National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"

Department
biomedical engineering

# Biophysics

**Working program of basic discipline (Syllabus)**

| Requisites for basic discipline | |
|---|---|
| **Level of higher education** | ***First (bachelor's)*** |
| **Branch of knowledge** | *16 Chemical and Bioengineering* |
| **Specialty** | *163 Biomedical Engineering* |
| **Educational program** | *Medical Engineering* |
| **Discipline status** | *Mandatory discipline* |
| **Form of study** | *full-time* |
| **Year of preparation, semester** | *2nd year, spring semester* |
| **The scope of discipline** | *4.5 ECTS credits* |
| **Semester control / Control measures** | *Test, Modular Control Work, Calculation and Graphic Work* |
| **Lessons schedule** | *According to the schedule on the site http://rozklad.kpi.ua/* |
| **Language of instruction** | *English* |
| **Information about course leader / teachers** | **Lecturer**:<br>**Practical**: |
| **Course placement** | Course page on Moodle:<br>https://do.ipo.kpi.ua/course/view.php?id=370 |

## Curriculum of the discipline

### 1. Description of the discipline, its purpose, subject of study and learning outcomes

***The Purpose of the Discipline.***

*The main purpose of the discipline "Biophysics" is the formation of students' ability to address fundamental and practical problems of physical and physicochemical properties in relation to biology and medicine, using basic theories, physical, physicochemical and physical-mathematical methods and computer technology. Training in the discipline "Biophysics" adopts the student-centered approach and strategy of interaction between teachers and students in order to guide students and help them master the material and gain practical skills.*

*The subject of the discipline "Biophysics" covers the phenomena in living nature that occur at all levels of its organization, from the quantum and molecular level and the biosphere as a whole; modern information technology used in modeling of medical and biological systems; bioelectromagnetic processes during cell function and biological systems in general (i.e., a series of interrelated systems at different levels of the biological hierarchy, from which the basic components of biomedical engineering are formed to improve the results of innovation and clinical engineering as well as medical instrumentation.*

*Given that the discipline is mandatory, it is necessary to be proficient in:*

- *skills: basic knowledge of mathematics, physics and biochemistry;*
- *competencies: to apply fundamental knowledge of biophysics in relation to applied problems of biomedical engineering and analysis of relationship and dynamics of phenomena; collection,*

*processing and analysis of the baseline data needed to calculate indicators characterizing new and traditional clinical technologies and equipment in health facilities; analyze and interpret statistical data in medical and biological processes and phenomena, identify trends in indicators; use databases, mathematical and software for data processing and computer modeling of biotechnical systems*

***General competencies (OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):***

- ***GC 1 -*** *Ability to apply knowledge in practical situations.*
- ***GC 2 -*** *Knowledge and understanding of the subject area and understanding of professional activity.*
- ***GC 6 -*** *Ability to search, process and analyze information from various sources.*
- ***GC 7 -*** *Ability to generate new ideas (creativity).*
- ***GC 8 -*** *Ability to make well-grounded decisions.*

***Special (professional) competencies*** *(OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):*

- ***PC 1*** *- Ability to use engineering software packages for research, analysis, processing and presentation of results, as well as for automated design of medical devices and systems.*
- ***PC 2*** *- Ability to provide engineering expertise in the process of planning, development, evaluation and specification of medical equipment.*
- ***PC 3*** *- Ability to study and apply new methods and tools for analysis, modeling, design and optimization of medical devices and systems.*
- ***PC 5*** *- Ability to apply physical, chemical, biological and mathematical methods in the analysis, modeling of the functioning of living organisms and biotechnical systems.*
- ***PC 12*** *- Ability to develop, plan and apply mathematical methods to analyze and model the function of biological object, systems and processes in biology and medicine*
- ***PC 14*** *- Ability to perfect experiments according to specified technical and medical methods, perform computer processing, analysis and synthesis of the results.*

***The program learning outcomes after studying the discipline "Biophysics" are*** *(OPP was put into effect by the Rector's Order NON/ 89/2021 of 19.04.2021):*

