Optical control of cell and nuclear shapes in multicellular systems

Project for students in master or engineering school

IBDM, Turing Center for Living Systems, Marseille

Team*: Physical Approaches to Cell Dynamics and Tissue Morphogenesis*

A fundamental challenge in biology is to understand how microscopic forces generated within individual cells bring about collective changes in cell shape and position to produce complex and reproducible morphologies. A classical strategy to tackle this challenge is to image developing tissues and to infer how cellular forces are generated and transmitted to shape tissues. However, the cells not only generate mechanical stresses but also respond to them, confounding our understanding of how mechanical stresses produce cell and tissue shapes. Here, we aim to develop and use an alternative method that consists of applying controlled forces on cells to determine the mechanical basis of morphogenesis.

The method combines multiple optical traps with high-resolution imaging (Nishizawa et al. 2023, Figure). It allows us to produce shrinkage and extension of cell-cell contacts through different push and pull manipulations in developing epithelia (Figure). This interdisciplinary project aims to control and probe cell and nuclear shapes in 3-D. More specifically, the developed method will be applied to determine the propagation of cell and nuclear deformation in different cellular assemblies, from single embryonic stem cells to 3D tissues. Furthermore, we will probe how mechanical forces affect cellular morphodynamics and cell differentiation.

The project requires a solid background in physics or biology, computational skills (Python, C++ or Matlab), and a strong interest in the dynamics of living systems. The project will be conducted in a biophysics lab combining experimental and theoretical approaches. This project may lead to a funded PhD (funds already secured).

Keywords: complex systems, advanced microscopy, image analysis, cell mechanics, developmental biology, physical models.

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Relevant publications:

- Nishizawa, K., Lin, S.-Z., Chardès, C., Rupprecht, J.-F., and Lenne, P.-F. (2023). Two-point optical manipulation reveals mechanosensitive remodeling of cell–cell contacts in vivo. Proceedings of the National Academy of Sciences *120*, e2212389120. 10.1073/pnas.2212389120.
- Lenne, P.-F., Rupprecht, J.-F., and Viasnoff, V. (2021). Cell Junction Mechanics beyond the Bounds of Adhesion and Tension. Developmental Cell. 10.1016/j.devcel.2020.12.018.