Universitat Autònoma de Barcelona

2020/2021

Bioenergetics

Code: 100866
ECTS Credits: 6

Degree	Type	Year	Semester
2500252 Biochemistry	OB	3	1

The proposed teaching and assessment methodology that appear in the guide may be subject to changes as a result of the restrictions to face-to-face class attendance imposed by the health authorities.

Contact

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Use of Languages

Principal working language: catalan (cat)

Some groups entirely in English: No

Some groups entirely in Catalan: No

Some groups entirely in Spanish: No

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

- 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.
- Make an oral, written and visual presentation of ones 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 ones own language.
- Understand the language and proposals of other specialists.
- Use ICT for communication, information searching, data processing and calculations.

Learning Outcomes

1. Apply open-system thermodynamics to the study of energy in living systems.
2. Collaborate with other work colleagues.
3. Describe the biological membranes in the physical and chemical mechanisms involved in the energy transformations associated with ATP formation in respiration and photosynthesis.
4. Describe the molecular principles of the selective transport of substances through cell membranes, and how it is regulated.
5. Design experiments and understand the limitations of experimental approaches.
6. Explain the chemical, thermodynamic and structural bases of energy transformations for ATP formation and for the cell tasks of biosynthesis, transport and mechanics .
7. Interpret experimental results and identify consistent and inconsistent elements.
8. Make an oral, written and visual presentation of ones work to a professional or non-professional audience in English and understand the language and proposals of other specialists.
9. Read specialised texts both in English and ones own language.
10. Understand the language and proposals of other specialists.
11. Use ICT for communication, information searching, data processing and calculations.

Content

1. INTRODUCTION: THE ENERGY AND THE BIOSPHERE. Topics covered by bioenergetics. Phototrophic and chemotrophic living systems. Cycle of matter and flow of energy in the biosphere.

2. THE PRINCIPLES OF THERMODYNAMICS AND MICROSCOPIC MODELS. First principle of thermodynamics. Second principle of thermodynamics: entropy and internal entropy production, the quality of the different types of energy, free energy and maximum useful work, chemical potential, applications to chemical reactions. Thermodynamic and microscopic models. Statistical mechanics: the entropy and the atomic-molecular model. Quantum mechanics: molecular distributions, interpretation of entropy. Applications to proteins and DNA.

3. THE CHEMICAL ENERGY OF LIVING SYSTEMS. Life as a chemical process: heat of combustion of food, direct and indirect calorimetry, basal metabolic rate. Cellular work: living systems as energy transducers. Energy of triacilglycerides and ketone bodies. Phosphoanhydride bonds: ATP, free energy of hydrolysis, coupled reactions and the common intermediate, phosphocreatine, other nucleoside triphosphates, pyrophosphate. Steady state: energy charge, independent regulation of pathways producing and consuming ATP. Critical discussion of the concept of "high-energy" bonds. Energetic aspects of enzymatic catalysis: thermodynamics and time, chemical kinetics, energetics of enzyme catalysis, relationship between thermodynamically possible reactions and enzymes.

4. PRODUCTION OF ATP IN FERMENTATIONS AND IN RESPIRATION. Production of ATP in fermentation: substrate-level phosphorylation. Production of ATP in respiration: oxidative phosphorylation, mitochondria. The mitochondrial electron transport chain: electron carriers, organization of the transporters in the inner mitochondrial membrane. Submitochondrial particles: ATP synthase. The problem of the coupling between electron transport and oxidative phosphorylation: chemical hypothesis, conformational hypothesis. Chemiosmotic hypothesis: vectorial reactions, electrochemical potential, experimental determination of the pH gradient and of the electric potential, ionophores, stoichiometry, Q cycle, carrier dynaics, structure of cytochrome c oxidase, evidence in favor a delocalized proton gradient. The ATPase F1Fo complex: properties, structure, mechanism of ATP synthesis. General considerations on the oxidative phosphorylation: yield and reversibility.

5. ATP PRODUCTION IN PHOTOSYNTHESIS. Dark and light phases. Chloroplasts and chromatophores. Absorption and transport of the energy of solar radiation: photoreceptors, the antenna model, mechanism of the energy transport from the antena to the photochemical center. Structure of antennas: phycobilisomes, antennas of bacteria and plants. The photochemical center: charge-transfer reaction, structure and chemical reactions in the photochemical center. Electron transport chain in photosynthetic bacteria. Chain of photosynthetic transport in plants: the cooperative effect of Emerson and the two photosystems, Z scheme, cyclic electron transport. Photosynthetic phosphorylation. Simple photosynthetic system: bacteriorhodopsin. Possible technological applications of our current knowledge about biological photosynthesis.

