

Mechano-nematic coupling in *Hydra* morphogenesis

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Hydra vulgaris is a freshwater polyp capable of **whole-body regeneration**, i.e. any piece cut from the animal (and even randomly reaggregated cells, Fig1) can reform an entire functional organism. This process goes through a series of steps to define a new head-to-tail axis (Fig1 at 22-35h) before morphogenesis occurs allowing it to retrieve its final shape.

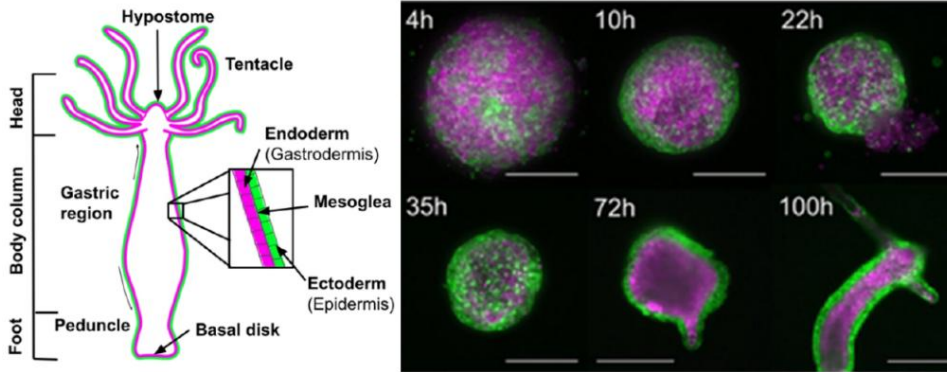


Fig 1. Left: Schematics of *Hydra* morphology. Right: **Timelapse of *Hydra* regeneration** from a cellular aggregate. The ectoderm and endoderm are shown in green and magenta, respectively. Scale: 200 μ m up to 72h, 500 μ m at 100h.

Recent results from our group¹ suggest that their morphogenesis relies on a complex interplay between changes in mechanical properties, the activity of actin fibers displaying a nematic order and molecular signaling put in place during patterning. Furthermore, we have shown that these three main ingredients interact with one another (Fig 2). *Hydra* regeneration thus provides a powerful experimental platform to study *in vivo* morphogenesis as an integrated chemical-mechanical-nematic process.

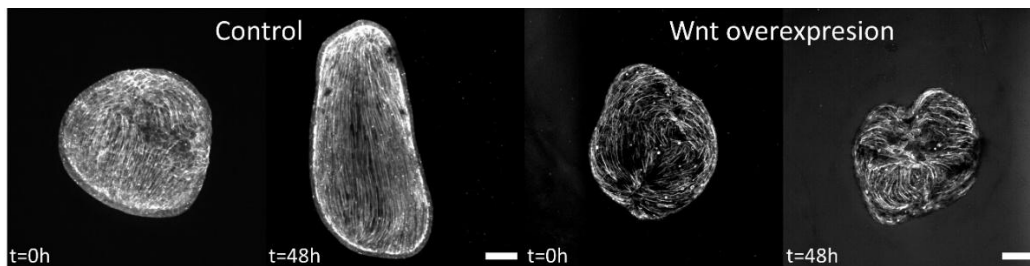


Fig 2. Visualization of actin fibers during regeneration in control conditions (left) and under Wnt activation (right). In control conditions, the fibers are aligned, and the *Hydra* elongates in that direction to form a new head to foot axis. When wnt is activated, the fibers seem to lose their proper alignment, and it results in abnormal shapes during morphogenesis. Scale: 200 μ m.

In this project, we will specifically focus on how mechanical cues can impact the nematic order of actin fibers² and lead to improper morphogenesis.

To do so, we will use various experimental techniques to mechanically perturb regenerating Hydras: microfluidic chambers for local microaspiration³ (Fig 3), custom-made agarose compression devices and paramagnetic nanoparticles⁴. We will then, in response to these perturbations, observe the changes in the nematic order of actin fibers and the overall 3d morphogenesis of the animal. To do so, we will use image analysis pipelines applied to 3d confocal images.

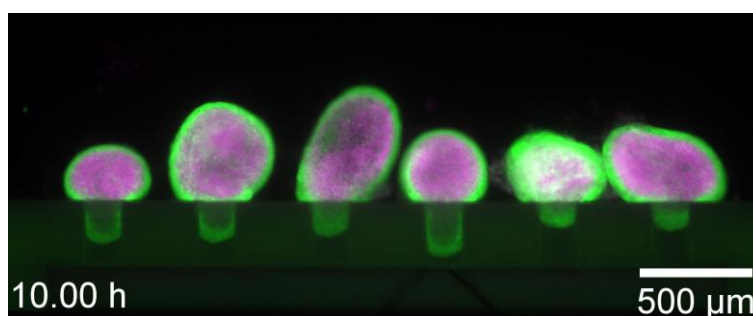


Fig3. Snapshot of parallelized microaspiration experiment to apply controlled local stresses on regenerating *Hydra* pieces. The endoderm and ectoderm of *Hydra* pieces are shown in magenta and green, respectively.

The student will be involved in the **following missions** throughout the internship.

Hydra care: The student will learn how to maintain, grow and use *Hydra* populations for experiments. Particular care will be given to the available transgenic lines.

Mechanical perturbation experiments: Existing microfluidic chambers will be used to apply microaspiration and vertical compression. The student will also participate in an ongoing collaboration with the team of M. Reffay (MSC, Université Paris Cité) to adapt paramagnetic nanoparticles to Hydra.

Microscopy, image and data analysis: Fluorescent spinning disk microscopy will be used to image the reaction of the samples to different perturbations. Existing image analysis tools will be used and further developed to reconstruct their 3d shapes and quantify the nematic field formed by the actin network. From these, curvature will be measured and various metrics will be envisioned to quantify the outcome of morphogenesis and correlate it with nematic defects.

The combination of these techniques will provide the student with a strong experimental background in quantitative biophysics at the tissue and organism scale including microfluidics, mechanics and nematics. Applications for continuation as a PhD are encouraged.

Relevant references for the project

1. Perros, T., Joly, S., Mbaye, A., Marcq, P. & Cochet-Escartin, O. Wnt signaling modulates tissue mechanics, actin order, and regeneration in *Hydra vulgaris*. *Phys. Biol.* **23**, 046003 (2026).
2. Westfried, A., Garion, L., Popović, M. & Keren, K. Body-Axis Reorientation in Regenerating Hydra under Geometric Confinement. *bioRxiv* 2026.06.25.734673 (2026) doi:10.64898/2026.06.25.734673.
3. Perros, T. *et al.* Mechanical characterization of regenerating Hydra tissue spheres. *Biophys. J.* **123**, 1792–1803 (2024).
4. Nagle, I. *et al.* Shaping 3D minimal model tissues with mechanical constraints to orchestrate muscle differentiation. *Commun. Biol.* **8**, (2025).