Internship director: Thomas Risler

Thesis possibility after internship: YES

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Active-gel theory of confined collective cell migration

The behavior of multicellular tissues arises from the coordinated actions of their individual cells. In living organisms, these cell populations interact with their surrounding microenvironment, which includes both physical and biochemical signals from the extracellular matrix (ECM) and neighboring tissues. These environments are intricate, covering a range of scales—from microscopic (molecular sizes of ECM biopolymers) to mesoscopic (large-scale variations like physical boundaries or confinement). Pascal Silberzan's team at PCC studies how collective cell migration is affected by different multiscale guiding cues in vitro. When plated on an adhesive surface, the cells' intrinsic activity generates spontaneous, large-scale collective flows. By designing various well-defined microfabricated surfaces, the team studies how subcellular and supracellular guiding cues control the properties of collective migration.

The theory group at PCC has expertise in using active-gel theory—a particular branch of active-matter theory—to describe out-of-equilibrium biological active matter [1-3]. Recently, inspired by intriguing experimental results, the theory group has studied the forces and self-propulsion velocity of active topological defects on a surface [4,5]. During this internship, we will use the general framework of active-gel theory to describe or predict migration patterns in populations of cells.

[1] Marchetti *et al.* (2013). *Hydrodynamics of soft active matter*. Rev. Mod. Phys. *85*, 1143.
[2] Saw, Xi, Ladoux, and Lim (2018). *Biological Tissues as Active Nematic Liquid Crystals*. Adv. Mat. *0*, 1802579.
[3] Joanny and Indekeu (2023). *Statistical physics of active matter, cell division and cell aggregation*. Physica A *631*, 129314.
[4] Brézin, Risler, and Joanny (2022). *Spontaneous flow created by active topological defects*. Eur. Phys. J. E *45*, 30.
[5] Sarkar *et al.* (2023). *Crisscross multilayering of cell sheets*. PNAS Nexus, *2*, pgad034.
[6] Giuglaris, C. (2024). *Controlling collective cell migration with multiscale cues*, PhD thesis.

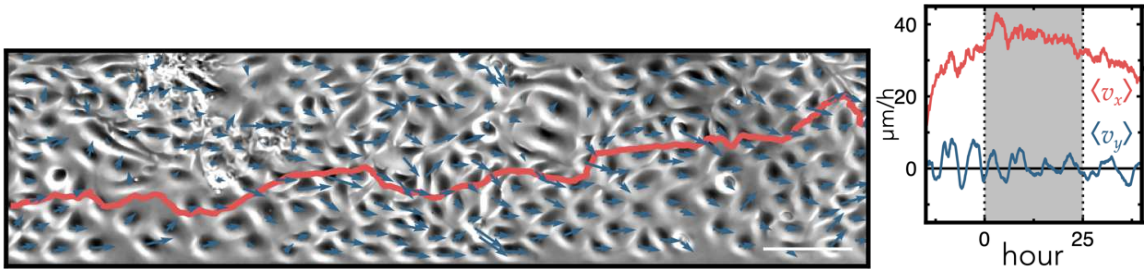

Figure 1: Left: Example of a spontaneous flow pattern on a microfabricated surface, taken from ref. [6]. Human Bronchial Epithelial Cells (HBECs) are plated on a "racetrack" adhesive pattern with a width of 250 µm, shown here in phase contrast. After reaching confluency, the cells collectively flow while exhibiting traveling waves in their density, cellular orientation, and velocity component orthogonal to the main flow direction. Red: example of a cell trajectory, displaying oscillations. Scale bar 100 µm. Right: Time evolution of the velocity components v_x and v_y in a track. Image courtesy of C. Giuglaris (ref. [6]).