

Master 2: International Centre for Fundamental Physics

INTERNSHIP PROPOSAL

Laboratory name: LPTMS CNRS identification code: UMR8626
Internship supervisor: FRULEUX, Antoine
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Internship location: Université Paris-Saclay, Orsay
Thesis possibility after internship: YES Funding: No

Stochastic Modeling of Plant Root Hair Growth

Plant cells are surrounded by a rigid extracellular matrix, the cell wall. Cell growth is commonly thought to result from a mechanical balance between the turgor pressure maintained inside the cell and wall tension. To grow, plant cells must remodel their cell wall, allowing viscoelastic relaxation and expansion. However, how the cell wall maintains its integrity to avoid rupture in response to mechanical perturbations or the stochasticity of secretion (exocytosis) remains largely unknown. In this project, we propose to investigate the couplings between the mechanical and chemical properties of the cell wall, focusing on a specific cell type: plant root hairs.

Plant root hairs are tube-shaped cells that extend radially from plant roots. They grow via polar tip expansion, a process in which turgor pressure, cell wall rheology, and biochemical remodeling interact through delayed feedback loops. These interactions produce oscillatory growth, characterized by quasi-periodic fluctuations in the expansion rate. We hypothesize that these oscillations arise as underdamped relaxation, driven by the stochasticity of molecular events and their coupling through delayed biochemical and mechanical feedbacks.

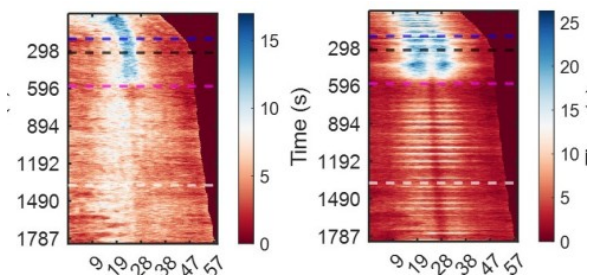


Figure 1: Spatio-temporal diagram of vesicular and calcium concentration at the cell apex. Courtesy of K.Haas

The intern will implement and analyze a model for root hair growth and its mechanochemical couplings using stochastic differential equations. Key tasks include numerical simulations, exploring dynamical regimes (e.g., oscillations, stability, or wall rupture), and validating predictions against experimental data. The project will also involve parameter inference using Bayesian methods and sensitivity analysis to identify critical factors influencing growth robustness. Regular collaboration with INRAE (Versailles) will ensure the model aligns with biological observations, providing a unique interdisciplinary experience.

The ideal candidate will have a background in theoretical physics, biophysics, or applied mathematics, with an interest in experimental collaboration. Autonomy, rigor, and a collaborative mindset are essential, as the intern will interact closely with experimentalists to refine the model.

Fruleux, Antoine, and Arezki Boudaoud. "Modulation of tissue growth heterogeneity by responses to mechanical stress." *Proceedings of the National Academy of Sciences* 116.6 (2019): 1940-1945.

Municio-Diaz, C., Muller, E., Drevensek, S., Fruleux, A., Lorenzetti, E., Boudaoud, A., & Minc, N. (2022). Mechanobiology of the cell wall—insights from tip-growing plant and fungal cells. *Journal of Cell Science*, 135(21), jcs259208.

Condensed Matter Physics: NO Soft Matter and Biological Physics: YES
Quantum Physics: NO Theoretical Physics: YES