UNIVERSITAT POMPEU FABRA

Department of Experimental and Health Sciences
Parc de Recerca Biomèdica de Barcelona
Dr. Aiguader 88, 08003 Barcelona

BIOCOMPUTING

Degree: Bachelor's Degree in Biomedical Engineering
Year: 2nd year, 3rd term
Number of ECTS credits: 6
Class hours: 66
Teachers: Jordi Garcia Ojalvo (CEXS, coordinator), Marçal Gabaldà (CEXS) and Gustavo Deco (DTIC)

1. Course presentation

The goal of the course *Biocomputing* is to introduce students with the fundamental principles that govern the detection and processing of information in living systems, from the level of biomolecules to the scale of full organs such as the brain. The course consists of lectures involving the active participation of the students, and practical sessions in a computational lab, in which specific projects will be carried out in python.

2. Contents

Lectures

Module 0. Introduction. The cell as a computer. Detection and processing of biochemical signals. Genetic and signaling networks, circuits and modules.

Module 1. Gene regulation circuits. Basic modes of cell regulation. Positive and negative feedback. Regulation cascades. Feedforward circuits. Mutual regulation circuits. Oscillations.

Module 2. Cell regulation networks. Network motifs. Modularity. Complex cellular networks. Robustness and lethality.

Module 3. Computation in cells. Finite state machines. Turing machines. Computability. Cellular computation.

Module 4. Biological information. Introduction to information theory. Information processing by cellular circuits.

Module 5. Computation in the brain. Neural excitability. Synaptic dynamics. Neuronal networks. Cortical networks.

Practical sessions

Practicals 1-2. Nonlinear dynamical systems: attractors, bifurcations, limit cycles

Practical 3. Zero-order ultrasensitivity

Practical 4. Irreversible stimulation

Practical 5. Perfect adaptation

Practical 6. Genetic oscillations

Practical 7. Bifurcations in gene regulation circuits

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Practical 8. Network motifs

Practical 9. The integrate-and-fire neuron model

3. Grading

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

a) Theory (30%): the theoretical concepts will be assessed with a single exam at the end of the term, which may contain both multiple-choice questions and open-ended questions.

b) Problem solving (30%): the ability to solve problems analytically will be assessed with a single exam at the end of the term.

c) Practical knowledge (30%): half of this grade will correspond to reports of the practical sessions, which will have to be delivered periodically. The other half will be given by the computational project that will be carried out during the final practical sessions of the course.

d) Course participation (10%): this part of the grade will be determined by the active participation in the theoretical and seminar sessions (asking and answering questions, solving problems in the blackboard, answering the review questions at the beginning of each theoretical session, and active participation in the Q&A forum of the Campus Global).

Additional requirements and comments:

- It is compulsory to attend the practical sessions.
- Passing the course requires obtaining a minimum score of 3 (in a scale of 0 to 10) in each one of the grades (a-d) listed above.
- The students that do not pass the course in December will be able to take the final exam again in July. In that exam we will assess the theory and problem solving parts of the grade (a and b above), but not the practical knowledge and class participation scores.

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4. Bibliography

4.1. Basic bibliography

- *An Introduction to Systems Biology*, U Alon, Chapman and Hall, 2007
- *Lectures on Computation*, RP Feynman, Westview, 1996
- *Theoretical Neuroscience*, P Dayan and L Abbott, MIT Press, 2005

4.2. Additional bibliography

- *Physical Biology of the Cell*, 2nd ed. Phillips, Kondev, Theriot, Garcia (Garland, 2012).
- *Systems Biology*. Klipp, Liebermeister, Wierling, Kowald, Lehrach, Herwig (Wiley, 2009)
- *Computational Cell Biology*. Fall, Marland, Wagner and Tyson (Springer, 2005).
- *Spikes*. Rieke, Warland, de Ruyter van Steveninck and Bialek (MIT Press, 1999)
- *Foundations of Cellular Neurophysiology*. Johnston and Wu (MIT Press, 1994).
- *Computational Neuroscience of Vision*. Rolls and Deco (Oxford Univ. Press, 2002).
- *Biophysics of Computation*. Koch (Oxford Univ. Press, 1998).
- *Introduction to Theoretical Neurobiology*. Tuckwell (Cambridge Univ. Press, 1988).