COURSE UNIT DESCRIPTION - BIOENERGETICS

Course unit title	Code
BIOENERGETICS	

Lecturer(s)	Department(s)
Coordinator: Assoc. prof. Elena BAKIENĖ **Other(s):**	Vilnius University, Department of Biochemistry and Molecular Biology, M.K.Čiurlionio g. 21/27, LT-03101 Vilnius

Cycle	Level of the course unit	Type of the course unit
Full-time studies (1st stage)	1 out of 1	Selective

Mode of delivery	Period of delivered	Language(s) of instruction
Face to face	5th semester, autumn	Lithuanian (English)

Prerequisites and corequisities	
Prerequisites: Students should know basics of general biology, general chemistry and biochemistry	**Corequisities (if any):**

Number of credits allocated to the course unit	Student's total workload	Contact hours	Self-study and research hours
4	**120**	**48**	**72**

Purpose of the course unit: programme competences to be developed

The course unit aims to develop:

Subject-specific competences:

- ability to explain molecular mechanisms of energy accumulation in cells and on energy transformation in living organisms.
- knowledge about general principles of regulation and control of the energy conversion processes in living organisms.
- knowledge about the main problems of bioenergetics and special techniques for studies of bioenergetics;
- skills to analyze, compare, and critically evaluate the bioenergetics-related information;
- ability to apply theoretical knowledge in solving quantitative and qualitative problems of both familiar and unfamiliar nature.

General competences:

- skills for self-development, learning skills in order to study both molecular biology and general science resources;

Learning outcomes of the course unit	Teaching and learning methods	Assessment methods
• Explains the sources of energy supply of the processes running in the living organisms and molecular mechanisms of the energy transformation in the cells; • Analyse,s compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic
• Desribes the thermodynamics of the biological (living) systems: exergonic and endergonic reactions, G ibbs (free) energy, spontaneous and non-spontaneous reactions, free energy changes of coupled reactions;	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic

• Desribes the biological oxidation-reduction reactions and mechanisms of electron transfer by transporters of respiratory chains; • Analyses, compares and critically evaluates the information related to this topic.		
• Desribes the basic forms of energy ("energy currency"), which living cells use to do their necessary work; energy transformation at the cellular level, energy storage compartments in eukaryotic and prokaryotic cells. • Analyses, compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic
• Desribes the mechanism and explain the significance of substrate-level phosphorylation in the intracellular energy storage; structure and roles of high-energy compounds, the ways of ATP synthesis in the cell and processes of cellular activities in which ATP energy is used. • Analyses, compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic
• Desribes the molecular principles of composition and structure of biological membranes. Will acquire detailed knowledge about the transport of the substances across membranes and the crucial role of biological membranes for the energy storame; • Analyses, compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic
• Explains the chemiosmotic theory of energy transformation and coupling, chemiosmotic cycle of protons, the mechanisms of oxidative phosphorylation, the generation of proton electrochemical gradient as well as pathways of electron transport and H^+ translocation by the components of biological membranes; • Analyse, compares and critically evaluatse the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic
• Desribes the different electron transport chains, to deepen knowledge on mitochondrial respiratory chain, its components and complexes; inhibitors of electron transport systems and the mechanisms of action of uncouplers of oxidative phosphorylation; • Analyses, compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic
• Desribes the basic molecular principles and stages of photosynthesis, photosynthetic generators of the protonmotive force, photophosphorylation; photochemical cycle of bacteriorhodopsin; • Analyses, compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic
• Explains the basic methods for quantitavive analysis of parameters characterizing the energetical status of the cell. • analyses, compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic

• Explains the structural and functional aspects of ATP-synthases and ATP-ases. • analyses, compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic
• Describes hypotheses of origin and evolution of energy-transforming biological systems. • analyses, compares and critically evaluates the information related to this topic.	Lectures, self-directed learning, seminar talks and discussions on selected topics, preparation of an essay	Written quiz, written (essay) and oral presentation on selected topic

