Master internship offer

Using statistical physics to unravel how gene selection leads to robust developmental traits

Abstract

The complexity of biological systems is partly due to the intricate structure of interactions between thousands of genes. The topology of gene networks has been under scrutiny since the emergence of systems biology, but little progress has been made to connect theoretically large-scale statistical features of networks (typically, scale-freeness) to concrete functional and evolutionary properties. Using the tools of statistical physics, we are combining analytical and computational models to unravel how natural selection shapes gene interactions and give rise to robust developmental traits.

We built a statistical description for a population of individuals each described by their genes' level of expression. In our model, the developmental dynamics of each individual were constrained by gene interactions encoded in an individual-specific matrix and included a noise source which accounted for the stochasticity inherent to developmental processes. With this framework we aimed at describing the long term population dynamics governed by the probability of each individual to survive, reproduce and mutate according to their developmental trajectories. Under reasonable assumptions, we deem it possible to derive an analytical model to obtain a reduced set of algebraic-Riccati-like equations for the developmental dynamics.

The analysis and further development of this model could represent a substantial improvement in theoretical systems biology, provided that the mathematical assumptions are biologically realistic. The purpose of this internship is (i) to set up an analytical model based on our preliminary results, (ii) to proceed to the numerical implementation of the model (individual-based simulations), and to analyze and test its predictions, and (iii) to identify a set of statistical tools measuring the relevant properties of the interaction matrix. Depending on the simulation results, new additional analytical developments will be proposed to improve sequentially the predictive properties of the mathematical model.

Keywords

Complex systems, Monte-Carlo simulations, Statistical physics, Gene network evolution

Supervision

This is an interdisciplinary project, involving Statistical Physics and Evolutionary Biology. The student will be co-supervised by Antoine Fruleux (CNRS researcher, LPTMS Paris Saclay) and Arnaud Le Rouzic (CNRS researcher, EGCE / IDEEV Paris-Saclay).

Contacts:
Antoine Fruleux antoine.fruleux@universite-paris-saclay.fr
Arnaud Le Rouzic arnaud.le-rouzic@universite-paris-saclay.fr

Implementation

The student will be located at the LPTMS (Building 530). The internship will last for 4-6 months between January and July 2024. The student will receive a stipend (about 600€/month).

Background

We are looking for a highly motivated student, interested in interdisciplinary questions, with a solid background in statistical / theoretical physics and programming.