Stress Response and Mechanisms

Credits: 7.5 ECTS
Course Code:
Established: 2026-02-16
Established by: Stress Response Modeling at IceLab
Syllabus valid from: 2026-02-16
Main field of study: Experimental and computational biological/environmental science
Grading system: G pass, U Fail
Level of Education: Doctoral course

1. Eligibility Requirements

This interdisciplinary course is intended for PhD students in the mathematical and computational sciences, as well as those in molecular biology, plant genetics, or ecology. The main prerequisite is familiarity with early university mathematics, especially calculus and statistics. It is also helpful to have some experience with basic computer programming in Python notebooks or similar.

2. Learning Outcomes

After the course, students will be able to identify stress-response mechanisms across diverse biological and ecological systems, including bacterial virulence, plant adaptation, and permafrost carbon feedback. More specifically, the students will be able to

- Translate empirical observations of stressors into formal mathematical and statistical concepts associated with feedback loops, tipping points, and trophic cascades.
- Apply statistical and network inference methods to extract meaningful functional modules from noisy, high-dimensional experimental data.
- Building and simulating dynamical systems models to predict system stability, resilience, and regime shifts.

These skills will enable students to contribute to collaborative, multidisciplinary research projects that integrate experimental data, statistics, and theoretical modeling.

3. Content

The course begins with an introduction to control theory to establish a common vocabulary for stress-response modeling. This section also briefly describes how different stress systems—from cells to climates—sense, process, and respond to perturbations. The remaining course material is organized into three pillars:

- **Pillar 1: Empirical Foundations**. This pillar explores stress-response experimental systems to identify universal patterns of sensing and adaptation.
- **Pillar 2: Statistical Modeling and Network Inference**. In this pillar, students learn how to apply advanced inference techniques to extract meaningful structure and predict missing links from noisy empirical datasets.
- **Pillar 3: Dynamical Systems**. This pillar focuses on formulating and solving mechanistic differential equations to simulate and analyze nonlinear responses. This approach provides a mechanistic understanding of the statistical relationships highlighted in Pillars 1 and 2.

4. Instructions

The course spans six intensive days that combine theory with practical application. Each day follows a structured format:

- **Morning Sessions:** Lectures centered on real-world case studies to ground theoretical concepts in practical scenarios.
- **Afternoon Sessions:** Computer labs where students work in pairs to solve anad analyze actual problems.

A central pedagogical feature of this course is to enable pairings between experimentalists and modelers. Students from diverse academic backgrounds can partner to collaborate on labs and a final project. Most computational exercises will be coordinated via Jupyter Notebooks.

5. Examination and Assessment

To successfully complete the course, students must demonstrate active engagement and technical proficiency measured as follows:

- **Participation & Lab Engagement.** Students must actively participate in person during hands-on lab sessions and contribute meaningfully to group discussions. Attendance is mandatory.

- **The Research Project.** The student pairs will develop a project that demonstrates the ability to synthesize empirical data with predictive modeling to address nonlinear stress responses. This project follows a two-stage evaluation process:
    1. **The Proposal (1-week post-course):** Pairs will present a project proposal in person, where peers and instructors give feedback to assess feasibility and help refine the research direction
    2. **Final Presentation & Report (3 weeks post-course):** Students will give an oral presentation and write a formal report.

6. Course Literature

The teachers distribute lecture notes, articles, and book chapters during the course