Universitat Autònoma de Barcelona

2023/2024

Bioenergetics

Code: 100866
ECTS Credits: 6

Degree	Type	Year	Semester
2500252 Biochemistry	OB	3	1

Contact

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Teaching groups languages

You can check it through this link. To consult the language you will need to enter the CODE of the subject. Please note that this information is provisional until 30 November 2023.

Prerequisites

Part of the knowledge of the 1st and 2nd courses of the degree is needed to be able to follow the course. Some materials of the following courses are particularly needed: Cell Biology, Thermodynamics and Kinetics, Physics, Biochemistry I and Biochemistry II, Chemistry and Engineering of Proteins, and Molecular Biology.

Objectives and Contextualisation

The Bioenergetics course will carry out a study in depth on the relationship between energy and living systems. The subjects of the course are listed in the contents. The aim of the course is that students acquire a solid knowledge about: (1)The application of the principles of classical Thermodynamics to the study of the fundamental biochemical processes; (2) Energy and chemical and physical mechanisms involved in the production of ATP in respiration and photosynthesis; (3) Energy transformations in biosynthesis, cellular transport and mechanical work; (4) Applications of Thermodynamics of open systems to the study of the energetics of living systems. The possible applications of Bioenergetics for the solution of energy problems in our technological civilization will also be considered.

Competences

- Act with ethical responsibility and respect for fundamental rights and duties, diversity and democratic values.
- Collaborate with other work colleagues.
- Design experiments and understand the limitations of experimental approaches.
- Explain the structure of cell membranes and their role in signal transduction processes, the transport of solubles and the transduction of energy.

- Identify molecular structure and explain the reactivity of the different biomolecules: carbohydrates, lipids, proteins and nucleic acids.
- Interpret experimental results and identify consistent and inconsistent elements.
- Introduce changes in the methods and processes of the field of knowledge to provide innovative responses to the needs and demands of society.
- Make an oral, written and visual presentation of one's work to a professional or non-professional audience in English and understand the language and proposals of other specialists.
- Read specialised texts both in English and one's own language.
- Take account of social, economic and environmental impacts when operating within one's own area of knowledge.
- Take sex- or gender-based inequalities into consideration when operating within one's own area of knowledge.
- Understand the language and proposals of other specialists.
- Use ICT for communication, information searching, data processing and calculations.

Learning Outcomes

1. Act with ethical responsibility and respect for fundamental rights and duties, diversity and democratic values.
2. Apply open-system thermodynamics to the study of energy in living systems.
3. Collaborate with other work colleagues.
4. Describe the biological membranes in the physical and chemical mechanisms involved in the energy transformations associated with ATP formation in respiration and photosynthesis.
5. Describe the molecular principles of the selective transport of substances through cell membranes, and how it is regulated.
6. Design experiments and understand the limitations of experimental approaches.
7. Explain the chemical, thermodynamic and structural bases of energy transformations for ATP formation and for the cell tasks of biosynthesis, transport and mechanics .
8. Interpret experimental results and identify consistent and inconsistent elements.
9. Introduce changes in the methods and processes of the field of knowledge to provide innovative responses to the needs and demands of society.
10. Make an oral, written and visual presentation of one's work to a professional or non-professional audience in English and understand the language and proposals of other specialists.
11. Read specialised texts both in English and one's own language.
12. Take account of social, economic and environmental impacts when operating within one's own area of knowledge.
13. Take sex- or gender-based inequalities into consideration when operating within one's own area of knowledge.
14. Understand the language and proposals of other specialists.
15. Use ICT for communication, information searching, data processing and calculations.

Content

1. INTRODUCTION: ENERGY AND THE BIOSPHERE. Phototrophic and chemotrophic living systems. Cycle of matter and flow of energy in the biosphere. Energy efficiency and conversion. Transport and storage of energy.

2. THE PRINCIPLES OF THERMODYNAMICS. Thermodynamic systems. Concept of heat and temperature. Equivalence between heat and work. Joule's experiment. First principle of Thermodynamics. Reversible and irreversible processes. Entropy and the second principle of thermodynamics. Mechanical interpretation of heat and entropy. Quantum interpretation of heat and entropy. Equivalence of the principles of maximum entropy and minimum energy. The concept of free energy. Enthalpy, Helmhotz Free Energy and Gibbs Free Energy.