Content: breakdown of the topics	**Contact hours**							**Self-study work: time and assignments**	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work placement	**Contact hours**	**Self-study hours**	**Assignments**
1. Introduction to bioenergetics. Energy transformation in living systems. Forms of energy, which can be used by the cell to perform useful work.	2		1				**3**	**4**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar
2. Thermodynamics of biological systems. The free energy changes of biological conversions. Exergonic and endergonic processes, standard free energy change, spontaneous and non-spontaneous reactions, energy coupling.	2		1				**3**	**4**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
3. "High-energy" compounds. The role of ATP in cellular energetics. Phosphoanhydride bond, the other "high energy" bonds. The pathways of ATP synthesis in the cell. Phosphorylation potential. The cellular processes in which ATP energy is used.	2		1				**3**	**4**	Learning of topic-related material in the course virtual learning

									environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
4. Biological oxidation-reduction reactions. Standard redox potential and its relationship with the free energy change. The role of nicotinamide and flavine cofactors as well, as metaloproteins in electron transport and in energy storage. Evaluation of energy obtained through the transfer of electrons down the respiratory chain.	2		1				**3**	**4**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
5. Substrate-level phosphorylation. The main stages and products of glycolysis, its role with regard to converting potential chemical energy to usable chemical energy. Krebs cycle: main stages, products and importance for energy transformation. Fermentation. Energy acquirement from degradation of lipids and proteins.	2		1				**3**	**4**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
6. Structure and functions of biological membranes.	4		2				**6**	**10**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
Major types of lipids found in biological membranes, different roles of lipids in the membrane. Membrane fluidity, factors governing Lipid diffusion in membranes, phase transition temperature. Integral and peripheral membrane proteins, their	2		1				3	5	

function and interaction with the lipid bilayer. Membrane asymmetry. Factors affecting membrane permeability.									
The role of membranes in the intracellular accumulation of energy. Structure and functions of mitochondria and thylakoids. Cell envelopes of bacteria and archaea.	2		1				3	5	
7. Movement of substances across membranes. The classification of membrane transport processes. Ion and metabolite transport across energy conserving membranes. Model systems of membrane transport.	2		1				**3**	**5**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
8. The fundamentals of chemiosmotic energy transduction theory. Chemiosmotic cycle of protons, the mechanism of oxidative phosphorylation, the generation of proton electrochemical gradient, protonmotive force. The pathways of electron transport and H^+ translocation by the components of biological membranes.	2		1				**3**	**5**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
9. Elektron transfer chains in biological membranes.	**4**		**2**				**6**	**9**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
Structural and functional organization of the mitochondrial respiratory chain. Complex I - NADH:ubiquinone oxidoreductase (NADH dehydrogenase); Complex II - succinate:ubiquinone oxidoreductase (succinate dehydrogenase); Complex III - ubiquinone:cytochrome c oxidoreductase (cytochrome bc_1 complex;	2		1				3	4	

Complex IV (cytochrome c oxidase). Movement of electrons, protons and charge mediated by respiratory chain.									
Inhibitors of electron transfer through respiratory chain. The mechanism of action of uncouplers of oxidative phosphorylation, model (synthetic) and natural (mitochondrial uncoupling proteins) uncouplers, thermogenic respiration. Respiration mediated generation of reactive oxygen species, oxidative stress. Cellular defences designed to detoxify superoxide generated by the respiratory chain. Diversity of respiratory chains of plants, bacteria and archaea, aerobic and anaerobic respiratory chains, respiration with an extracellular final electron acceptor.	2		1				3	5	
10. Photosynthesis.	**4**		**2**				**6**	**9**	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an say and arrangements to discuss it at a seminar.
The main pigments of photosynthesis, chlorophyll. The stages of photosynthesis. The light reactions. Photosynthesis in plants: chloroplasts, thylakoids, non-cyclic electron transport chain, photosystems I and II. Photolysis of water (oxygen releasing system). The light-stage dependent ATP synthesis (photophosphorylation). Dark-stage reactions.	2		1				3	4	
Oxygenic and anoxygenic photosynthesis in prokaryotes, photoautotrophs and photoheterotrophs. The cyclic electron transport chain of photosynthetic bacteria. Photochemical cycle of bacteriorhodopsin.	2		1				3	5	
11. Composition and structure of ATP-synthase, the mechanism of ATP synthesis. Inhibitors of phosphorylation. ATP-ases. The measurements of ATP content.	2		1				3	4	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
12. Special techniques of bioenergetics: methods for quantitavive analysis of parameters characterizing the energetical status of the cell. The assessment of proton conductance, the methods of oxygen pulse and acid pulse. Measurements of espiration rate with an oxygen electrode. Mitochondrial respiratory steady states, respiratory control.. The estimation of protonmotive	2		1				3	5	Learning of topic-related material in the course virtual learning environment,

