PhD Position: Theoretical modeling of rheology and active-fluid instabilities in vertebrate somitogenesis

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PhD subject: How do embryos build robust, repeatable structures while tissues flow, remodel, and actively generate forces? A striking example is somitogenesis: in vertebrate embryos, the presomitic mesoderm (PSM) periodically segments into discrete cell aggregates called somites, the precursors of the vertebral column (Fig. 1A) [1].

Inspired by the resemblance between somitogenesis and the Plateau–Rayleigh instability in liquid streams, this PhD aims to develop a theoretical framework to elucidate somite formation as an instability of an active, viscoelastic tissue. While Plateau–Rayleigh breakup has been widely explored using passive and viscoelastic fluid models [2, 3], these approaches typically neglect key features of living tissues, including active stress generation, structural order, and non-local viscoelastic effects. We will build models that connect experimentally accessible parameters (effective viscosity, surface tension, adhesion, active stresses) to instability thresholds, pattern selection, and dynamics.

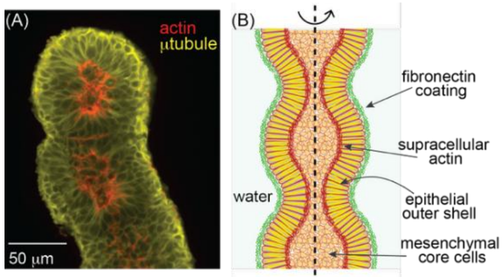

Figure 1: (A) Immunostaining of an isolated mesoderm, showing an actin ring at the center (red) and microtubule asters (yellow). (B) Elements of the active pearling model: contractile actin cables at the inner side of the epithelial layer, the extracellular matrix components coating the PSM (fibronectin, collagen, etc.), and the microtubule asters attributed to the elongated epithelial cells. The bulk of the mesoderm is composed of soft mesenchymal cells.

We will use the continuum theory of active gels [4]. In our model (Fig. 1B), the PSM consists of an inner disordered fluid bulk (mesenchymal core) enclosed by a thin outer layer (epithelial shell), which is expected to display a viscoelastic response. The PhD will investigate the dynamics of the free boundary between the PSM and its surrounding medium, first in regimes of small interfacial deformations (amenable to linear stability analysis and asymptotic approaches), and then by exploring nonlinear regimes.

In parallel, the PhD will develop rheological modeling to interpret quantitative mechanical measurements performed by project collaborators (e.g., aspiration-based assays). The goal is to go beyond standard homogeneous passive material interpretations and incorporate heterogeneity and activity, in order to extract effective tissue parameters that can directly constrain the active-fluid theory.

This 3-year PhD project will start in Fall 2026 and is funded by an ANR project. The student will be enrolled at Université de Lorraine (Metz, France) and co-supervised with Institut Curie (Paris), spending a substantial fraction of the time in each lab. Regular exchanges with the experimental teams of the ANR consortium (K. Guevorkian and B. Sorre at Institut Curie) will guide the theory and provide quantitative datasets for model calibration and validation.

Candidate profile: Master's degree in physics or closely related fields with a strong mathematical foundation and proficiency in statistical physics and nonlinear physics. 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. Knowledge of French is useful but not required.

How to apply: Please send CV, full academic transcript, a short statement of interest, and contact details for 1-2 referees to david.gr@univ-lorraine.fr and carles.blanch-mercader@curie.fr
Informal inquiries are also welcome.

Deadline: 30 April 2026 (or until filled).

References:
[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).