Interaction between fluids and cell membranes:
Instabilities and pattern formation

The ability of a cell to alter its shape is a fundamental feature in cell biology, and it is vital for the cell to achieve a variety of functions. One of the sources of the alterations in cell-membrane shape are the forces exerted on the membrane by the surrounding fluids, such as the dense layer of actin filament which surrounds the membrane.

In this internship, we will study theoretically the fluid mechanics of a cell membrane interacting with such a surrounding fluid. We model the membrane as a two-dimensional fluid layer, which flows, alters its tension and shape. Actin exerts forces on the membrane because of its flow, and thus alters the membrane shape. On the other hand, the membrane shape alters the actin state through a geometrical constraint: The actin velocity at the membrane must match that of the membrane layer. This feedback yields a **rich, complex physics** which will be the main subject of investigation of the internship.

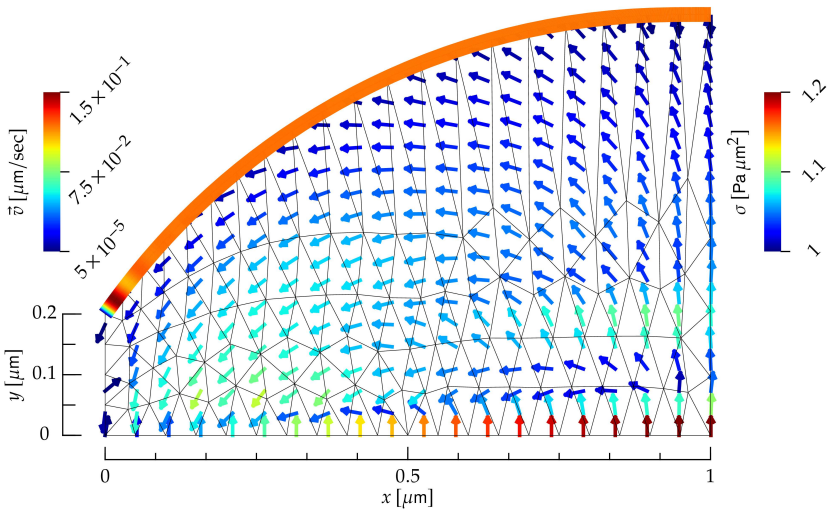


Figure 1: *A membrane, the colored curve edge on top, interacting with a bulk fluid, which fills the region with arrows. The fluid is injected from the bottom with a velocity directed upwards. The velocity direction and intensity is shown by the arrows and left color bar, respectively. The membrane tension is shown in the right color bar. See here for an animated version.*

We are looking for a motivated student with a background in theoretical physics (soft matter or fluid mechanics) and a working knowledge of Python.

The scientific goal of the internship will be, among others, to **characterize instability thresholds leading to membrane buckling**. To achieve this, the student will be tasked with the numerical solution, with the finite-element method, of the partial differential equations which describe the fluid flow on a curved geometry, and with the physical interpretation of the results. This solution will be made with a **user-friendly library** [1] written in Python, named .

The strong points of this internship are:

- **Scientific publications will be aimed at the best scientific journals**, both in physics and at the boundary between physics and biology.
- **The student will acquire valuable skills**, such as proficiency in Python, learning and mastering of the finite-element method.
- The lively scientific environment at UMR 168, Institut Curie, will allow the student to find and establish new experimental collaborations, to push forward and test the model precisions. Also, the cross-disciplinary character of this internship, bridging between theoretical physics (fluid dynamics), differential geometry (membrane shape), and experimental physics and biology (experimental applications), will offer numerous directions for future developments.

Practical information:

- Internship duration is flexible, ranging from three to six months.
- After the internship, **the student will be supported and supervised for his/her application to a Ph.D. position**—for example the École Doctorale "Physique en Île-de-France" Ph.D. scholarship.
- Salary: the student will be paid according to the French regulations for internships.

For further information, please contact me at michele.castellana@curie.fr.

References

[1] Dennis Wörthmüller, Gaetano Ferraro, Pierre Sens, and Michele Castellana. IRENE: A fluId layeR finitE-elemeNt softwarE. *Comput. Phys. Commun.*, 330:110366, 2027.