

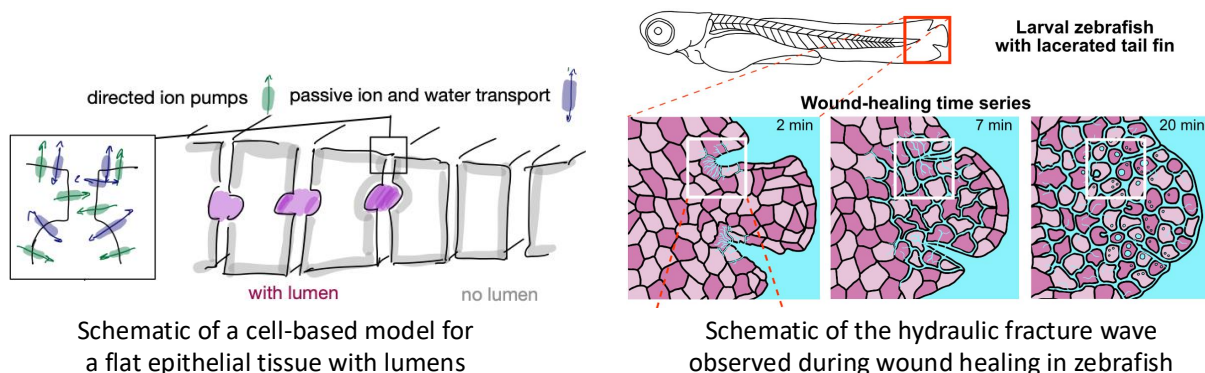
INTERNSHIP PROPOSAL

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Thesis possibility after internship: yes Funding: yes (ANR)

A cell-based model for tissue electrohydraulic properties

In addition to generating forces and reacting to mechanical cues, tissues are capable of actively transporting fluids and of creating electric currents. Interestingly, water transport due to osmotic pressure difference is capable of generating mechanical stresses, sometimes larger than those due to the acto-myosin cortex [1]. The hydraulic properties of tissues are also crucial during morphogenesis: for instance, the mammalian embryo actively transports water to create a spherical fluid-filled cavity (lumen) around which it self-organizes [2]. Similarly, the bioelectric properties of nonexcitable cells are crucial for signaling and triggering proliferation after a wound [3], and are suspected to play a role in tissue patterning [4].

Theoretical modelling of cell tissues however often focuses on their active mechanical properties, while their bioelectric and hydraulic abilities remain largely undiscussed. The goal of this internship and PhD project will therefore be to design and explore a cell-based model that brings together tissue mechanical, electrical and hydraulic properties. This model will be inspired by the vertex model [5] for the mechanical parts but will furthermore include explicitly ion and fluid transport in the spirit of the pump-and-leak model [6] (see Figure). The ground state of the model will be explored analytically, while the dynamics and non-stationary states will be obtained from numerical simulations. A first topic that will be tackled with this hydraulic tissue model is the propagation of a hydraulic fracture wave observed during wound healing in zebrafish [7].



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[2] Dagher et al., "Intercellular fluid dynamics in tissue morphogenesis", Curr. Biol. 34, R1031 (2024) DOI: 10.1016/j.cub.2024.05.061
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[4] Nunes and Barriga, "Bioelectricity in Morphogenesis", Annu. Rev. Cell Dev. Biol. 41, 187 (2025) DOI: 10.1146/annurev-cellbio-101323-032747
[5] Farhadifar, Röper, Aigouy, et al., "The Influence of Cell Mechanics, Cell-Cell Interactions, and Proliferation on Epithelial Packing", Curr. Biol. 17, 2095 (2007) DOI: 10.1016/j.cub.2007.11.049
[6] Rollin, Joanny and Sens, "Physical basis of the cell size scaling laws", eLife 12, e82490 (2023) DOI: 10.7554/eLife.82490
[7] Kennard et al., "Post-injury hydraulic fracturing drives fissure formation in the zebrafish basal epidermal cell layer", Curr. Biol. 33, 2616 (2023) DOI: 10.1016/j.cub.2023.05.021