pH-gradient-driven membrane deformations

Supervisor : Hélène Berthoumieux
e-mail: helene.berthoumieux@espci.fr Phone number:0664430483
Web page: https://www.lptmc.jussieu.fr/users/berthoumieux
Stage location : Gulliver lab, ESPCI.

Cosupervisor: Jonas Ranft, jonas.ranft@ens.psl.eu, IBENS Paris

Summary:
Mitochondria are the power house of the cell as they are the place of ATP production. This organelle is organized in compartments of nanometric size, delimited by lipid membranes, which shape is dynamic and depends on the rate of ATP production. The system is maintained out-of-equilibrium via a surface pH gradient occurring at the organelle membrane which is generated by the transmembrane proteins of the respiratory chain. Understanding the relation between the molecular composition, the membrane shape and the efficiency for ATP synthesis is of particular interest as mitochondria are involved in essential processes such as the cell death.

In this internship, we propose to develop a theoretical framework modeling the coupling between the mitochondria membrane shape, the rate of ATP synthesis and the surface proton flux. To do so, we introduce a mechanical description for inhomogeneous membrane using the Helfrich model and reaction-diffusion schemes for the transmembrane proteins and the proton concentration gradient. Using Green's function formalism, we will derive the phase diagram of compartment shapes as a function of the coupling between membrane mechanics and the surface reaction-diffusion.

This is a theoretical internship in collaboration with the experimental group of S. Bloch in the Freïe Universität, Berlin.

References:
1. Review Mitochondrial Cristae: Where Beauty Meets Functionality, Cogliati et al., Trends in Biochemical Sciences, 41 (2016).
2. Membrane Deformation under Local pH Gradient: Mimicking Mitochondrial Cristae Dynamics, Khalifat et al., Biophysical Journal, 95 (2008).
3. Mitochondrial cristae modeled as an out-of-equilibrium membrane driven by a proton field, Patil et al., Phys. Rev. E, 102 (2020)
4. A model of membrane deformations driven by a surface pH gradient, Mendes et *al*. ArXiv, (2022)