6. CELLULAR WORK. Examples of biosynthesis work: energetic aspects of gluconeogenesis compared to glycolysis, relationship between the values of ΔG and the points of regulation of these two pathways, futile cycles, Calvin cycle in the dark phase of the photosynthesis, C3 and C4 plants, photorespiration, use of photosynthesis for the production of energy and materials. Transport work: facilitated diffusion, active transport and passive transport, biochemical mechanisms of transport across membranes. Mechanical work: transformation of chemical energy into mechanical energy in muscle contraction, molecular motors, direct transformation of the energy of proton gradientsinto mechanical energy in the bacterial flagella.

7 RELATIONSHIPS BETWEEN INFORMATION THEORY, THERMODYNAMICS AND BIOLOGY. Basic topics of the information theory. Information content. Relationship between information content and entropy. Relationship between energy and information: the problem of the Maxwell's demon. Biological implications. Living systems and the second law of thermodynamics.

8. THE THERMODYNAMICS OF IRREVERSIBLE PROCESSES AND BIOLOGY. Need for a new thermodynamics of open systems. Systems near to equilibrium: entropy production, Onsager equations, steady-state , principle of minimum entropy production, applications to living systems. Far from equilibrium systems: Bénard instability, Zhabotinsky reaction. Dissipative structures: applications to the study of living systems.

9. ENERGY ASPECTS IN THE FORMATION OF CELLULAR STRUCTURES. Formation of supramolecular structures: differences between the work of biosynthesis and the formation of supramolecular structures, renaturations, self-assembly, entropy-driven processes, hydrophobic effect, cooperativity. Energy considerations about the origin of life: sources of energy for the synthesis of atoms and the fundamental molecules of life, formation of macromolecules, hypercycles, open systems. Evolution of redox reactions employed by living systems: evolution of the electron transport chains, emergence of heterotrophs, photosynthetic autotroph organisms, and eukaryotes.

10. BIOENERGETICS AND ECOLOGY. Flow of energy in ecosystems: the trophic chain, the second law of thermodynamics and energy pyramid in mature ecosystems, necessity of the existence of an energy flow.

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. 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.

Classes will be taught alternately with 50% of the students present physically in the classroom, while the rest can follow the classes virtually through the TEAMS platform.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Lectures	35	1.4	1, 4, 3, 6, 7
Problems/specific subjects	10	0.4	11, 1, 2, 4, 3, 5, 6, 7, 9, 8

Type: Supervised			
Tutorials in classroom	4	0.16	1, 4, 3, 6, 7
Type: Autonomous			
Grup activity: report of a problem/specific subject	12	0.48	11, 1, 2, 4, 3, 5, 6, 7, 9, 8
Individual study	67	2.68	11, 1, 4, 3, 5, 6, 7, 9
Individual study of specific subjects	15	0.6	11, 1, 4, 3, 5, 6, 7, 9

Assessment

The evaluation is based on four elements:

(1) Preparation of a report about a specific subject (group report): maximum of 2 points (20%). To get the maximum score the report has to be written in English (0.5 points).

(2) First midterm exam: maximu of 4 points (40%).

(3) Second midterm exam: maximu of 4 points (40%).

There is no reassessment exam for the group report.

Students can do a reassessment exam to try to improve the score obtained in the first and/or second midterm exam; the score obtained in this reassessment exam overrides the score obtained in the first and/or second midterm exam (even if the score in the previous exam was higher).

To be eligible for the retake process, the student should have been previously evaluated in a set of activities equaling at least two thirds of the final score of the course or module. Thus, the student will be graded as "No Avaluable" if the weighting of all conducted evaluation activities is less than 67% of the final score.

To pass the course the sum of the scores must be ≥ 5 points (maximum of 10 points).

The date for the review of the exams will be announced at least 2 days in advance.

Assessment Activities

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

Bibliography

Lehninger: Principios de Bioquímica. D.L. Nelson & M.M. Cox (2009) 5a edición. Ediciones Omega.

Bioquímica. L. Stryer, J.M. Berg & J.L. Tymoczko (2008) 6a edició. Editorial Reverté.

Concepts in Bioenergetics. L. Peusner (1974) Prentice-Hall.

Foundations of Bioenergetics. H.J. Morowitz (1979) Academic Press.

The Vital Force: A Study of Bioenergetics. F.M. Harold (1986) W.H. Freeman and Company.

Molecules, Dynamics and Life: An Introduction to Self-organization of Matter. A. Babloyantz (1986) J. Willey and Sons.

Energy and the Evolution of Life. R.F. Fox (1988) Academic Press.

Energy Transduction in Biological Membranes: A Texbook of Bioenergetics. W.A. Cramer & D.B. Knaff (1990) Springer-Verlag.

Bioenergetics at a glance. D.A. Harris (1995) Blackwell Science.

Energy and Life. J. Wrigglesworth (1997) Taylor and Francis.

Bioenergetics 3. D.G. Nicolls & S.J. Ferguson (2002) Academic Press.

Scientific articles that will be indicated in the VC.