3. STATISTICAL MECHANICS AND MICROSCOPIC SYSTEMS. Thermodynamics and microscopic models. Statistical mechanics: entropy and the atomic model. Boltzmann's distribution and the partition function. Applications to proteins and nucleic acids.

4. ENERGY PRODUCTION IN PHOTOSYNTHESIS. Dark phase and luminous phase. Chloroplast structure. Chromophors. Absorption and transport of solar radiation energy. Marcus theory of electronic transfer. The quantum tunnel effect and estimation of the tuneling distance. Photoreceptors, antenna model, antenna energy transport mechanism in the photochemical center. Net electronic transfer rate. The photochemical center: reactions of charge transfer, structure and operation of photochemical centers. Photosynthetic transport chain in bacteria. Photosynthetic transport chain in plants: Emerson's cooperative effect and the two photosynthetics. Fixation of CO_2 in the Calvin cycle. The capacity to fix CO_2 and the climate change.

5. ENERGY PRODUCTION IN FERMENTATIONS AND RESPIRATION. Production of ATP in fermentations: phosphorylation at substrate level. ATP production linked to respiration: oxidative phosphorylation and the mitochondria. The mitochondrial electronic transport chain: transporters and their arrangement, location of transporters in the internal mitochondrial membrane. Particles: ATP synthases. The coupling problem between electronic transport and oxidative phosphorylation: chemical coupling hypothesis, conformational coupling hypothesis, chemosmotic coupling hypothesis. The ATPase F1-Fo complex: properties, structure, ATP synthesis mechanism.

6. TRANSPORT WORK. Definition of transport work. Simple diffusion. Fick's first law. Fick's second law. Simple diffusion model through the cell membrane. Membrane permeability. Facilitated diffusion. Facilitated iffusion models. The glucose transporter. Ionic channels. Channels operated by voltage. Ionic equilibrium and the Nernst equation. Simple models of ion channels operated by voltage. Channels operated by ligand binding. The Monod-Wyman-Changeaux model. Entropic force in exit channels. Active transport. Active transport of glucose. Glucose flow in the gut.

7. MECHANICAL WORK. Molecular motors. Cytoskeleton. Structure of microtubules and actin filaments. Polymerization, nucleation and elongation. Simple polymerization model. Polar polymerization model. Polymerization model with ATP hydrolysis. Polymerization disasters. Translational motors: myosin, kinesin and dinein. Muscle contraction. Translation models: the random path model. Relationship between polymerization speed and ATP consumption. Rotational motors and the Brownian ratchet. Polymerization motors and centriole location. Translocation motors and secretion systems.

8. BIOSYNTHESIS WORK. Differences between anabolism and catabolism. Relationship between ΔG values and metabolic pathway regulation points. Energetic aspects of metabolic pathways and control strategies: common intermediaries, compartmentalization and enzymatic control. Some energetic aspects of enzymatic catalysis: thermodynamics and time, chemical kinetics, energy interpretations of the catalytic action of enzymes. Examples of biosynthesis work: gluconeogenesis compared to glycolysis.

9. THE THERMODYNAMICS OF IRREVERSIBLE PROCESSES AND BIOLOGY. Thermodynamics of open systems. Systems not far from balance: internal entropy production speed, Onsager equations, stationary state, principle of minimal entropy production. Systems far removed from balance: Bénard instability, Zhabotinski reaction. Dissipative structures: possible applications to the study of living systems.

10. FORMATION OF BIOLOGICAL PATTERNS. Cell differentiation and embryogenesis. Morphogenic gradients. The model of the French flag. Formation of heterocycists in photosynthetic organisms. Turing patterns with and without diffusion. Generation of temporary patterns: the growth of microorganisms on the surface. Effect of biological noise on patterns. Advantages of biological noise. The ComK system of competition in B. subitilis and the bacterial mechanisms of persistence.

11. A THERMODYNAMIC VISION OF THE ORIGIN OF LIFE AND EVOLUTION. Definition of life. Current theories about the origin of life. Thermodynamic definition of life: self-replication. Spontaneous self-replication. Life understood as a phase transition: the concept of life on the edge of chaos. Concept of self-organized criticality. Darwinism and evolution: the concept of morphogenic space. The role of genes in evolution.