- ***PLO 6 -*** *Knowledge of object research methods, analysis and processing of experimental data.*
- ***PLO 13 -*** *Use of methods and means of systematization and processing of experimental information.*
- ***PLO 22 -*** *Use of methods of statistical processing, modeling and simulation of processes and systems of physical and biological nature in biomedical engineering.*
- ***PLO 28 -*** *Use of databases, mathematical and software for data processing and computer modeling of biotechnical systems.*

**2. Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of education according to the relevant educational program)**

*The discipline "Biophysics" is an interdisciplinary study that integrates according to its subject knowledge from other disciplines: physics, biochemistry, mathematics, etc. Following the structural and logical scheme of the training program, the discipline "Biophysics" is closely related to other disciplines of general and professional training: "Biomedical Mechanics", "Fundamentals of Clinical*

*Engineering and Radiology", "Biothermodynamics and Mass Transfer". It is preceded by the discipline "Physics".*

*The acquired practical skills and acquired theoretical knowledge during the study of the discipline "Biophysics" can be used in the disciplines:*

*- from the cycle of professional training (educational-professional program "Medical Engineering"): "Biomedical devices, equipment and complexes";*

*- in elective disciplines (educational-professional program "Medical Engineering"): "Medical Medical Equipment", "Development and operation of physiotherapeutic medical devices", "Medical-diagnostic complexes based on biophotonic converters", "Design of medical information systems", as well as when passing*

*- undergraduate practice and diploma design.*

**3. The content of the discipline**

*The main sections and topics considered in the course:*

***Section 1**. Basic principles and methods of biophysics. Molecular biophysics and biophysics of complex systems*

*Subject 1.1. Subject and methods of biophysics*

*Subject 1.2. Thermodynamics of biological processes*

*Subject 1.3. Molecular biophysics*

*Subject 1.4. Fundamentals of mathematical biophysics*

*Subject 1.5. Biophysical bases of medical nanotechnology and nanodevices*

***Section 2.** Biophysics of the human body.*

*Subject 2.1. Physical bases of hemodynamics*

*Subject 2.2. Bioacoustics*

*Subject 2.3. Photobiological processes. Physical bases of vision*

*Modular control work*

*Subject 2.4. Electromagnetic phenomena in living systems. Biophysical aspects of electromagnetic radiation exposure*

***4. Training materials and resources***

***Basic literature:***

*1.Костюк П.Г. Біофізика : підручник для студ. біологічних спец. вищих навч. заклад. / П.Г. Костюк [та ін.] ; Київський нац. ун-т імені Тараса Шевченка. - К.: Обереги, 2001. -544 с.*

*2.Рубин А. Б. Том 1,2 - Теоретическая биофизика . - М. : Книжный дом «Университет», 2000. - 468 с. // http://www.twirpx.com/file/61321/; // http://www.twirpx.com/file/61322/*

*33.Тиманюк В. А. – Биофизика. - Национальный фармацевтический ун-т. - Х.: Издательство НФАУ : Золотые страницы, 2003. - 702 с. // http://www.twirpx.com/file/216571/*

*4.Медична та біологічна фізика / під ред Чалого О.В. , - Київ: Книга плюс, 2005. - 760 с.*

*5.Гродзинский Д.М. Радіобіологія.-К.:Либідь, 2000.-448с.*

***Additional literature:***

*1.Самойлов В.О. Медицинская биофизика. - СПб.: Спецлит, 2004. - 496 с. // http://www.twirpx.com/file/606334/*

*2.Волькенштейн М. В. Биофизика. - СПб. ; М. ; Краснодар : Лань, 2008. - 595 с.*

*3.Радиочастотная гипертермия злокачественных новообразований, нанотехнологии и динамический хаос : [монография / Орел В. Э. и др.]. – 2012.*

*4.Адашевский В.М.Теоретические основы механики биосистем. Видавництво НФАУ "Золоті*

