

Academic Year of Degree: 2025/26

22133 - Systems Biology

Teaching Guide Information

Academic Course: 2025/26

Academic Center: 337 - Engineering School

Study: 3378 - Bachelor's degree in Biomedical Engineering

Subject: 22133 - Systems Biology

Credits: 5.0

Course: 4

Teaching languages:

Theory: Group 1: English

Practice: Group 101: English

Seminar: Group 101: English

Teachers: Jorge Garcia Ojalvo

Teaching Period: First term

Presentation

The vast majority of cellular processes do not rely on the operation of a single component of the cell's machinery (e.g. a single gene or protein), but on the interplay between multiple components working together as a *system*. The goal of this course is to describe how this emerging behavior arises from the interaction between multiple cellular components, in the form of gene and protein circuits and networks. Given the presence of feedback loops in these circuits, their behavior cannot be predicted intuitively by tracking the state of the network components along their interaction paths. Due to these limitations, mathematical modeling is necessary to establish the range of possible behaviors that a cellular network can have, and the effect of perturbations (genetic or biochemical) on these behaviors. This course presents an overview of emerging phenomena that arise from cellular circuits and networks, emphasizing their mathematical description. To that end, we will mainly focus, but not limit ourselves to, the self-engineering of animal embryos as a case example.

Associated skills | General learning outcomes

Generic competences:

1. Ability to be critical and self-critical
2. Ability to plan and manage time
3. Capacity to generate new ideas (creativity)
4. Ability to search for, process and analyse information from a variety of sources
5. Ability to identify, pose and resolve problems
6. Ability to undertake research at an appropriate level
7. Ability to work in a team
8. Ability to design and manage projects

Specific competences:

1. Recognize that biological functions emerge from the interaction between multiple elements (genes, proteins, cells)
2. Understand the minimal gene circuits generating biological oscillations, cell-fate decision and development

3. Recognize the relevance of noise in biological processes
4. Ability to simulate stochastic processes in biological systems
5. Understand how synchronization emerges in coupled biological oscillators
6. Identify the different mechanisms leading to cell-fate decision and pattern formation in living systems

Learning outcomes | Specific learning outcomes

After following this course, students will be able to pose hypotheses about how emerging biological processes arise from the interaction between a variety of elements (such as genes, proteins, and cells), and to verify these hypotheses using theoretical modeling and data analysis.

Contents

0. Introduction

1. Cell-fate decisions

Positional information, Waddington landscape, potentials and irreversibility, binary decisions, morphogenesis

2. Noise

Master equation, stochastic simulations, Langevin equation, biological consequences of noise

3. Oscillations

The cell cycle, the circadian clock, the somitogenesis clock, synchronization

4. Systems medicine (seminar)

Sustainable Development Goals

3 - Good Health and Well-being

14 - Life below water

15 - Life on land

Evaluation and grading system

The final grade of the course will be distributed in the following way:

- Exam (45%): the concepts introduced in class will be assessed through a final exam at the end of the term, which may contain both multiple-choice questions and open-ended questions.
- Course project (45%): this grade will be divided in four equal parts, that will evaluate (1) the project preparation, (2) the progress throughout the term, (3) the oral presentation, and (4) the written paper.
- Class grade (10%): assignments, class participation and other learning activities.

Additional requirements and comments:

- It is **compulsory** to attend the workshops and the presentation sessions of **all teams**.
- Passing the course requires obtaining a **minimum score of 3** (in a scale of 0 to 10) in the exam.
- The students that do not pass the course in December will be able to retake the final exam again in July.