Morphogenetic emergence across biological scales (PhD thesis in biomathematics, Toulouse, France)

Description of the project

During development, dynamic interactions between cells allow the emergence of organ shapes. Because of the diversity of cell properties and behaviors, such as migration, division, or adhesion, complex morphogenetic processes have been difficult to tackle experimentally. We study the development of the posterior part of the vertebrate embryo as it contains progenitor cells that will both specify and form distinct tissues, the neural tube (future nervous system), and the paraxial mesoderm (future vertebrae, muscle, and derm). Using time-lapse movies, we will quantify quail embryonic cells and tissues behavior by image analysis. Based on these quantifications, we will develop agent-based and continuum (PDE) models to understand the relationships between the different levels of organization of our system: cell/cell, cell/tissue, and tissue/tissue interactions. These models will be analyzed theoretically and numerically (qualitative behavior, link between the different models) and tested against our biological data. Altogether, we will be able to combine unique experimental results and theoretical/numerical approaches to understand how distinct cellular behaviors synergize to build embryonic tissues and structures.

Keywords: Morphogenesis, cell and tissue behavior, self-organization, agent-based modeling, continuum modeling, partial differential equations, numerical simulation, scaling/hydrodynamic limits, free boundary problem, time-lapse imaging, migration.

References

Romanos M, Allio G, Roussigné M, Combres L, Escalas N, Soula C, Steventon B, Trescases A., Bénazéraf B.. *Cell-to-cell heterogeneity in Sox2 and Bra expression guides progenitor motility and destiny.* Elife. 2021 Oct 5;10.
Degond P, Hecht, S, Romanos, M and Trescases, *A. Multi-species viscous models for tissue growth: incompressible limit and qualitative behaviour* https://arxiv.org/abs/2203.13099

Conditions and application

The candidate will work in a highly interdisciplinary collaborative context. Image and data analysis will be performed at the Centre for Integrative Biology (CBI) in Toulouse under the supervision of Bertrand Benazeraf (https://cbi-toulouse.fr/eng/equipe-benazeraf). The theoretical side will be supervised by Ariane Trescases at the Institute of Mathematics of Toulouse (IMT) (http://atrescases.perso.math.cnrs.fr/index.html/Home.html)

Candidates must have a Master's degree or equivalent in mathematics or a subject with a strong mathematical component (e.g. physics, bio-physics, bio-mathematics, engineering, computer science), skills in programming, and experience and/or demonstrate a strong interest in image analysis and morphogenesis. Funding: CNRS PRIME MITI (three years); Start date: Sept/October 2022.

For application send a unique PDF file containing a CV, mark reports since the beginning of higher education, and a motivation letter with 2 reference contacts to bertrand.benazeraf@univ-tlse3.fr and ariane.trescases@math.univ-toulouse.fr
Deadline for application: 18 July 2022