*сторінки". Харьків.2001.-235с.*
*5.Электромагнитное поле радиоволн в онкологии / В.Э. Орел, И.И. Смоланка, С.И. Коровин, А.Ю. Паливец, М.И. Данко, Н.Н. Дзятковская. – К.: Книга плюс, 2005. – 152 с.*
*6.Орел В.Э. Хаос и рак, механохимия, механоэмиссия. – К. : АОЗТ «Телеоптик», 2002. – 296 с.*
*http://info-library.com.ua/books-text-4072.html*
*http://www.twirpx.com*

## Educational content

### 5. Methods of mastering the discipline (educational component)

| № s/n | Subject | Program learning outcomes | The main tasks | |
|---|---|---|---|---|
| | | | Control measure | Deadline |
| 1. | Subject and methods of biophysics | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 1 | Week 3 |
| 2. | Molecular biophysics | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 2 | Week 4 |
| 3. | Thermodynamics of biological processes | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 3 | Week 5 |
| 4. | Fundamentals of mathematical biophysics | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 4 | Week 6 ,7 |
| 5. | Biophysical bases of medical nanotechnology and nanodevices | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 5 | Week 8 |
| 6. | Physical bases of hemodynamics | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 6 | Week 9 |
| 7. | Modular control work | PLO 22<br>PLO 28 | Taking the modular control work | Week 10 |
| 8. | Calculation and graphic work | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Preparation and handling in the work | Week 11 |
| 9. | Bioacoustics | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 7 | Week 12 |
| 10. | Photobiological processes. Physical bases of vision. | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 8 | Week 13 |
| 11. | Electromagnetic phenomena in living systems. Biophysical aspects of electromagnetic radiation exposure | PLO 6<br>PLO 13<br>PLO 22<br>PLO 28 | Practical work 8 | Week 13-14 |

## 6. Independent student work

*One of the main types of semester control during the mastering of the discipline "Biophysics" is the calculation and graphic work. Calculation and graphic work is performed following the requirements, within the period specified by the teacher.*

*The main purpose of calculation and graphic work is to solve a practical problem using the material learned during lectures and independent work, and practical skills gained in practical works. The student can write the work only on the subject agreed with the teacher.*

***Approximate subject of calculation and graphic work:***

*1. To analyze the side effects of non-ionizing electromagnetic fields from a biological and medical perspective.*
*2. Calculate the parameters and magnitudes of the non-ionizing electromagnetic field that can cause side effects.*
*3. To analyze the side effects of ionizing radiation from a biological and medical perspective.*
*4. Provide the parameters and values of ionizing radiation that can cause side effects from a biological and medical perspective.*
*5. To analyze the side effects of acoustic waves from a biological and medical perspective.*
*6. Calculate the parameters and magnitudes of acoustic waves that cause medical and biological side effects.*
*7. To analyze the side effects of mechanical vibration from medical and biological perspective.*
*8. Calculate the parameters and values for mechanical vibration, which can cause biological nad medical side effects.*

** The student can choose another topic of calculation and graphic work at his own request, agreed with the teacher.*

*The title page of the calculation and graphic work should have the following content: the name of the university; name of the faculty; name of department; name of specialty, name of educational-professional program, name of academic discipline; theme of calculation and graphic work; surname and name of the student, course, number of the academic group, year.*

*The title page is followed by a detailed plan (content) of the calculation and graphic work, which should highlight the introduction, sections of the main content (main topics studied), their subdivisions (if necessary), conclusion, list of sources used. The table of contents on the right indicates the page numbers at the beginning of each question. Each section begins on a new page.*

*The total content of calculation and graphic work, depending on the chosen topic can vary from 15 to 25 pages of the main text (in consultation with the teacher). The content of calculation and graphic work is determined by the student's ability to briefly and at the same time comprehensively explain and analyze the program code in the Code Composer Studio environment.*

*Mandatory requirement: clear reference to sources of information. All figures, facts, opinions of scientists, quotations, formulas should have a reference in the form [2, p. 54] (the first digit means the number of the source in the list of references given at the end of the creative work, and the second digit - the page number in this source). It is desirable to use tables, diagrams, graphs, charts, etc. The list of used sources (not less than 15 sources) is made out according to operating rules. If the information is taken from the Internet, you need, as for ordinary literature, specify the author, the title of the article, and then provide the address of the site on the Internet.*