force: the measurements of membrane voltage ($\Delta\psi$) and pH gradient. Evaluation of overall parameters of energy transduction by inhibitory analysis.									self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
13. Hypotheses of origin and evolution of energy-transforming biological systems. Bioenergetics of extremofiles.	2		1				3	5	Learning of topic-related material in the course virtual learning environment, self-directed learning, preparation of an essay and arrangements to discuss it at a seminar.
Total	**32**		**16**				**48**	**72**	

Assessment strategy	**Weight,%**	**Assessment period**	**Assessment criteria**
Midterm quiz	30	6th week of the course	Written quiz (virtual learning environment) from topics 1-6 (30-40 test questions and 1-3 open questions (short essay); the answers will be assessed on a point system based on the complexity of questions). Assessment range: 100% - 90% answered questions –10 (excellent) 90% - 80% answered questions – 9 (very good) 80% - 70% answered questions –8 (good) 70% - 60% answered questions – 7 (highly satisfactory) 60% - 50% answered questions – 6 (satisfactory) 50% - 40% answered questions – 5 (sufficient) <40% answered questions –<4 (insufficient)
Midterm quiz	30	12th week of the course	Written quiz (virtual learning environment) from topics 6-10 (30-40 test questions and 1-3 open questions (short essay); the answers will be assessed on a point system based on the complexity of questions). Assessment range: 100% - 90% answered questions –10 (excellent) 90% - 80% answered questions – 9 (very good) 80% - 70% answered questions –8 (good) 70% - 60% answered questions – 7 (highly satisfactory) 60% - 50% answered questions – 6 (satisfactory) 50% - 40% answered questions – 5 (sufficient) <40% answered questions –<4 (insufficient)
Written (essay, 6-15 p.) and oral presentation on selected topic at a seminar and participation in seminar discussions.	10	After each lecture	1 mark (10%). Presentation is based on a topic relevant for the course, with reference to the latest scientific literature. The problem is discussed in detail. The presentation demonstrates in-depth knowledge of subject, is logically organized and shows student's ability to analyze and evaluate the topic-related information. Conclusions follow from the information presented. Essay is stylistically and grammatically correct. Topic is presented

			at the seminar (PowerPoint slides, etc.) and discussed. 0.5 mark (5%). The problem is not analyzed in detail; there are style and spelling errors in essay. Presentation at a seminar is not thorough and coherent enough. 0 mark. Presentation is not delivered or is unsatisfactory.
Exam	30	During the exam session	Written quiz (virtual learning environment) from topics 10-13 (30-40 test questions and 1-3 open questions (short essay); the answers will be assessed on a point system based on the complexity of questions). Assessment range: 100% - 90% answered questions –10 (excellent) 90% - 80% answered questions – 9 (very good) 80% - 70% answered questions –8 (good) 70% - 60% answered questions – 7 (highly satisfactory) 60% - 50% answered questions – 6 (satisfactory) 50% - 40% answered questions – 5 (sufficient) <40% answered questions –<4 (insufficient)

Author	Year of publica-tion	Title	Issue of a periodical or volume of a publication	Publishing place and house or web link
Compulsory reading				
Virtual learning environment of the course (course material: lectures, seminar papers, assignments**,** recent scientifi c literature publications)	Created in 2011, continuous ly updated	Bioenergetics		http://vma.esec.vu.lt
R. Daugelavičius	2008	Ląstelės molekulinė energetika (“Molecular energetics of the cell“, textbook in Lithuanian)		KTU leidykla „Technologija“
D.G. Nicholls, S.J. Ferguson	2002	Bioenergetics 3		London, Academic Press
Optional reading				
W.A. Cramer, D.B. Knaff	1991	Energy transduction in biological membranes. Textbook of Bioenergetics		Berlin, Springer-Verlag and Heidelberg, GmbH & Co
J. Kadziauskas	2008	Biologinės membranos (“Biological membranes”, textbook in Lithuanian)		KTU leidykla „Technologija“
J.A. Illingworth		Oxidative Phosphorylation Home Page		http://www.bmb.leeds.ac.uk/illingworth/oxphos/