MEDICAL UNIVERSITY – PLOVDIV

FACULTY OF MEDICINE

SYLLABUS

IN

BIOPHYSICS

Approved by the Department Council – Protocol №93/09.06.2022

Confirmed by the Faculty Council – Protocol №6/15.06.2022

BIOPHYSICS

Syllabus

COURSE	Final exam/ semester	Auditorium classes				ECTS non-auditorium classes	ECTS total	Academic hours in years and semesters	
								1st year	
		Total	Lectures	Practices	ECTS			I	II
Biophysics	II	60	30	30	2.0	5.0	7.0	-	2/2

COURSE NAME:
Biophysics

TYPE OF COURSE ACCORDING TO THE UNIFORM STATE EQUIREMENTS:
Mandatory

LEVEL OF QUALIFICATION:
Master's /M/

FORMS OF TRAINING:
Lectures, laboratory practices, seminars, research involvement for talented students.

YEAR OF TRAINING:
1st year

DURATION OF TRAINING:
2 semesters

ACADEMIC HOURS:
30h of lectures and 30h of laboratory practices

TECHNICAL EQUIPMENT APPLIED IN THE TRAINING:
Microscopes, Models for simulations of biophysical processes, Electrophoresis, Digital oscilloscopes, Apparatus of electro muscle and neuronal stimulations.

FORMS OF EVALUATION:
Practical tests, oral exam and final exam.

EVALUATION CRITERIA:
Final grade is calculated according to the formula: Final Grade = $0.3*X+0.7*Y$, where X is the accumulated grade from practical tests, and Y is the grade from the final exam.

ASPECTS OF EVALUATION CRITERIA:

1. Running evaluation – (criteria for the grade) – demonstration of knowledge during classes, participation in the laboratory exercises, the ability to collect, analyses, and present data during laboratory practices.
2. Midterm evaluation (average grade from the running evaluation).
3. Final grade (after final exam – entry test, written and oral exam).

SEMESTER EXAM:

Written exam based on multiple choice and open questions.

STATE EXAM:

No

LECTURER:

Professor from the department of Medical Physics and Biophysics.

DEPARTMENT:

Medical Physics and Biophysics

ANNOTATION

Biophysics is considered a fundamental biological course studied by medical students at MU-Plovdiv. The course is mostly theoretical. It discusses the physical nature of the organization and function of bio-objects at the molecular, sub-cellular, cellular and tissue levels.

Medical students gain knowledge on common principles upon which are based fundamental phenomena and processes in living tissue, as well as the occurring mechanisms.

This course clarifies the molecular relationships responsible for: cell membrane structure, mechanisms of membrane transport, nerve conduction, muscle contraction, conjugation between mechanical, electrical and energy processes in cells.

The theoretical part also describes the processes of intercellular realization and signaling pathways, as well as the effects and mechanisms of influence of external factors like electric current, light, ultraviolet and infrared rays, and ionizing radiation on biological objects.

MAIN TASKS OF THE COURSE

The first task is to acquire knowledge regarding the general principles on which the basic phenomena and processes in living tissues occur. Moreover, they will get a profound understanding of the mechanisms by which these processes are realized. Even more, this course provides clarification, via a specific interdisciplinary approach, of physical and physico-chemical reactions and processes occurring in biological systems with different degrees of organization. This will stand as a basis for the development of physiological and pathophysiological processes.

EXPECTED RESULTS

After completing the biophysics training program and passing the exam, students must have acquired knowledge on:

- main components, principles of construction and organization of biomembranes;
- energy prerequisites for passive and active transmembrane transport, processes and membrane structures involved in the transport;
- bioelectrogenesis - membrane potential, action potential in cells of excitable tissues, tissue specificity of the processes, mechanisms of propagation of the action potential;
- types of muscle contractions and the types of thermal processes during the muscle contraction;
- the specifics of the mechanisms in skeletal, cardiac and smooth muscles contraction;
- ways of exchange of intercellular information communication;
- receptors as cellular information inputs and their influence on the activation of basic intracellular signaling pathways;
- electrokinetic phenomena in bio-objects - surface electric charge, mechanism of existence, dependence on pH and ionic strength of the medium, influence on the electrophoretic characteristics of biomolecules and cells;
- quantum biophysics;
- influence of external factors - electric current, visible light, ultraviolet, infrared rays and ionizing radiation on biological objects - physical interactions, specifics of biological effects and hypotheses that explain them.

FROM THE PRACTICAL EDUCATION IN BIOPHYSICS

Mastering the technical skills and the experimental methods for:

1. Measurement and calculation of the dimensions of a lipid monolayer in laboratory setup. Work with micropipettes. Calculation of the amount of substance in a solution and unit conversions.

2. Analysis of the changes in the spontaneous mechanical activity of smooth muscle tissue after the treatment with different pharmaceutical substances.

3. Attachment of electrodes to human skin. Measurement of the impedance of human skin for different frequencies of the stimulus. Plotting impedance vs. frequency. Determination of the resistance of human skin.

4. Basic techniques for transcutaneous neuromuscular stimulation: preparation of the skin, attachment of electrodes, choosing the frequency and the duration of the electrical pulses.

5. Conduction of rheographic test. Attachment of the electrodes to the selected area with a rubber band. Analysis of the amplitude and time parameters of the rheographic recording. Manipulation of the speed of the recording equipment.

6. Work with "Voltage Clamp - computer simulation": manipulating and analyzing the parameters of the trans-membrane current in axon of a squid. Application of specific channel blockers for Na^+ and K^+ ion channels. Determination of the threshold depolarization.

7. Measuring the parameters of pulses generated by a cardiac pacemaker. Work with oscilloscope. Determination of the amplitude, duration, and the period of the stimulation pulse.

