INTERNSHIP PROPOSAL

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How can a differentiation factor also set pattern spacing? Deciphering the role of PatN in *Anabaena* through experimentally-driven mathematical modeling

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Duration and available dates for the internship: 3 to 4 months, starting in January 2027 at the earliest

Location: Laboratoire de Chimie Bactérienne, Marseille

Deadline for applications: 30th November 2026

Send a cover letter and a CV – informal inquiries welcomed

Expected profile:
M1 student with sufficient mathematical background (e.g., applied maths, physics, interdisciplinary programs)

Contact: florence.bansept@univ-amu.fr

Short description of the host team:

Our group's research focuses on understanding the eco-evolutionary dynamics governing the composition and function of microbial communities. To study these questions, we use mathematical modeling, combining analytical and numerical techniques with stochastic simulations. We also exchange frequently and collaborate with experimentalists to inform our models' development.

Description of the internship project:

Anabaena sp. PCC 7120 is a filamentous cyanobacterium that fixes nitrogen and lives in freshwater. It is a model organism for studying multicellularity and cell differentiation, as it develops specialized nitrogen-fixing cells called *heterocysts*, while the the remaining *vegetative* cells perform photosynthesis. This division of labor into separate compartments can be explained by the need to protect the enzyme fixing nitrogen, nitrogenase, from oxidative stress. The heterocysts are regularly spaced along the filament, occurring approximately every 10 vegetative cells. This remarkably regular pattern opens the way to Turing-like modeling accounting for the underlying genetic regulation pathways.

Our collaborators in the group of Amel Latifi identified PatN, a regulator with a dual role: its inactivation abolishes differentiation, while its overexpression reduces heterocyst frequency and increases internode distance. PatN also negatively regulates *patA*, a gene essential for intercalary heterocyst formation. This combination of phenotypes raises an an apparent paradox. If PatN promotes differentiation but represses *patA*, through which regulatory architecture can it simultaneously control developmental competence and pattern spacing? **We propose to address this question by combining quantitative experimental analyses with mathematical modelling**.

The project will extend a stochastic cell-based model of heterocyst patterning [1]. The model links regulatory interactions, noise, and spatial transport to heterocyst positioning. We will extend this model by introducing PatN as an additional dynamic variable and testing alternative regulatory architectures. Hypotheses include direct repression of *patA* alongside independent activation of differentiation, or modulation of the PatA–HetF–HetR module, the differentiation threshold, or inhibitory signals. Models will be constrained using mutant phenotypes to discriminate among mechanisms, and additional experiments will be planned in the collaborator's group for the next stages of the project.

Interdisciplinarity and disciplines involved: This project is proposed in close collaboration with the experimental group of Amel Latifi (also at LCB) which studies the regulation pathways that determine the phenotype of *Anabaena*. It combines mathematical modeling with approaches from complex systems and numerical simulations with experimental data, with the purpose of answering a biological question.

Bibliography

[1] : Casanova-Ferrer P, Ares S, Muñoz-García, Terminal heterocyst differentiation in the Anabaena patA mutant as a result of post-transcriptional modifications and molecular leakage, PLoS Comp Bio, 2022