COURSE DATA

Data Subject	
Code	36354
Name	System Biology
Cycle	Grade
ECTS Credits	6.0
Academic year	2021 - 2022

Study (s)			
Degree	**Center**	**Acad. year**	**Period**
1109 - Degree in Biochemistry and Biomedical Sciences	Faculty of Biological Sciences	4	Annual

Subject-matter		
Degree	**Subject-matter**	**Character**
1109 - Degree in Biochemistry and Biomedical Sciences	14 - Materia de asignaturas optativas	Optional

Coordination	
Name	**Department**
MARIN NAVARRO, JULIA VICTORIA	30 - Biochemistry and Molecular Biology

SUMMARY

Systems Biology is an optional course included in the Biochemistry and Biomedical Sciences degree syllabus whose main goal is to acquaint the students with a perspective of living beings at the molecular and cellular level in which interrelations between constituent elements are remarked, functional consequences of these relations are analyzed, quantitative aspects are highlighted and the need for mathematical modelling to handle the complexity of life is emphasized. This approach is relatively new to the students because, after assuming that the descriptive contents of matters such as Biochemistry, Cell Biology and Genetics are already mastered, further abstraction is made to generalize functional aspects, analyzing their advantages and limitations as seen through the eyes of an engineer. The goal is not so much to describe living beings but rather to abstract, from their complex description, the crucial constitutive elements in order to find out the underlying functional logic. In this regard, the promising field that has been recently opened by the so called "Synthetic Biology", which aims to produce "design" organisms tailored to new properties of industrial, therapeutical or social interest, should be remarked. This topic is, without doubt, of great interest for the molecular biologist but also asks for a retaking of some mathematical and physical foundations which, even if already studied in the past, may have been parly forgotten because of their reduced appearance in other courses. Therefore, this course starts with a

review of basic concepts to be subsequently applied to biological problems of increasing complexity.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

No specialized knowledge of Mathematics or Physics is required beyond the matters studied in the first course of the degree, but a certain sympathy (or, at least, absence of hostility) to these disciplines is desirable. Full profit of the course requires also the understanding of English at the level of scientific text reading.

OUTCOMES

1109 - Degree in Biochemistry and Biomedical Sciences

- Be able to think in an integrated manner and approach problems from different perspectives.
- Know how to use the different bibliographic sources and biological databases and be able to use bioinformatic tools.
- Know how to design multidisciplinary experimental strategies in the field of molecular biosciences to solve complex biological problems, especially those related to human health.
- Know how to use mathematical and statistical tools to solve biological problems.
- Know the chemical and physical principles that determine the properties of biological molecules and govern the reactions in which they are involved.
- Know the structural and functional characteristics of macromolecules.
- Know the biochemical and molecular bases of cell function.
- Be able to assimilate scientific texts in English.

LEARNING OUTCOMES

The main objective of this course is to reconcile the description of living beings (in particular, that steming from molecular and cell biology) with the universal physical laws operating in nature. The student should become acquainted with the quantitative analysis of biological phenomena realizing that living matter obeys the same physical laws (which can be expressed through mathematical equations linking quantitative variables) ruling the whole universe and, therefore, become aware that these laws are relevant to the description of life. Besides, the student should learn that, inside the strict frame provided by these physical laws, living beings have developed original solutions to regulatory problems compromising survival and adaptation to the environment. The mathematical analysis of these solutions reveals the rationale of the functional design of the organisms and the adaptive value of these peculiarities of living matter. The ultimate goal of this course is to familiarize the student with this analytical view of the living which connects biology with the rest of the natural sciences and, moreover, allows addressing essential problems of biology whose complexity escapes intuitive understanding.

In particular, the course training intends that the student develops the following skills:

A) Acquisition of knowledge

1) Review of mathematical and physical concepts that are relevant for the description, analysis and understanding of life phenomena

2) Learning the functional design of biological macromolecules and their capacities and limitations as microscopic machines

3) Learning of cellular processes that are important for life activities, analyzed from the point of view of physics and mathematics

B) Development of scientific skills

1) Habit of penetrating the biological problems as to connect with their physical foundations

2) Ability of establishing quantitative relations between biologically relevant magnitudes in the form of mathematical models with predictive value

3) Familiarity with mathematical procedures for model analysis allowing to deduce the properties and restrictions of the modelled process based on the interactions that control it.

C) Development of social skills

Living beings are probably the most complex objects in the universe. Fully understanding them requires all tools available in the different fields of science and, therefore, surely demands the collaboration of scientists (biologists, chemists, physicists, mathematicians, engineers) with radically different specialization. As an interdisciplinary matter, Systems Biology offers to the molecular and cell biologists a general scientific background that facilitates the communication with specialists of other fields with whom he/she may desire to collaborate or, simply, to exchange ideas or information. In this sense, the contents of this course promote the development of an open mind, ready to incorporate ideas coming from other scientific fields for investigating the functional features of living organisms.

Besides, this course fosters also the development of other social skills (rational approach to problem solving, arguing ability, use of information sources, practice of English through the bibliography, etc.) which are common to the study of any science.

DESCRIPTION OF CONTENTS

1. Basic concepts

Introduction to Systems Biology. Mathematical and physical concepts that are useful in Biology. Free energy flow in the living matter. Energy couplings.

2. Modeling

Deterministic models in time-dependent differential equations. Dynamical systems. Steady states and stability. Limit cycles and sustained oscillations. Bifurcations and dynamic chaos.

