2010-11 Academic Year

Basic Sciences I (20332)

Qualification/course: Bachelor's Degree in Human Biology
Year: 1
Term: 1
Number of ECTS credits: 7
Number of study hours: 175
Course Language(s): Catalan
Teaching Staff: Martí Lacruz / Ricard Solé

1. Presentation of the course

Basic Sciences I is one of the basic first-year subjects of the Bachelor's Degree course in Biology at Pompeu Fabra University. It has a value of 7 ECTS credits and consists of two independent modules: **Module 1. Physics for Health Sciences, and Module 2. Mathematics**.

MODULE 1
This subject is broken down into two aspects: theoretical and practical/experimental. Lecturers from the Medical and Radiophysics Departments of the Radiotherapeutical Oncology Service at the Esperança Hospital in Barcelona will be responsible for teaching this module. The subject coordinator is Martí Lacruz, the Head of the Physics Section, who will be responsible for teaching the theoretical part together with Jaume Quera, the assistant radiophysicist. The practical parts will be taught by the Head of Service, Manel Algara, and his assistant doctors Palmira Foro, Xavier Sanz and Nuria Rodríguez.

MODULE 2
Mathematics for Health Sciences is one of the basic first-year subjects of the Bachelor's Degree course in Biology at Pompeu Fabra University. The subject is based on the use of differential equations to study a range of biological problems, including the development of cancer and its treatment, the dynamics of epidemics, cellular communication, cross-membrane transport, transcription kinetics and protein synthesis, etc. The lecturers responsible for teaching this subject are Ricard Solé (theory) and Sergi Valverde (practical work).

2. Competences to be achieved

MODULE 1
The basic aims of this course, and consequently the teaching staff's goals for the students, can be summarised as the following:

- To provide students with the fundamental concepts that will help them understand that any phenomenon that they observe during their professional careers will have an implicit cause that can be explained in terms of physics.
- To collaborate with the rest of the teaching staff in imparting a scientific methodology of learning that will give students a tool with which to undertake their research efforts.
- To transmit to students a passionate interest in the cause-effect relationship and encourage them to take pleasure in their research.

MODULE 2
A fundamental objective is to educate students in the mathematical and computational modelling of biological problems. This modelling work will be their first insight into the world of theoretical models in biology.

3. Contents

MODULE 1
THEORY SYLLABUS
The training programme can be broken down into five topics:

Topic 1. The primordial universe
The first three minutes. Formation of matter. Elementary particles. Space, time and relativity. Development towards complex structures.

Topic 2. Atomic and nuclear physics
Quantum nature of the atomic nucleus. Radioactivity. Interaction between radiation and matter. The electromagnetic spectrum. Previous knowledge required of the student: non quantum nature of the atom; electronic configuration of the atomic shell; basic molecular chemistry.

Topic 3. Mechanics of physical bodies
Statics of fluids: gravity on fluids, equilibrium of bodies, surface tension. Fluid dynamics: circulation through narrow pipes. Laminar flow and turbulent flow. Acoustics: longitudinal and transverse waves. Sound. Doppler Effect. Previous knowledge required of the student: nature of fluids; wave theory (mathematics and physics).

Topic 4. Electromagnetism
Electricity: electric dipole. Electric potential. Bioelectricity. Electric current: electrical networks. Nerve impulse. Nernst potential. Magnetism: magnetic fields and induced fields. Magnetic properties of matter. Biomagnetism. Previous knowledge required of student: Coulomb's law, electrical field and electrical force; insulators and conductors; Ohm's law, direct current and alternating current; vector calculus.

Topic 5. Optics
Nature of light. Reflection and refraction on flat surfaces. Lenses and their aberrations. Polarization of light. Previous knowledge required of the student: electromagnetic nature of light. Laws of reflection and refraction. Basic geometry.

PRACTICAL SYLLABUS

Practical Session 1. Application of physics to medicine. Objective: practical application of atomic and nuclear physics, electromagnetism and acoustics to medicine. This practical session will be held in the lecture-rooms at the Faculty of Life and Health Sciences, and will consist of four parts: a first part in which the concept of three-dimensional space will be explained; a second part dedicated to the specialisation of Medical Physics; a third part in which we will examine the physical basis for obtaining images for radiodiagnostics, and a fourth and final part in which the effects of total body irradiation (ICT) of a living being will be explained. Assessment: examination.

Practical Session 2. Interaction of radiation with matter. Practical application to living beings via a computer simulation program. Preparation of three-dimensional dosimetry. Objective: practical observation of the behaviour of radiation in the interaction with human body organs of differing electronic densities. The session will be held at the Radiotherapy Department of the Esperança Hospital. Assessment: examination and presentation of dosimetry.

Practical Session 3. The physics of life. Objective: all the phenomena that occur in nature, even everyday situations which we have never stopped to think about, have an explanation based on a law of physics. The objective of the session is for students to find the law or explanation given by physics for certain everyday situations, i.e. to formulate the general rule on the basis of specific situations. The aim is to stimulate the skills of discovery, observation and abstraction. The session will be divided into two parts: preparation of a written report and presentation of the results in the classroom. Assessment: questions on the topics presented and evaluation of the written report, and of the oral presentation of the topics.