*Calculation and graphic work is evaluated by the following criteria: logic of the plan; completeness and depth of topic disclosure; reliability of the received data; reflection of practical materials and*

*results of calculations; correctness of formulation of conclusions of the received results and conclusions; design; substantiation of the student's own opinion on this issue in the form of a conclusion.*

*The deadline for submission of calculation and graphic work for verification: week 13-14 of study.*

*Calculation and graphic work is not tested for plagiarism, but must meet the requirements of academic integrity. In case of academic dishonesty, the work is canceled and not checked.*

## Policy and control

***7. Policy of academic discipline (educational component)***

***Attending classes***

*Attendance at lectures is optional. Attending practical classes is desirable, as they are used to write express tests / tests, as well as to defend practical work.*

*The grading system is focused on obtaining points for student activity, as well as performing tasks that are able to develop practical skills and abilities.*

***Control measures missed***

*Missed control measures (defense of practical work) must be practiced in the next classes, provided that the task is scheduled for the current lesson, or in consultations.*

*Omissions of writing a module test and express test are not fulfilled.*

*Calculation and graphic work, which is submitted for inspection in violation of the deadline is evaluated with a decrease in the number of weight points.*

***Violation of deadlines and encouragement points***

| *Encouragement points* | | *Penalty points ** | |
|---|---|---|---|
| *Criterion* | *Weight points* | *Criterion* | *Weight points* |
| *Improving practical work* | *1 point (for each practical work)* | *Untimely implementation and test of practical work* | *From -0.5 points to -5 points (depending on the delivery date)* |
| *Passing distance courses on topics that are agreed with teachers* | *5 points* | *Untimely execution and test of calculation and graphic work* | *From -2 points to -20 points (depending on the construction period)* |
| *Registration of scientific work for participation in the competition of student scientific works* | *10 points* | | |
| *Writing abstracts, articles, participation in international, national and / or other events or competitions on the subject of the discipline* | *5 points* | | |

** if the control measure was missed for a good reason (illness, which is confirmed by a certificate of the established sample) - penalty points are not accrued.*

***Academic integrity***

*The policy and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Read more:* https://kpi.ua/code.

***Norms of ethical behavior***

*Normative principles of behavior of students and employees, defined in sections 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute". Read more: https://kpi.ua/code.*

***Procedure for appealing the results of control measures***

*Students have the opportunity to raise any issue related to the control procedure and expect it to be addressed according to predefined procedures.*

*The student has the right to appeal the results of the control measure according to the approved provision on appeals in the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (approved by the order №NON/128/2021 from 20.05.2021) - https://osvita.kpi.ua/index.php/node/182*

***Inclusive education***

*The discipline "Biophysics" can be taught to most students with special educational needs, except for students with severe visual impairments who do not allow to perform tasks using personal computers, laptops and / or other technical means.*

***Distance learning***

*Distance learning takes place through the Sikorsky Distance learning Platform «Sikorsky».*

*Distance learning through additional online courses on certain topics is allowed subject to agreement with students. If a small number of students wish to take an online course on a specific topic, studying the material with such courses is allowed, but students must complete all the tasks provided in the discipline.*

*The list of courses is offered by the teacher after the students have expressed a desire (because the bank of available courses is updated almost every month).*

*The student provides a document confirming the completion of the distance course (in the case of a full course) or provides practical tasks from the distance course and subject to an oral interview with the teacher on the topics can receive grades for control measures provided for the studied topics (express control / test tasks, practical work).*

*Performance of practical works, and also performance of settlement and graphic work, is carried out during independent work of students in a remote mode (with a possibility of consultation with the teacher through e-mail, social networks).*

***Learning the discipline in a foreign language***

*Teaching in English is carried out only for foreign students.*

*At the request of students, it is allowed to study the material with the help of English-language online courses on topics that correspond to the topics of specific classes.*

