

TITRE: Plateau-Rayleigh Dynamics in an Active Fluid Model of Somitogenesis

DIRECTEURS de Stage :

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Ce stage peut être poursuivi en thèse : OUI

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SUJET du stage:

Somitogenesis is a fundamental embryonic process in vertebrates, during which the presomitic mesoderm (PSM) periodically segments into discrete cell aggregates called somites, the precursors of the vertebral column (Fig. 1A) [1]. Inspired by the striking resemblance between somitogenesis and the Plateau-Rayleigh instability in liquid streams, we propose studying an active fluid model to elucidate the mechanisms underlying somite formation. While the Plateau-Rayleigh instability has been extensively explored using viscoelastic fluid models [2, 3], these studies neglect key features of somitogenesis, including structural order, and non-local viscoelasticity.

To address this gap, we propose using the continuum theory of active gels [4], which incorporates the above effects. In our model (Fig. 1B), the PSM consists of an inner bulk disordered fluid phase—representing the mesenchymal core cells—enclosed by a two-dimensional fluid layer with nematic order, modeling the external epithelial shell. Due to nematic alignment, the epithelial shell is expected to exhibit a viscoelastic response to mechanical perturbations. The external medium is an ideal liquid.

The goal of this internship is to investigate the dynamics of the free boundary between the PSM and the external medium, particularly how its motion depends on the non-local viscoelastic properties of the PSM. We will initially focus on regimes of small interfacial deformations, allowing us to linearize the model. This approach is expected to be tractable using asymptotic methods such as linear stability analysis, providing insights into the mechanisms that may destabilize the PSM interface.

The internship is part of the ANR consortium *Fidelio*, which brings together experimentalists and theoreticians from Institut Curie and Université de Lorraine. Regular exchanges with experimental teams will guide the theory, and a funded PhD on this topic will start in Fall 2026.

[1] O. Pourquié, *Annu. Rev. Cell Dev. Biol.*, 17, 311-350 (2001). [2] E. Hannezo et al, *Phys. Rev. Lett.*, 109, 018101 (2012). [3] D. Gonzalez-Rodriguez et al, *Phys. Rev. Lett.*, 115, 088102 (2015). [4] K. Kruse et al, *Eur. Phys. J. E*, 16, 5-16 (2005).

Expected profile of the candidate: The ideal candidate will be a physicist with proficiency in statistical physics and nonlinear physics. Prior knowledge in soft matter and complex systems will be an asset. The candidate should be willing to interact closely with experimentalists. Prior knowledge of experimental biophysics is not required.

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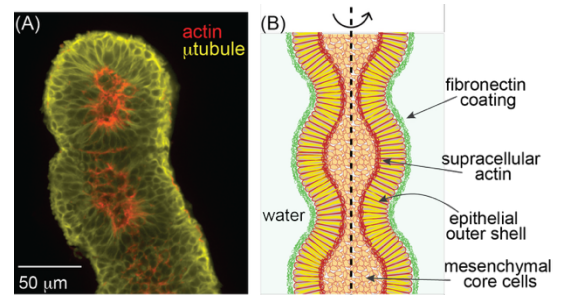


Figure 1: (A) Immunostaining of an isolated mesoderm, showing an actin ring at the center (red) and microtubule asters (yellow). (B) Elements of the active pearling model: contractile actin cables at the inner side of the epithelial layer, the ECM components coating the PSM (fibronectin, collagen, etc.), and the microtubule asters attributed to the elongated epithelial cells. The bulk of the mesoderm is composed of soft mesenchymal cells. The model of ex vivo PSM is immersed in culture medium with the same viscosity as water.