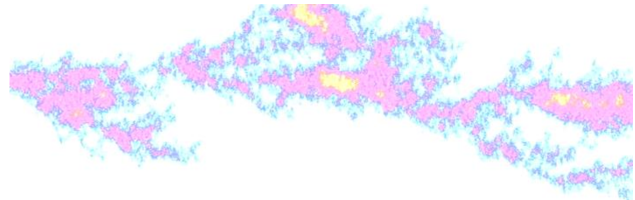
# Adaptive Dynamics



UNBIO1-073
**3 ECTS**

**October 27-31, 2025**
**Room 321**

## Instructors

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## Course summary

Adaptive dynamics modeling has become the dominant theoretical framework for 'Darwinian ecology', i.e. the investigation of the ecological causes and consequences of evolution. The course will present the key concepts underlying the adaptive dynamics approach: environmental feedback loop, invasion fitness, evolutionary singularity, evolutionary stability, evolutionary branching, evolutionary suicide, pairwise invasibility plots and canonical equations. The general framework will be applied to study the eco-evolutionary dynamics of populations competing for resources, predator-prey interactions, and mutualistic systems. Hands-on tutorial sessions will aim at simulations of specific examples and the development of individual mini-projects.

## Course format

This is a one-week intensive course. Lecture-style presentations will be complemented with computer-based tutorials. In the tutorial sessions, students will work to implement the theory and study model examples numerically, as well as develop a simple case study based on their own research interest. This will involve the guided writing of simple code in Python. We will use MOODLE to communicate about the class and provide teaching support material.

## Targeted audience and pre-requisites

The targeted audience is advanced undergraduates and graduate students in ecology and evolutionary biology and related fields, with a strong interest in mathematical modeling. Participants trained in other fields are welcome provided they had exposure to notions of population and community ecology and have sufficient mathematical training (advanced calculus). Enrolled students are expected to feel comfortable with basic population and community theory (e.g. logistic population growth, Lotka-Volterra competition…) and calculus applied to the natural sciences (modeling with differential equations, notion of equilibrium and stability analysis).

## Evaluation

Student evaluation is based on individual oral presentations of the exploratory work carried out in the tutorial/project sessions.

## Course content and learning objectives

**Lecture 1:** Introduction to AD : biological motivation. Modeling approach: ecological model, model of resident-mutant interaction, derivation of invasion fitness and selection gradient, evolutionary singularity. First example: How microbial adaptation reshapes soil carbon feedback to climate warming.

**Lecture 2:** Analysis of evolutionary singularities in 1D trait space: trait substitution sequence, pairwise invasibility plot, stability properties discussed graphically. Example of Doebeli-Dieckmann model. Evolutionary dynamics: trait substitution sequence, stochastic process of birth with mutation – interaction – death. Evolutionary branching.

**Lectures 3:** Evolutionary suicide, evolutionary rescue. Multidimensional trait evolution. Canonical equation. Examples. Extension to polymorphic populations.

**Tutorial 1:** Introduction of Claessen's model (2007): one predator-two prey model, evolution of specialization. Equilibrium analysis of ecological model, approximation, Python code for PIP construction.

**Tutorial 2:** Influence of tradeoff shape on ES stability properties. Stochastic simulations (Gillespie algorithm). Numerical evidence of evolutionary branching. Simulations under assumptions of TSS.

**Tutorial 3:** Simulations of canonical equation. Comparison with stochastic simulations.

## Schedule

**Prior to class**

- Check access to course site and course material on Moodle.
- Familiarize with Moodle tools.
- Set up softwares and download notebooks for tutorials and project.

### Monday 10/27

**10-12** **Lecture 1 (RF)** – *please note starting time at 10am.*

**2-5** **Lecture 2 (RF)**

**Homework** *Think about a biological question of interest to you that you could address using adaptive dynamics modeling. Try and be specific about the trait (keep it one-dimensional!), tradeoff, and the environmental feedback. Be prepared to present your idea with one slide in class the next day.*

### Tuesday 10/28

**9-12** **Introduction to computing environment and Tutorial 1 (Chloé Dumeige, RF)**

**2-5** **Lecture 3 + discussion of potential topics for individual projects (RF)**

**Homework** *Revise and update your project idea. Propose an ecological model (set of ordinary differential equations) and go as far as you can analytically (pencil and paper) to write the mutant growth model, derive invasion fitness, calculate evolutionary singularity(ies), evaluate their dynamical properties. Please be prepared to share your work the next day.*

### Wednesday 10/29

**9-12** **Tutorials 2 and 3 (CD)**

**2-5** **Supervised work on individual projects (CD)**

**Homework** *Revise and update project work. Start preparing slides: 1. Biological question; 2. Modeling translation: trait, tradeoff, environmental feedback; 3. Ecological model; 4. Invasion fitness; 5. Selection gradient and evolutionary singularity(ies).*

### Thursday 10/30

**9-12** **Supervised work on individual projects (CD, RF)**

**2-5** **Supervised work on individual projects (CD, RF)**

**Homework** *Update slides and prepare questions about specific difficulties you are encountering, to share with the instructors and class the next day.*

### Friday 10/31

**9-12** **Supervised work on individual projects (CD, RF)**

**2-5** **Supervised work on individual projects (CD, RF)**

## Supporting references


Brännström A, Johansson J, von Festenberg N (2013) The hitchhiker's guide to adaptive dynamics. *Games* **4**: 304-328. doi:10.3390/g4030304

Dieckmann U, Law R (1996) The dynamical theory of coevolution : a derivation from stochastic ecological processes. *Journal of Mathematical Biology* **34**: 579-612.

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Doebeli M, Dieckmann U (2000) Evolutionary branching and sympatric speciation caused by different types of ecological interactions. *Am. Nat.* **156**: S77-S101.

Geritz SAH, Kisdi E , Meszéna G , Metz JAJ (1998) Evolutionarily singular strategies and the adaptive growth and branching of the evolutionary tree. *Evolutionnary Ecology* **12**: 35-37.

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IIASA (*coll.*) (2000) Studying the evolution of complex adaptive systems: the Adaptive Dynamics Network project. *Options* Spring 2000: 1-22.

Kisdi E (1999) Evolutionary branching under asymmetric competition. *Journal of Theoretical Biology* **197**: 149-162.