Master 2: Physics of Complex Systems

INTERNSHIP PROPOSAL

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This internship can be followed by a thesis.

Pattern formation during Hydra regeneration

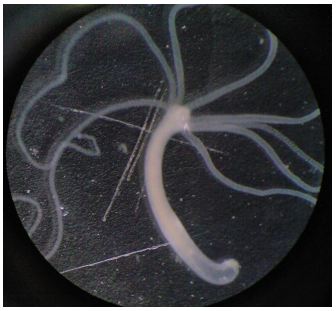
Keywords: pattern formation, theoretical biophysics, mechanobiology

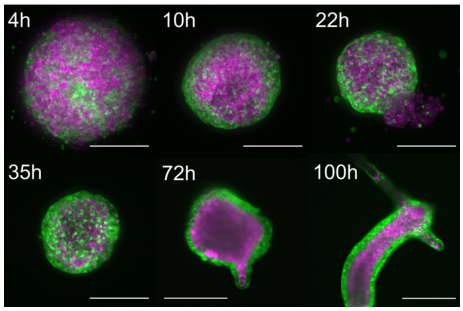
Chemical instabilities such as the Turing instability [1] have had a profound impact on our understanding and definition of self-organization. They are fascinating examples of how non-linear interactions of several components can lead to order at a higher level. Chemical instabilities have naturally been proposed to explain the morphogenesis of living organisms through a chemical patterning driven by the diffusion and reaction of morphogens [2].

Hydra vulgaris is a freshwater polyp famous for its regenerative capacities, as virtually any tissue piece amputated from an adult Hydra or even re-aggregated cells can regenerate into a viable organism and do so through a *de novo* axis definition.

Remarkably, spherically-shaped regenerating *Hydra* pieces undergo several osmotically-driven oscillations [3] before a Turing-like instability determines the position of the future head of the organism as the local maximum of a morphogen's concentration.

Based on known observational and biochemical data [3,4], the intern will formulate and analyse a reaction-diffusion model on an oscillating sphere, able to recapitulate the first symmetry-breaking of *Hydra* during the process of its regeneration.

a. 

b. 

***Hydra*: a.** Image of an adult organism (Courtesy Wikipedia). **b.** Timelapse images of *Hydra* regeneration from an aggregate of cells. At 35 h, the sample has a spherical shape whose symmetry is broken by 72 h. Scale: 200 μm up to 72h, 500 μm at 100 h. (Courtesy O. Cochet-Escartin).

References

[1] Turing, A. M., 1952. *Phil. Trans. R. Soc. B* **237**:37-72.
[2] Schweisguth, F., and F. Corson, 2019. *Developmental Cell* **49**:659-677
[3] Kücken, M., *et al.*, 2008. *Biophysical Journal* **95**:978-985.
[4] Vogg, M. C., *et al.*, 2019. *Nature Communications* **10** 312

Expected skills: The project requires both analytical and computational skills, at the interface between theoretical biophysics and pattern formation.