MODULE 2
THEORY SYLLABUS

Topic 1. Linear differential equations. Model of exponential decay (molecular degradation and radioactivity). Stationary states. Exponential growth: analysis and validation. Chemical equilibrium: reversible and irreversible reactions.

Topic 2. Logistic model. Growth with limited resources. Stationary states. The concept of stability. Application to tumour growth.

Topic 3. Linear stability. Concept and mathematical treatment. Linearization and limitations. Attractors. Examples: logistic model, particle diffusion, cell signalling, enzymes.

Topic 4. Bifurcations in dynamic systems. Concept of bifurcation. Bifurcation diagram. Examples: cancer treatment, organization of tissues, non-linear chemical reactions.

Topic 5. The dynamics of cancer. Tumour growth: basic biology and open problems. Simple models of competition between cancerous and healthy tissue. Conditions for the propagation of tumours. Colon crypts and cancer.

Topic 6. Propagation of epidemics. Infection: mechanisms and prevention. SIS Model: microscopic rules and theory. Eradication thresholds. Emerging viruses and evolution of pathogens.

Topic 7. Proteins, ribosomes and polymerization. The logic of the genetic code. Combinatorics. Ribosomes as molecular machines. Polymerization kinetics.

PRACTICAL SYLLABUS

Practical Session 1. Introduction to NetLogo and to object-oriented programming. Presentation of the NetLogo environment and of the object-oriented programming language. Concept of simulation using computer programs. Basic commands: instruction, assignment, loop. Flow control diagram. Implementation of the exponential decay equation (molecular degradation and radioactivity).

Practical Session 2. Simulations and differential equations. Molecular degradation through a population of disintegrating particles. Concepts: *turtle, patch, observer*. Attributes and methods of a turtle. Random numbers. Real-time visualization. Generation of 2D graphics. Design of graphical interfaces. Introduction to the simulation of life and death processes. Orders: *create-turtles, clear-all, die, fd, setxy, random-float, ask turtle, plotxy*.

Practical Session 3. Introduction to spatial growth processes. Spatial reproduction processes. Interaction between turtles and *patches*. Dynamic response as a function of position. Formation of spatial patterns. Introduction to the model of tumour growth. Orders: *ask patch, sprout, ask neighbors, turtles-here*.

Practical Session 4. Model of tumour growth. Simulation of the tumour growth process with two types of cells: human and cancer cells. Processes of spatial competition. Exploration of different possible scenarios. Orders: *set-current-plot-pen, color, count*.

Practical Session 5. The SIR Epidemic Model. Simulation of epidemics using the SIR model (*susceptible-infected-recovered*). Movement of turtles. Extension of the basic program to different types of states/individuals. Concept of infection threshold. Logistic growth of the number of infected individuals. Numerical evaluation of the impact of vaccinations. Commands: *rt, fd, one-of*.

Practical Session 6. Cell adhesion model. Introduction to the mechanism of cell adhesion and the formation and development of organs. Spontaneous formation of cell aggregates of the same type. Concept of energy minimization in a system. Forces of attraction and repulsion. Orders: *let, move-to, pach-right-and-ahead, random-pxcor*.

4. Assessment

Each module has its own assessment criteria, which will be made available to students in the specific course syllabuses. The subject mark will be proportional to the number of credits for the two modules. In order to attain the average mark of the two modules, a minimum mark of 4 is required in each. If students do not pass one of the modules at the first attempt, they will be required to re-sit the examination exclusively for the module concerned at the second examination session.

Assessment of progress

THEORY (70%) OF THE FINAL MARK
PRACTICAL WORK (35%) OF THE FINAL MARK

ASSESSMENT CONTROL FACTOR (summative mark)

5. Bibliography and teaching resources

5.1. Basic bibliography

Text books:

CROMER, A. H. *Física para las ciencias de la vida*. 3a ed. Barcelona: Reverté, 1992.
CUSSÓ, F.; LOPEZ, C.; VILLA, R. *Física de los procesos biológicos*. Ed. Ariel.

5.2. Complementary bibliography

Reference books:

BOGDANOV, K. *El físico visita al biólogo*. Moscou: Editorial Mir.
GASS. *Introducción a las ciencias de la tierra*. Ed. Reverté.
GUILLET, J. P. *Manual de física de radioterapia*. 1a. ed. Barcelona: Masson, 1996.
HAWKING, S. *Historia del tiempo*. Ed. Crítica.
HOYLE, F. *El universo inteligente*. Ed. Grijalbo.
HEWIT, PAUL G. *Conceptos de física*. Limusa Noriega Editores.
ORTUÑO, M. *Física para biología, medicina, farmacia y veterinaria*. Crítica.
RESNICK. *Conceptos de relatividad y teoría cuántica*. Limusa Noriega Editores.
SEARS-ZEMANSKY. *Física general*.
VALLS, A.; ALGARA, M. *Radiobiología básica*. Madrid: Eurobook, SL, 1994.

6. Methodology

7. Activities schedule