3. Probability and Statistical Mechanics

Probability distributions. Boltzmann distribution. Kinetic and thermodynamic consequences. Cyclic fluxes and detailed balance. Types of noise and their description.

4. Biological machines

Biological machinery. Thermodynamical restrictions. Interactions at the molecular level. Design of receptors, transporters, catalysts and molecular motors. Proofreading mechanisms and error control.

5. Cybernetics

Frequency response of a system. Feedback. Analysis of regulatory circuits. Homeostatic circuits and damping of fluctuations. Circuits for perception of stimuli. Amplification cascades and diversification of signals. Oscillatory circuits. Biological rythms and clocks.

6. Processes in space and time

Partial differential equations. Random walk and diffusion laws. Time to capture. Diffusion with drift and reaction-diffusion models.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	45,00	100
Classroom practices	15,00	100
Study and independent work	15,00	0
Preparation of evaluation activities	40,00	0
Preparation of practical classes and problem	35,00	0
TOTAL	**150,00**	

TEACHING METHODOLOGY

The matter will be taught as a series of one-hour long classroom lectures. These lectures will include the exposition of new concepts and of examples of application of these concepts to biological modeling. Theoretical considerations will be frequently interrupted to apply them to practical cases (requiring calculations), treated as problems that will be solved in detail. In parallel, some other problems will be raised and left to the students as homework to be solved (with the teacher's advice) with the guide of the theory and problems discussed in the classroom, and/or using additional bibliography that the teacher may suggest.

Because the course relies on the progressive assimilation of a number of fundamental concepts that should be mastered to allow further advance, evaluation will be continuous along the course to promote a persistent attention to the matter by the students.

EVALUATION

A continuous evaluation is proposed through short written exams taking place abour every four weeks. The matter covered by each exam will not be eliminated but will accumulate along the course. Alternatively, for those students not passing the continuous evaluation, there will be a final exam covering the matter of the whole course.

Exams will include theoretical questions and problems (that, in some occasions, might be solved with the help of books and classnotes). In both cases not only knowledge will be evaluated but also the ability to apply it to the modelling of biological problems while extracting relevant conclusions from the models. To that end, all exams will include at least a biological case that the student will have to modelize, proposing equations based on relevant interactions, analyzing the consequences of the model and contrasting its predictions with the expected biological response. Exams will be graded up to 10 points, while 5 points (either as an average of the periodic short exams along the course or as a score of the final exam) are needed to pass the course.

REFERENCES

Basic

- ALON, U. An introduction to Systems Biology: Design principles of biological circuits. Chapman & Hall/CRC, 2007.
- COVERT, M.W. Fundamentals of Systems Biology. CRC Press, 2014.
- DiSTEFANO, J. Dynamic Systems Biology Modeling and Simulation. Elsevier, 2013.
- FALL, C.P., MARLAND, E.S., WAGNER, J.M. y TYSON, J.J. Computational Cell Biology. Springer, 2002
- INGALLS, B.P. Mathematical Modeling in Systems Biology. MIT Press, 2013.
- PHILLIPS, R., KONDEV, J., THERIOT, J. y GARCÍA, H.G. Physical Biology of the Cell. 2nd ed. Garland Science, 2012.

- VOIT, E. A first course in Systems Biology. Garland Science, 2012.
- SNEPPEN,K. Models of life: Dynamics and regulation in biological systems. Cambridge University Press, 2014

Additional

- BEARD, D.A. Biosimulation. Cambridge University Press, 2012.
- EDELSTEIN-KESHET, L. Mathematical models in biology. McGraw & Hill, 1988.
- NELSON, P. Physical Models of Living Systems. W.H. Freeman & Co., 2015.
- PALSSON, B.Ø. Systems biology: Simulation of dynamic network states. Cambridge University Press, 2011.
- Van den BERG, H. Mathematical models of biological Systems. Oxford University Press, 2011.
- SEGEL, L.A. y EDELSTEIN-KESHET, L. A primer on mathematical models in Biology. SIAM Press, 2013.

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

1 y 2) Contenidos y Volumen de trabajo.

No se prevén cambios en los contenidos ni volumen de trabajo.

3) Metodología.

El punto de inicio dado el número de estudiantes y las aulas disponibles es de plena presencialidad en las actividades. Sin embargo, ante la posibilidad de que la evolución de la situación derivada de la COVID-19 obligue a una reducción de la presencialidad, se tomarán las siguientes medidas:

1) Las actividades presenciales en aula se sustituirían en función de las herramientas tecnológicas disponibles en el aula en el momento de desarrollo del curso, por las siguientes metodologías:

-Videoconferencia síncrona

-Presentaciones Powerpoint locutadas en Aula Virtual

2) Para tutorías y dudas se utilizarían las siguientes metodologías:

-Comunicación directa profesor-estudiante a través del correo institucional

- Comunicación profesor-estudiante (de forma individual o en pequeños grupos) a través de videoconferencia

4) Evaluación.

La evaluación se mantendrá de acuerdo a lo indicado en la guía docente original.

En caso de que los exámenes no pudieran ser presenciales, se realizarían 'on line' en Aula Virtual mediante las herramientas disponibles.

Los detalles concretos de la adaptación a las situaciones que se pudieran producir se supervisarán por la CAT y se comunicaran a los estudiantes a través de Aula Virtual