Methodology

Theory. The professor will explain much of the content of the course with the support of material that will be available to students in the Virtual Campus (VC). The theory sessions address the conceptual parts of the course. Other parts of the course must be studied independently by students. The professor will indicate exactly which topics will have to be studied in this way and the material to be used.

Problems. The professor will propose several problems related with specific subjects of Bioenergetics usign the software CellDesigner. The group will be divided into 12 subgroups and each of the subgroups will have to write a summary of the proposed problems. All students can participate actively in discussions. Questions about hese problems can be included in the exams.

Tutorials. In the sessions of tutoring in classroom, there will be guidance on the strategy to be followed in order to study the subjects of individual learning.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Lectures	35	1.4	2, 5, 4, 7, 8
Problems/specific subjects	10	0.4	12, 15, 2, 3, 5, 4, 6, 7, 8, 9, 11, 10
Type: Supervised			
Tutorials in classroom	4	0.16	2, 5, 4, 7, 8
Type: Autonomous			
Grup activity: report of a problem/specific subject	12	0.48	1, 13, 15, 2, 3, 5, 4, 6, 7, 8, 11, 10
Individual study	67	2.68	15, 2, 5, 4, 6, 7, 8, 11
Individual study of specific subjects	15	0.6	15, 2, 5, 4, 6, 7, 8, 11

Assessment

Continued Evaluation:

The assessment will be based on 3 elements:

(1) Submission of a report on a specific topic (group evaluation, practical exercises with CellDesigner): maximum of 2 points (20%). To obtain the maximum grade, the report must be in English (0.5 points).

(2) Partial exam 1 on theoretical content: maximum of 4 points (40%).

(3) Partial exam 2 on theoretical content: maximum of 4 points (40%).

The report submission is not recoverable.

Students can take the referral exam to attempt to improve the grade obtained in the first and/or second partial exam; the grade obtained in this second exam cancels out the grade obtained in the previously taken partial exam (even if the latter grade was higher).

The subject will be passed when the sum of the obtained grades is ≥ 5 points (out of a maximum of 10).

To participate in the referral exam, students must have been previously evaluated in a set of activities that account for at least two-thirds of the total grade for the subject or module. Therefore, students will receive the qualification of "Not Evaluable" when the weight of the evaluation activities carried out is less than 67% of the final grade.

Examination-based evaluation:

Students who opt for examination-based evaluation must complete the classroom practices (exercices with CellDesigner) during the face-to-face sessions and submit an individual report. This report will account for 20% of the final grade, without reassesment.

The examination-based evaluation consists of a single synthesis exam covering the content of the entire program. The grade obtained in the synthesis exam represents 80% of the final grade for the subject.

The examination-based evaluation exam will take place on the same date scheduled for the last continued evaluation exam, and the same referral system as for continual evaluation will be applied. The deadline for submitting the report will also be on the same day as the exam.

The subject will be passed when the sum of the obtained grades is ≥ 5 points (out of a maximum of 10).

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Assessment of problems/specific subjects	20%	1	0.04	1, 13, 15, 2, 3, 5, 4, 6, 14, 7, 8, 11, 10
First midterm exam	40%	3	0.12	12, 2, 5, 4, 6, 7, 8, 9, 11
Second midterm exam	40%	3	0.12	2, 5, 4, 6, 7, 8, 11

Bibliography

Lehninger: Principles of Biochemistry. D.L. Nelson & M.M. Cox (2021) 8th edition. W. H. Freeman.

The molecules of life. John Kuriyan, Boyana Konforti and David Wemmer (2012) 1st edition. W. W. Norton & Company

Physical Chemistry for the Life Sciences. Peter Atkins and Julio de Paula (2015) 2nd edition. Oxford University Press.

Bioenergetics 4. David G. Nicholls (2013) 4th edition. Academic Press.

Cell biology by the numbers. Ron Milo and Rob Phillips (2015) 1st edition. Garland Science.

The origins of order. Stuart A. Kauffman (1993) Oxford University Press.

Software

CellDesigner: A modeling tool of biochemical networks (http://www.celldesigner.org)