UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Analisi Qualitativa e Quantitativa di Sistemi Biologici

2526-1-F0803Q079

Aims

The course aims to train students in the qualitative and quntitative analysis of biological systems in their most generic and broad sense (networks of biochemical reactions, basic cellular functions such as metabolism, growth and cycle, single cells or populations dynamics), according to both the deterministic and stochastic approaches.

Knowledge and understanding:
At the end of the course, students will be able to obtain quantitative and qualitative information on the behavior of biological systems through qualitative analysis and simulations of the mathematical models that describe them. The tools for the numerical simulation in MATLAB of the studied biological systems will also be given.

Ability to apply knowledge and understanding:
At the end of the course, students will be able to apply the acquired methodologies to complex biological systems of various kinds, not necessarily covered in class

Autonomy of judgment:
Students will be able to re-elaborate and apply the most appropriate analysis methodologies learned, according to the biological contexts investigated. These critical and judgment skills will be refined through the interactive analysis of case studies conducted during lessons and through the cost/benefit evaluation related to the choice of model adopted for the specific phenomenon under investigation.

Communication skills:
At the end of the course, students will be able to express themselves appropriately in the description of the topics addressed with properties of language and confidence in exposure.

Learning ability:
At the end of the course, students will be able to analyze, apply, integrate and connect the knowledge acquired - and subsequently matured with the consultation of the literature - with what they have learned in related courses, in order to solve scientific problems in Biological Sciences and Biotechnologies.

Contents

This course provides methodologies for the analysis of dynamical models of biological systems. The methodologies include the qualitative analysis (what are the emergent properties of a system?) and the quantitative analysis (how can I simulate the computational model of a biological system?).
The examples of the course will deal with different biological contexts, including networks of biochemical reactions, basic cellular functions such as metabolism, growth and cell cycle, tumor growth and epidemic spreading models. These last two examples align with the themes of the Sustainable Development Goal "Health and Well-being", highlighting how the methodological tools discussed in class enable a better understanding of the phenomenon and, consequently, a more effective control action.
Most topics will be analyzed through multidisciplinary analysis of specific case studies. One or more of the case studies will also be anlyzed in the course Systems Biochemistry with a complementary biological, biochemical and molecular perspective

Detailed program

- Input/output relationships: a biological system is characterized by the richness of laboratory experiments. State/inputs/outputs of a system. Discrete-time and continuous-time systems. Stationary systems. Linear systems. Free and forced evolution. Regime and transient response.
- Analysis of the qualitative behavior of a system. Equilibrium points, stability and multi-stability. Exponential growth. Bifurcations, oscillations and limit cycles. Chaotic behaviors. Examples on models of enzymatic reactions, cell growth, spread of epidemics.
- The stochastic approach: application to biochemical networks and transcription networks. The Gillespie simulation algorithm
- Case study: integration of kinetic, metabolic and proteomic data for the identification of a metabolic network.
- Simulation of deterministic models of biological systems. All simulations will be carried out in MATLAB environment.

Prerequisites

No specific knowledge of mathematics other than those already acquired in the basic courses of a three-year degree in Biological Sciences or Biotechnology is required.

Teaching form

All didactic activities are conveyed by means of face-to-face lectures

- 28 hours of delivered didactics (Didattica Erogativa, DE)
- 1CFU (7 hours) of interactive teaching (Didattica Interattiva, DI), in collaboration with the teacher of Systems Biochemistry (Prof. Marco Vanoni) to jointly address a case study. This didactic approach will allow for presentation and examination from complementary points of view pathways, functions and biological systems seen through the eye of biologist and computational modeller.
- 10 hours of in-person tutorial activities aimed at guiding and assisting students throughout hands-on applications by interactive teaching (Didattica Interattiva, DI)

If necessary, we will evaluate the possibility of recording the lessons

Textbook and teaching resource

The slides and MATLAB codes developed at lessons will be available on the e-learning page of the course. Further review articles and book chapters will be recommended in class and uploaded to the e-learning platform of the course

The following texts are recommended for appropriate further information:

- U. Alon, An introduction to systems biology: design principles of biological circuits, Chapman & Hall/CRC, Taylor & Francis Group, 2019
- E. Klipp, W. Liebermeister, C. Wierling, A. Kowald, Systems Biology – A textbook. 2nd Ed. Wiley, 2016

Semester

Second semester

Assessment method

The exam is divided into two parts:

- In the first part, the student will be evaluated (orally) on the in-depth analysis of a scientific article previously assigned to them
- Oral questions on the entire syllabus covered in class.

In both cases, the student will be assessed on their ability to express and summarize, as well as their understanding of the topics covered.

Office hours

Students are invited to contact the teacher by email to agree upon a date (also on WebEx)

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING