Course guide
2703116 - NSB - Networks and Systems Biology

Last modified: 30/01/2026

Unit in charge: Barcelona School of Informatics
Teaching unit: 748 - FIS - Department of Physics.
1039 - UPF - Universitat Pompeu Fabra.

Degree: BACHELOR'S DEGREE IN BIOINFORMATICS (Syllabus 2024). (Compulsory subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer:

Others: Segon quadrimestre:
LAURA AVIÑÓ ESTEBAN - 12
DAVID ORIOLA SANTANDREU - 11, 12
ADRIÁN FRANCISCO TAUSTE CAMPO - 11, 12

LEARNING RESULTS

Knowledges:
K1. Recognise the fundamental principles of biology, from the cellular to the organismic scale, and how they relate to current knowledge in bioinformatics, data analysis and machine learning, achieving an interdisciplinary vision with an emphasis on biomedical applications.
K2. Identify statistical and computational methods and mathematical models that can be used to solve problems in molecular biology, genomics, medical research and population genetics.
K3. Identify the mathematical foundations, computational theories, algorithmic schemes and principles of information organisation relevant to modelling biological systems and efficiently solving bioinformatics problems through the design of computational tools.
K4. Integrate the concepts offered by the most widely used programming languages in life sciences to model and optimise data structures and build efficient algorithms, relating them to each other and to their application cases.
K7. Analyse sources of valid and reliable scientific information to determine the state of the art of a bioinformatics problem and how to tackle it.

Skills:
S1. Integrate omic and clinical data to better understand and analyse biological phenomena.
S2. Computationally analyse DNA, RNA and protein sequences, including comparative genomic analysis, using computation, mathematics and statistics as the basic tools of bioinformatics.
S3. Solve problems in molecular biology, genomics, medical research and population genetics by applying statistical and computational methods and mathematical models.
S5. Communicate information, ideas, problems and solutions from bioinformatics and computational biology to a general audience.
S7. Implement programming methods and data analysis based on the development of working hypotheses within the area of study.
S8. Make and defend reasoned decisions when solving problems in biology and, in appropriate fields, the health sciences, computer science and experimental sciences.

Competences:
C2. Recognise the complexity of the economic and social phenomena typical of a welfare society and relate welfare to globalisation, sustainability and climate change in order to use techniques, technology and principles of economics and sustainability in a balanced and compatible way.
C3. Communicate orally and in writing with others in English about learning outcomes, thought processes and decision making.
C4. Work as part of a multidisciplinary team, whether as a team member or in a leadership role, to contribute to the development of projects (including business and research projects) with pragmatism, a sense of responsibility and ethical principles, undertaking commitments with due regard to the resources available.

TEACHING METHODOLOGY

Lectures will be mainly of expository type. There will be also problem-based sessions and exercise sessions using Python.

LEARNING OBJECTIVES OF THE SUBJECT

1.Model biological information in mathematical language for further analysis and processing.
2.Understand and develop algorithms with computer languages.
3.Critical thinking and problem solving skills

STUDY LOAD

Type	Hours	Percentage
Self study	90,0	60.00
Hours large group	30,0	20.00
Hours small group	30,0	20.00

Total learning time: 150 h

CONTENTS

Cell biology by the numbers

Description:
Introduction to systems biology. Back-of-the-envelope calculations in biology.

Dynamical systems modelling of cellular regulation processes

Description:
Introduction to dynamical systems theory. Gene expression and protein synthesis. Michaelis-Menten and Hill Equations.

Network motifs in biology

Description:
The negative feedback loop: robustness and homeostasis.
The feedforward motif: pulse generation and adaptation.
The positive feedback loop: bistability and memory.

Biochemical oscillators

Description:
Linear stability analysis. Design principles of biochemical oscillators: delayed negative feedback and amplified negative feedback.

Noise in biological systems

Description:
Transcriptional noise. Master equation. The chemical Langevin equation. The Gillespie Algorithm.

Biological networks

Description:
Introduction to network theory. Network topology. Random graphs. Percolation.
Network inference from dynamical data.

ACTIVITIES

Theory lectures

Specific objectives:
1, 2

Full-or-part-time: 72h
Theory classes: 27h
Self study: 45h

Final exam

Specific objectives:
1, 2, 3

Full-or-part-time: 3h
Guided activities: 3h

Midterm exam

Specific objectives:
1, 2, 3

Full-or-part-time: 2h
Guided activities: 2h

Problem solving sessions

Full-or-part-time: 73h
Practical classes: 28h
Self study: 45h

GRADING SYSTEM

For the evaluation of the subject, the grade of the partial exam (P), the grade of the final exam (F) and participation to the problem-based learning sessions (PBL) will be taken into account through the following formula:

Grade=max(0.3*P+0.6*F+0.1*PBL;0.1*PBL+0.9*F)

A student is considered to have taken the subject if he/she takes the final exam and handed in all the practicals. If the student has taken the subject but has failed, then the student may take the re-evaluation exam (R) and in this case the grade for the subject will be the maximum between R and 0.1*PBL+0.9*R.

BIBLIOGRAPHY

Basic:
- Alon, Uri. An Introduction to systems biology : design principles of biological circuits. Boca Raton, Fla: Chapman & Hall/CRC, 2020. ISBN 9781439837177.
- Strogatz, Steven H. Nonlinear dynamics and chaos : with applications to physics, biology, chemistry, and engineering. 3rd ed. Boca Raton, FL: CRC Press, Taylor and Francis Group, 2024. ISBN 9780367026509.

Complementary:
- Milo, Ron; Phillips, Rob. Cell Biology by the numbers. New York: Garland Science, 2016. ISBN 9780815345374.
- NOVAK, Bela; TYSON; John J.. "Design principles of biochemical oscillators". Nature Reviews Molecular Cell Biology [on line]. Available on: https://doi.org/10.1038/nrm2530.- BARABASI, Albert-László; OLTVAI, Zoltán N.. "Network biology: understanding the cell's functional organization". Nature Reviews Genetics [on line]. Available on: https://www.nature.com/articles/nrg1272.

RESOURCES

Hyperlink:
- https://numpy.org/doc/stable/reference/