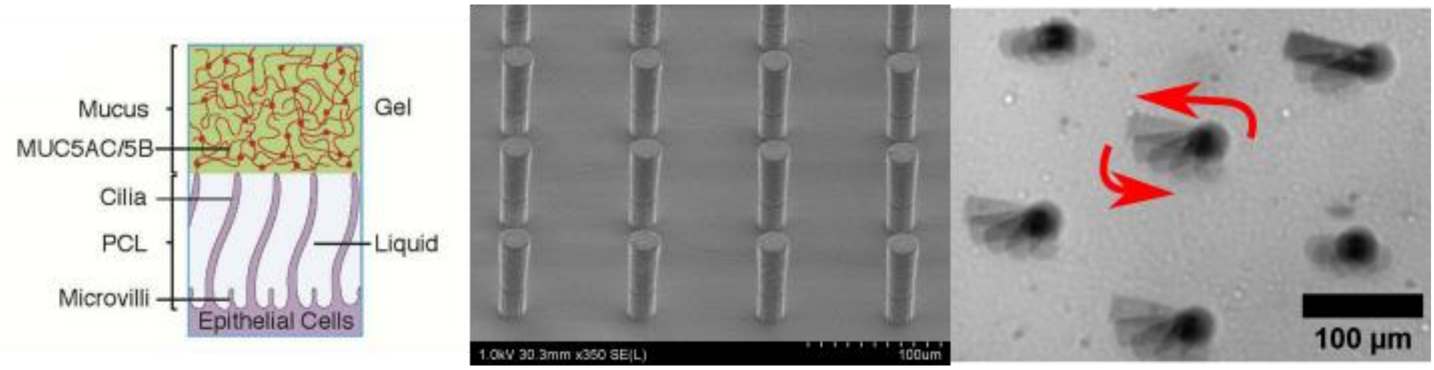
Stage de Master 2

Couette-Poiseuille Transition in Artificial Magnetic Microcilia Induced Flow

Our lungs are lined with a thin layer of mucus which aids in clearing away foreign particulate, like dust or smoke. To remove this dirty mucus from the lung, the bronchi are lined with cilia: small hair like structures which beat, forcing the mucus to flow upwards. The transport of mucus promotes convective mixing, keeping some particles on the mucus surface, while others transcend it. The mucus itself consists of two layers: a thick layer that protects the lungs, and a thin periciliary layer, which allows the cilia to efficiently beat, moving the fluid forward[1]. These cilia move in an asynchronous *antiplectic* pattern, which has been shown experimentally to increase the efficiency of transport[2]. Both the periciliary layer, and the *antiplectic* movement of the cilia have a considerable effect on the flow profile of transported mucus, and thus its mixing. Most experiments of cilia flow show a Couette dominant flow[3], with a maximum velocity at the cilia tip, however recent experiments have shown that this is not always the case, with a Poiseuille dominated flow developing in a closed circuit.

The goal of this M2 internship will be to establish under what conditions cilia induced flow transitions from a pressure driven profile to a shear driven profile. To do this, a variety of cilia arrangements as well as fluid conditions will need to be compared with their flow profiles. To better model human pulmonary mucus, we intend to eventually extend this study to include biphasic flows imitating the watery periciliary layer and hydrogel mucus layer flow.



Left: A diagram of the human bronchial lining, including cilia, paraciliary fluid and mucus[1]. Middle: SEM images of microfabricated magnetic cilia Right: Time lapse of a magnetic cilia due to magnetic actuation.

Specific techniques or methods:

- Design and microfabrication of microchannels, including microcilia with embedded magnetic microparticles.
- Brightfield and fluorescent microscopy, with special focus on micro-particle image velocimetry.
- Image analysis, preparing video for particle tracking.

References:

[1] Button *et al*. (2012) *Periciliary brush promotes the lung health by separating the mucus layer from airway epithelia*. Science 337(6097): 937-941.

[2] Osterman and Vilfan (2011) *Finding the ciliary beating pattern with optimal efficiency*. PNAS 108(38): 15727-15732.

[3] Shields *et al.* (2010) *Biomimetic cilia arrays generate simultaneous pumping and mixing regimes*. PNAS 107(36):15670-15675.

Internship period: February - July 2024. Dates can be adapted around this period. This internship will take place in PHENIX laboratory, located on the Pierre et Marie Curie campus of Sorbonne Université.

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Sorbonne University is a world-class, research-intensive university bringing together a broad range of arts, humanities, social sciences, natural sciences, engineering and medicine. The scientific Pierre and Marie Curie campus was completely refurbished in 2016. PHENIX is a laboratory at the interface between Chemistry, Physics and Materials Science with a long-standing expertise of colloidal systems, electrolytes and fluids under confinement. Its strength lies in a combination of experimental and modelling activities (numerical simulations). Several international projects and networks are in place in PHENIX, providing a rich and multinational environment.