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Title of the internship: A population genetics view of collective behaviours

Duration and available dates for the internship: 8 weeks to 6 months, starting in January 2025 at the earliest

Short description of the host team (5 lines):

Our group's research focuses on understanding the eco-evolutionary dynamics governing the composition of the gut microbiota. We are currently particularly interested in the mechanisms that allow the maintenance of the microbial community diversity, a key indicator of health [1], [2]. To study these questions, we use mathematical modeling, combining analytical and numerical techniques with stochastic simulations. We also exchange frequently and collaborate with experimenters to inform our models' development.

Description of the internship project (10 lines):

From proteins that combine together to fuel metabolism up to cells in multicellular organisms, and even V-shaped flight formation in migratory birds, collective behaviours span the entire scale of life. These phenomena are generally of critical importance for the development, reproduction and survival of organisms. Some of these collective behaviours, known as evolutionary transitions in individuality [3], [4], were even key to the origin and further evolution of life itself as they enabled the emergence of new levels of organisation (eg., cells that evolved to be part of a multicellular organism). For such collective behaviours to emerge, biological entities need to interact, which requires that they be colocalised. Population genetics offers a broad, easy-to-interpret framework in which colocalisation emerges from underlying birth-death-migration processes, as in Wright's fixation indexes approach [5]. Surprisingly enough, Wright's framework has nonetheless remained limited to intraspecific interactions. This is true despite the similarities of the processes involved when interactions bring together different species in community assembly, as occurs for microbiomes. **Here, we propose to extend classical population genetics models to account for these interspecific interactions.**

Expected results / deliverables of the internship (5 lines):

During this internship, the intern will introduce the possibility of interspecific interactions in Balding Nichols model [6], [7], [8], which captures group/population formation through a Dirichlet process. The student will introduce the possibility for birth and migration rates to depend on the strains/species, relaxing the fact that these properties are shared between them. The analytical framework will then be compared to simulations, starting with results recently obtained with a model describing stochastic community assembly [9]. The model

may then be further extended to other levels of organisation and/or to think more conceptually on what types of interactions define an organism (eg., whether bacteria in our gut are part of our individuality) [10].

Interdisciplinarity and disciplines involved (5 lines)

This work is at the crossroads of evolutionary ecology, systems biology and probability theory, and is also deeply rooted in philosophical questions. The student will develop a probabilistic model, both analytically and through simulations, and will compare the outcomes to published datasets/models. Depending on her/his background, the student will thus combine an evolutionary approach with applied and/or pure maths and one or several different fields including systems biology, cell biology and ecology. As the internship is based in a microbiology lab, the intern may also benefit from the feedback of experimenters specialised in cell biology.

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References

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