8. Work with micro electrophoresis equipment. Measurement of the speed of dispersed- phase particles.

9. Preparation of the equipment for paper electrophoresis. Conduction of paper electrophoresis and spectrometric identification the fractions.

PROGRAM OF BIOPHYSICS LECTURES

№	LECTURE COURSES	HOURS
1.	1. Thermodynamic systems and processes. First principle of thermodynamic. Application in biological systems. 2. Secondary principle of thermodynamic. Entropy. Free energy.	**2**
2.	3. Application of the secondary thermodynamic principle in biological objects. Equation of Prigogine. 4. Biological membranes. Common features. Construction of the lipid molecules. Organization of the membrane.	**2**
3.	5. Membrane proteins and glycoproteins. Localization of the membrane carbohydrates. 6. Mobility of the membrane components.	**2**

4.	7. Phase transitions in the biological membranes. 8. Gradients. Chemical, concentrational and electrical potential. Electrochemical potential. Equations potentials.	**2**
5.	9. Diffusion, trans-diffusion, osmosis and filtration. 10. Passive transport. Eased and exchanged diffusion.	**2**
6.	11. Ionophores. Ion channels. 12. Active transport. Model of sodium — potassium pump. Calcium pump.	**2**
7.	13. Diffusion potential. Bernstein's and Goldman's equation. Permeability and conductivity. Potential of a rest condition. 14. Action potential of nerve cells	**2**
8.	15. Membrane current at the time of the excitation. 16. Ion theory of the excitation. Theory of Hodgkin and Huxley.	**2**
9.	17. Refractory period. Following potentials. Accommodation. 18. Propagation of the action potential. Electrotonic potential. Mechanism of conduction. Speed of spreading.	**2**
10.	19. Bioelectrical activity of the excitable tissues. 20. Structure and mechanical characteristics of striated muscles.	**2**
11.	21. Types of muscle contraction. Temporary characteristics of single muscle contraction. 22. Contracting mechanisms by striated muscles. The role of the Ca^{2+}.	**2**
12.	23. Propagation of the excited process. Electromechanical connection. 24. Smooth muscles structure. Mechanism of smooth muscles contraction. The role of the Ca^{2+}. Phasic and tonic contractions.	**2**

13.	25. Comparative characteristic between smooth muscle and striated muscle contractions. 26. Double electrical layer. Electrokinetic potential, dependence on the pH of the medium.	**2**
14.	27. Electrical permeability of the tissue for constant current. Polarization. Types. 28. Impedance. Dispersion of the dielectric permittivity. Application of the method in the biology and in the medicine.	**2**
15.	29. Application of the constant current and low frequencies pulses in clinical practice. 30. Application of the alternating current and electromagnetic fields in biological objects.	**2**

PRACTICAL COURSE SYLLABUS

Practical № 1

Monolayer of surface-active substance – a study model of the specific features of lipid aggregates in aqueous medium. Spatial characteristics and density of the monolayer molecules in different conditions resembling membrane phase transitions.

Practical № 2

Membrane transport of H_2O molecules. Role of osmosis in the increase of the water content in tissue.

Practical № 3

Membrane ion channels. Ion channel blockers. Effects of blocking Ca^{2+} - channels.

Practical № 4

Diffusion and membrane potentials: experimental models.

Practical № 5

Hodgkin and Huxley model - Ion theory of excitation. Method of the fixed voltage. Changes of the ion currents across the cell membrane of the squid axon on blocking Na^+ -and K^+ - channels.

Practical № 6`

Analysis of the action potential of cardiac muscle, illustrated by an implantable cardiac stimulator.

Practical № 7

Mechanical activity and reactivity of smooth muscle tissue. The role of Ca^{2+}.

Practical № 8

Experimental determination of the electrokinetic potential.

Practical № 9

Electrical conductivity of biological tissues in the presence of electric current. Neuromuscular synapses. Electro-muscularstimulation. Dependence of current threshold on pulse duration.

Practical № 10

Electrophoresis. Separation and study of fractions by means of preparatory electrophoresis.

Practical № 11

In vivo determination of the dependence of skin resistance on the frequency of alternating current.

Practical № 12

Determination of the dependence of force of muscular contraction on the extracellular concentration of Ca^{2+} – ions and *in vivo* experiments.

Practical № 13

Investigation of the changes in the Atlantic squid axon's membrane potential provoked by means of stimulation with pulsed electric current with different density, direction and duration.

Practical № 14

Biophysical basis of the rheography. Determination of temporal and amplitude rheographic parameters, characterizing the functioning of the heart and of the pulsatile blood influx.

Practical № 15

Determination of the half-life of ^{99m}Tc – radionuclide applied in the medical practice for the investigation of the thyroidgland.

Practical № 16

Receptors: information gates of the cell. Activation and inhibition of M-cholinoreceptors.

BIBLIOGRAPHY

1. Emilia Milieva, Franco Milano, Iordan Kostourkov, MartiannaYaneva, Lubka Mihova – "Physics and Biophysics of Clinical Radiation Therapy" – 2017
2. Notebook in Biophysics – 2017
3. Biophysics Multiple Choice Questions Booklet, Edited by Prof. Atanas Krastev, DBSc, First Edition – 2018
4. Tom A. Waigh – "Applied Biophysics", John Wiley and Sons, Ltd, Manchester, UK – https://epdf.pub/biophysics.html
5. Rodney M. J. Cotterill, "Biophysics"- An introduction, John Wiley and Sons, Ltd – 2002 – https://epdf.pub
6. Patrick F. Dillon, Biophysics – A Physiological Approach, Published by Cambridge University Press, 2012

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