Collective fluid-structure interactions of bio-inspired active channels

M2 internship (5-6 months)
Location : IRPHE, 49 Rue F. Joliot Curie 13013 Marseille
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Grant: ~600 euros/month
Starting date: February 2025 (flexible)
PhD opportunity: possibility to apply to the doctoral school PhD call.

Keywords. Biological fluid mechanics, Fluid-structure interactions, Numerical simulation, Collective behavior

Context. From unicellular organisms to humans, liquid flows in vascular networks are among the most effective ways to transport matter and information for life. In mammals, the lymphatic network provides interstitial fluid transport from tissues to the cardiovascular system in the absence of a central pumping system [1]. Instead, robust fluid transport emerges from the coordination of local fluid-structure interactions, combining active vessel contractions and passive leaflet deformation (Fig. 1(a)). The asymmetric flow-structure behavior of the leaflets provides flow directionality and results in net flow transport in response to contractions. Understanding this natural design is essential for understanding dysfunctions of the lymphatic system and for inspiring the design of engineered systems capable of autonomous and robust fluid transport. **How did nature select the optimal distance between leaflets? Without physiological constraints, can we design a system more efficient than nature to transport fluid? Can we control complex collective behavior of the leaflets, such as waves?** To address these questions, we have designed a bio-inspired experimental setup in which a bed of soft leaflets responds to wall contractions in a mini-channel (Fig. 1(b)). The goal of the internship is to develop and apply a computational/theoretical framework that can help us understand the collective flow-structure response of the leaflets.

Research objectives. The student will get familiar with a 2D lattice-Boltzmann code previously developed in the group [2] and **perform new developments and simulations aiming to reproduce the observed experimental dynamics**. He/she will **perform detailed analysis of the computational results, including space-time analysis of the flow-structure response and the development of analytical models** recapitulating the observed dynamics. Additional

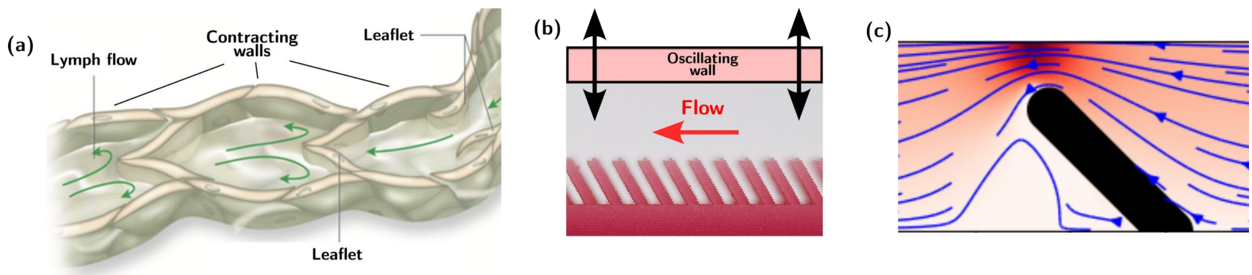

Fig. 1- (a) Schematic view of a lymphatic vessel. (b) Bio-inspired experimental setup where a bed of soft leaflets in a mini-channel is forced by an oscillating wall. (c) Example of simulated fluid flow around a model leaflet.

numerical explorations will allow to go beyond regimes currently reached in the experiments by considering alternative boundary conditions, excitation signals and leaflets properties, thus providing insights for possible future experimental developments. The student will closely interact with other students in the group, especially with two PhD students respectively developing the numerical code and performing the experiments.

Candidate profile. The internship is open to students with a background in **applied mathematics, physics or mechanics.**

[1] Moore & Bertram, Ann. Rev. Fluid Mech., 2018, 50 (459-482)
[2] Gsell et al., Phys. Rev. E, 2019, 100, 033306