## *8*. Monitor and evaluate the system of evaluation of learning outcomes (Rating System of Evaluation)

***Evaluation system (current control):***

| № s/n | Control measure | % | Weight points | Number | Total |
|---|---|---|---|---|---|
| 1. | Express control works / test tasks | 28 | 2 | 14 | 28 |
| 2. | Assessment of practical works | 40 | 5 | 8 | 40 |

| | | | | | |
|---|---|---|---|---|---|
| 3. | Modular control work (MCW) | 12 | 12 | 1 | 12 |
| 4. | Calculation and graphic work (CGW) | 20 | 20 | 1 | 20 |
| 5. | Test | 80 | 80 | 1 | 80 |
| | Total | | | | 100 |

*The student receives a positive credit score for the results of the semester, if he has a final rating for the semester of at least 60 points and has met the conditions of admission to the semester control, which are determined by the Syllabus.*

*With applicants who have met all the conditions of admission to the test and have a rating of less than 60 points, as well as with those applicants who want to increase their rating, in the last scheduled lesson in the semester, the teacher conducts semester control in the form of test or interviews. After performing the test, if the score for the test is higher than the rating, the applicant receives a score based on the results of the test.*

*If the grade for the test is lower than the rating, the previous rating of the applicant (except for points for the semester individual task) is canceled and he receives a grade based on the results of the test. This option forms a responsible attitude of the applicant to the decision to perform the test, forces him to critically assess the level of his training and carefully prepare for the test.*

***Calendar control (CC)** - is carried out twice a semester as monitoring of the current state of compliance with the requirements of the syllabus.*

*The purpose of calendar control is to improve the quality of student learning and monitor the implementation of the schedule of the educational process by students.*

| Criterion | | | The first CC | The second CC |
|---|---|---|---|---|
| Deadline of calendar controls | | | 8th week | 14th week |
| Conditions for obtaining a positive result from the calendar control | Current rating | | ≥ 24 points | ≥ 42 points |
| | Practical work | PW № 1- 4 | + | + |
| | | PW № 4-8 | - | + |
| | Express control works / test tasks | At least 4 of any lectures | + | - |
| | | At least 8 of any lectures | - | + |
| | Modular control work | Assessed MCW | - | + |
| | Calculation and graphic work | Assessed CGW | - | - |

*In case of detection of academic poor quality during training - the control measure is not credited.*

***Semester certification of students***

| Mandatory condition for admission to the test | | Criterion |
|---|---|---|
| 1 | Current rating | RD ≥ 30 |
| 2 | Obtaining a positive assessment for the performed calculation and graphic work | More than 6 points |
| 3 | All practical works are tested | More than 0 points |
| 4 | Writing at least 6 express tests / tests | More than 6 points |

*The results are announced to each student separately in the presence or remotely (by e-mail). Also recorded in the system "Electronic Campus".*

***Optional conditions for admission to closure:***

1. *Activity during practical classes.*
2. *Positive result of the first attestation and the second attestation.*
3. *Attending lectures.*

***Table of translation of rating points to grades on a university scale:***

| *Total rating points* | *Grades according to the university scale* |
|---|---|
| *100-95* | *Excellent* |
| *94-85* | *Very good* |
| *84-75* | *Good* |
| *74-65* | *Satisfactory* |
| *64-60* | *Passed* |
| *Below 60* | *Unsatisfactory* |
| *Violation of passing requirements* | *Not passed* |

## 9. Additional information on the discipline (educational component)

*The list of questions for preparation for modular control work, and also for preparation for credit is given in appendix 1.*

*Distance learning through additional online courses on certain topics is allowed subject to agreement with students. If a small number of students wish to take an online course on a specific topic, studying the material with such courses is allowed, but students must complete all the tasks provided in the discipline.*

*The list of courses is offered by the teacher after the students have expressed a desire (because the bank of available courses is updated almost every month).*

*The student provides a document confirming the completion of the distance course (in the case of a full course) or provides practical tasks from the distance course and subject to an oral interview with the teacher on the topics can receive grades for control measures provided for the studied topics (express control / test tasks, practical work).*

***Work program of the discipline (syllabus):***

***Compiled by***

***Approved by*** *the Department of Biomedical Engineering (protocol № ___ from 25 June 2021)*

***Approved by*** *the Methodical Commission of the Faculty of Biomedical Engineering (protocol № __ from 27 August 2021)*

