Actin networks as an isotropic active gel

Internship offer
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The cytoskeleton is a set of structures involved in maintaining and altering cell shape, as well as for a large fraction of intra-cellular transport. It is mostly composed of active networks of connected semi-flexible filaments. The actin cytoskeleton is made of filaments with a persistence length $l_p \sim 20\mu m$ connected by crosslinkers and molecular motors. The out-of equilibrium dynamics of filaments, and the energy consumption of molecular motors make it an active material.

Actin network are often represented in physics as active continuous visco-elastic materials, with possibly polar order. The theory describing their behaviour is called active gel theory, and has been of great interest for physicists and biologists.

However, there is little direct evidence that these models are relevant to actual actin networks. Moreover, the relations between the microscopic properties of actin and the material properties of the active gel remain largely elusive.

Project

In this internship, we propose to bridge the microscopic and macroscopic scale using a combination of discrete simulations and continuous theory.

We will use state-of-the-art simulations (Cytosim) to mimick large scale networks of actin filaments and molecular motors. We will compare their large-scale behaviour to the active gel theory. In particular, it is possible to measure the active stress in simulations. We will aim at understanding how an active stress emerges from network architecture and motor properties.

Methods

The student need to be familiar with some of the physical concepts required for this project (e.g. visco-elasticity, semi-flexible filaments). The student should develop skills in Python scripting to analyze simulations results. The student should have a keen interest for the biological and physical system under consideration.

Mentoring

The student will be mentored by Serge Dmitrieff (*Cellular Spatial Organization*, Institut Jacques Monod, Paris), a theoretical physicist developing analytical and numerical tools applied to cell mechanics and data analysis.

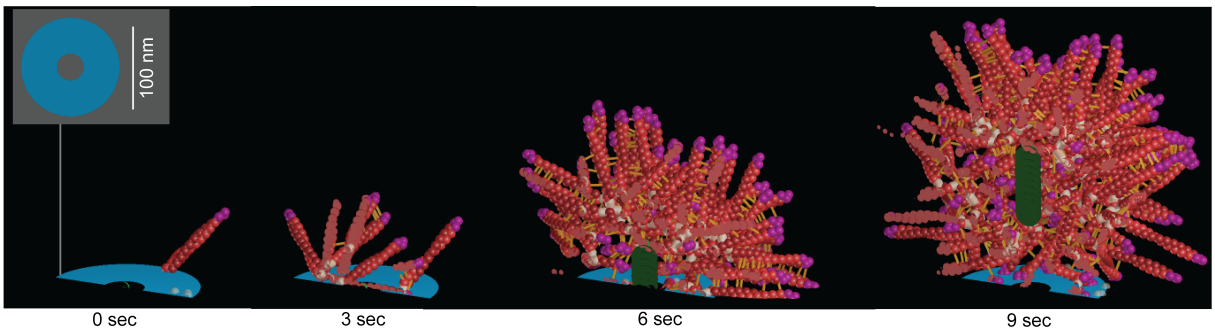

Figure 1: Overdamped Langevin simulation of actin filaments in yeast endocytosis. Actin filaments (red) polymerize at the nucleation disc (blue). Since actin is tethered to the vesicle (green), the polymerization of new filaments will pull the vesicle upwards. (+) ends of actin filaments are shown in purple.