Mechanical regulation of morphogenesis – A multi-scale analysis

Location: Ecole Normale Supérieure de Lyon
RDP, *Biophysics and Development* team
Supervisors: Antoine FRULEUX & Arezki BOUDAOUD

Biophysics — Data analysis — Morphogenesis — Plant development

Figure 1: Cell growth is heterogeneous in space and time. Example of a sepal (green organ that protects a flower before it opens) from the model plant Arabidopsis thaliana. The colour scale corresponds to growth rates (high in red, low in blue).

The two hands of most humans almost superimpose. Similarly, flowers of an individual plant have similar shapes and sizes. This is in striking contrast with growth and deformation of cells during organ morphogenesis, which feature considerable variations in space and in time, raising the question of how organs and organisms reach well-defined size and shape. In order to link cell and organ scales, we built a theoretical model of growing tissue with fibre-like structural elements that may account for for the plant cell wall or animal cytoskeleton or extracellular matrix [1]. We made two important predictions. First, fluctuations occurring at cellular scale exhibit long-range correlations. Second, the response of fibres to growth-induced mechanical stress may enhance or buffer cellular variability of growth, making it possible to modulate the robustness of morphogenesis.
The main objective of the proposed internship is to reveal how tissue response to mechanical signals controls robustness in development, based on adapting methods developed in statistical physics, signal processing, and graph theory [2] to analyse experimental data on tissue growth. Preliminary results are encouraging and show the feasibility of the work proposed. The intern will start by analysing morphogenesis

of Arabidopsis thaliana[1] sepals, the green leaf-like organs that protect a flower before its opening. In a second step, the approaches will be extended to mutant plants and to other organs, with different mechanical responses, in order to reveal the role of mechanical regulation of fluctuations in development. These approaches will also likely be applicable to morphogenesis in other multicellular systems, including animals.
The host team has coordinated an international project on this topic, involving collaborators in Germany, Japan, Poland, Sweden, and the USA. Accordingly, we have access to a wealth data on plant morphogenesis. The intern will benefit from these collaborations and from a stimulating and multi-disciplinary environment in the team.

References

[1] Antoine Fruleux and Arezki Boudaoud. Modulation of tissue growth heterogeneity by responses to mechanical stress. `https://doi.org/10.1101/425355`, 2018. To be published; on bioRxiv.

[2] David I Shuman, Sunil K Narang, Pascal Frossard, Antonio Ortega, and Pierre Vandergheynst. The emerging field of signal processing on graphs: Extending high-dimensional data analysis to networks and other irregular domains. *IEEE Signal Processing Magazine*, 30(3):83–98, 2013.

[1] Thale cress (*Arabidopsis thaliana* is a weed commonly used as model organism in plant biology.