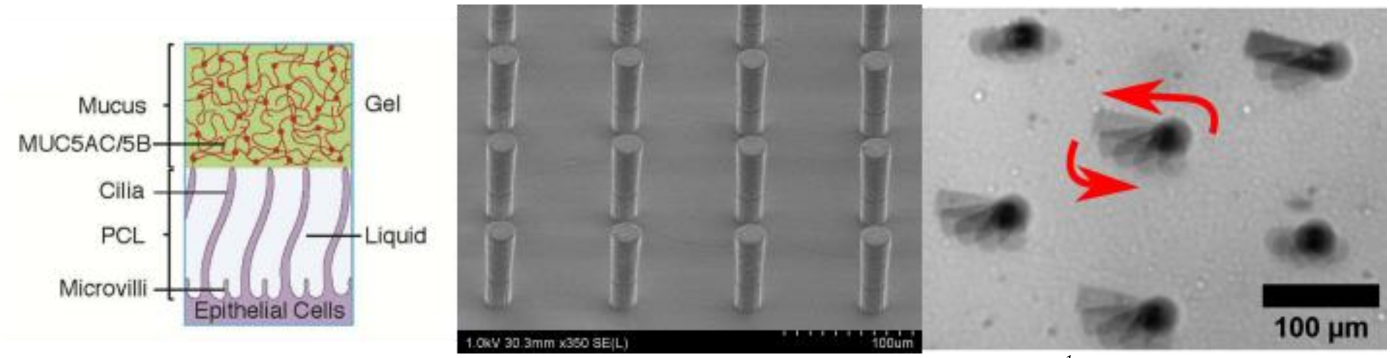
Stage de Master 2

Biphasic fluid flow induced by artificial magnetic cilia

Our lungs are lined with a thin layer of mucus which aids in clearing away foreign particulate, like pathogens and airborne particles (pollution, smoke). To remove this dirty mucus from the lung, the bronchi are lined with cilia: small hair like structures which beat, forcing the mucus flows upwards to be swallowed and eliminated by the digestive system. The transport of mucus promotes convective mixing, keeping some particles on the mucus surface, while others transcend it. Mucus itself however is a thick viscoelastic gel, which resists deformation and thereby strongly resists flow[1].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[2]. These cilia move in an asynchronous *antiplectic* pattern, which has been shown experimentally to increase the efficiency of transport[3]. 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.

The goal of this M2 internship will be to experimentally evaluate the impact of *antiplectic* cilia beating on the movement of biphasic fluid. To achieve this, we first create artificial magnetic microscopic cilia arrays. These arrays can then be actuated by an external magnetic field, imitating the movement of epithelial cilia. Microchannels containing these cilia can be filled with a special biphasic fluid, which imitates the periciliary and gel layer of the airway mucus. In doing so we intend to establish the relationship between the thickness of the mucus layers, and the overall mucus flow due to cilia beating.



Left: A diagram of the human bronchial lining, including cilia, periciliary fluid (PCL) and mucus[1]. Middle: scanning electron microscopy 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 artificial cilia 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] Radiom *et al.* (2021) *Magnetic wire active microrheology of human respiratory mucus*. Soft Matter 17: 7585-7595.

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

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

Internship period: February - July 2025. Dates can be adapted around this period. This internship will take place in the Matière et Systemes Complexes laboratory at Université Paris Cité.

Contact: Jean-François Berret - jean-francois.berret@u-paris.fr
Charles Paul Moore - cpmoore@ualberta.ca

Le laboratoire « Matière et Systèmes Complexes » (MSC) est une unité mixte de recherche du CNRS et de l'université (UMR 7057). Il a pour sujet d'étude la matière et les systèmes complexes sous toutes leurs formes, des fluides montrant des phénomènes complexes non-linéaires aux systèmes proches de la géophysique, de l'environnement et des systèmes vivants.