***The list of questions for preparation for modular control work as well as for preparation for test***

1. To determine the place of medical biophysics amongst natural sciences.
2. Analyze the main sections of biophysics.
3. Justify the correspondence of biological and physical concepts.
4. Describe the main methods of studying biophysics.
5. Explain the X-ray diffraction analysis of biopolymers.
6. Explain the electronic paramagnetic resonance of biopolymers.
7. The Lotka-Volterra model or the predator-victim equation.
8. Manifestations of self-similarity of biological objects. Features of quasi-fractal forms in living organisms.
9. Calculation of the fractal dimension.
10. The concept of deterministic chaos. The main properties of the dynamic chaos of medical and biological systems.
11. Application of nonlinear dynamics methods for evaluation of biophysical processes.
12. Application of two-sample Student's t-test to check the similarity or difference of independent samples.
13. Application of the Mann-Whitney U-test to estimate the difference between the two samples.
14. Thermodynamics of medical and biological processes - subject and terminology.
15. Formulate and explain the first law of thermodynamics.
16. Analyze the effects of energy conversion in the body.
17. Formulate and explain Hess's Law. What is the thermodynamic potential?
18. Formulate and explain the second law of thermodynamics.
19. Justify the statistical nature of entropy.
20. Analyze the design and principle of operation of the respiratory calorimeter.
21. What are dissipative structures? Prigogine's theorem. Changes in entropy in the process of life.
22. Heat balance of the body, methods of heat transfer.
23. Describe types of relatiobships and interactions in biologically important molecules.
24. .Explain the features of the structure of the protein.
25. Analyze the spatial organization of proteins.
26. Evaluate the circular closed form of DNA.
27. To substantiate the principle of operation and the scheme of the nanomotor.
28. Give the composition of biological membranes.
29. Biological functions of membranes.
30. Give the structure of the membranes.
31. Analyze the elastic properties of membranes.
32. Analyze the phase transitions in the lipid bilayer of biomembranes.
33. Explain the flexoelectric effects in membranes. Pathology of biomembranes.
34. Analyze free radical reactions of the monovalent pathway of oxygen reduction.
35. Analyze free radical lipid peroxidation.
36. Biological dosimetry.
37. Justify the physical effects of enzyme-substrate interaction.
38. Substantiate models of enzymatic catalysis.
39. Assessment of electronic-conformational interactions.
40. Analyze the effects of oxidative phosphorylation.
41. To substantiate the chemical concept of oxidative phosphorylation
42. Chemiosmotic connection of the respiratory chain.
43. To substantiate the conformational theory of oxidative phosphorylation.
44. Describe and justify the electrical and magnetic properties of body tissues.
45. Analyze the properties of the electromagnetic field of radio waves. Overview.

46. Justify the non-thermal effects of electromagnetic fields of radio waves.
47. Formulate the magnetic principles of control of chemical reactions.
48. Justify the thermal effects of electromagnetic fields of radio waves
49. Biopotential of cell rest. What are the ratios of the relative permeability of different ions for the cell at rest?
50. Biopotential of action. Characteristics of the biopotential of action.
51. Structure and function of potential-dependent sodium channel.
52. Features of generation and propagation of the receptor potential of the photoreceptor cell (for example, rods).
53. Analyze photobiological processes. Overview.
54. Analyze the patterns of light absorption by biosystems.
55. Analyze intramolecular energy metabolism.
56. Formulate a definition of the phenomenon of luminescence.
57. To substantiate intermolecular energy transfer in photobiological processes.
58. Explain the biophysical basis of vision.
59. Explain the features of color vision.
60. Explain the basics of hearing physics.
61. Analyze the human hearing aid.
62. Noise and its importance in medicine.
63. The human vocal apparatus.
64. Give the structure of the muscle.
65. Justify the mechanical properties of muscle.
66. Analyze mechanochemical processes.
67. To substantiate the theory of muscle contraction.
68. Analyze the physical patterns of blood flow in large and small vessels.
69. Justify the concept of "heart as a pump".
70. Explain the features of hemodynamics in pathological processes.