PhD PROJECT

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TURING CENTRE FOR LIVING SYSTEMS

Active mechanics of biological tissues

Host teams
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Scientific background

Think of embryonic development as an out-of-equilibrium hydrodynamic problem: what makes a living material spontaneously flow in a sufficiently well-controlled manner to shape functional organs?

Embryonic tissues are composed of layers of cohesive cells which are reminiscent of classic air-liquid foams; yet, a foam at thermal equilibrium will not spontaneously flow. The origin of such time-reversal symmetry breaking lies in molecular motors, which break detailed balance by converting biochemical energy into forces. Recent work [ref. 1 & video] highlighted the role of motor-driven stochastic activity in a solid-to-fluid transition during the zebrafish embryonic development. But how can such molecular-motor forces scale up to generate flows at the embryonic scale?

To address such question, we will use a combination of analytical theories & numerical tools to predict under which conditions an active cellular material will flow (viscous response) or resist deformation (elastic response). Up to now, most cell-based material models assume that deviations from mechanical equilibrium are Boltzmann-distributed; however, we have recently shown that motor-driven active fluctuations can drive exotic features, reminiscent of a Casimir effects, which drastically deviate from expectations based on a Boltzmann-statistics [2].

PhD Objectives

We aim at a theoretical understanding of solid-to-fluid transitions in disordered cellular materials in the presence of motor-driven active fluctuations.

Proposed approach (experimental / theoretical / computational)

The problems of embryogenesis is extremely complex, involving high order non-linearities and curved geometry. Our approach is to identify mappings into simplifying geometries with the objective of extracting a minimal set of relevant parameters.
We will incorporate the physics of active motor-drive fluctuations in both numerical and analytical models of tissue mechanics. Based on our previously developed in-house vertex model code [3], we will benchmark parameters against existing analytical hydrodynamic theories that are predictive of active turbulence [4].

PhD student's expected profile

We are expecting students with a Physics background, highly motivated in combining tools from statistical physics and hydrodynamics; some coding experience in Matlab will be appreciated.
Applications from computer science/math students can also be considered.

References

[1] Mongera et al. Nature 2018 + https://www.youtube.com/watch?v=2gZMJBThigU
[2] Rupprecht et al. PRL 2018;
[3] Rupprecht et al. MBoC 2017;
[4] Duclos et al. Nat. Phys. 2018.