Federal State Autonomous Educational Institution of Higher Education "Moscow Institute of Physics and Technology (National Research University)"

APPROVED
Head of the Phystech School of Biological and Medical Physics
D.V. Kuzmin

Work program of the course (training module)

course: Molecular Biology/Молекулярная биология
major: Biotechnology
specialization: Biomedical Engineering/Биомедицинская инженерия
Phystech School of Biological and Medical Physics
Center for educational programs in bioinformatics
term: 3
qualification: Bachelor

Semesters, forms of interim assessment:
5 (fall) - Pass/fail exam
6 (spring) - Grading test

Academic hours: 90 AH in total, including:
lectures: 30 AH.
seminars: 60 AH.
laboratory practical: 0 AH.

Independent work: 90 AH.

In total: 180 AH, credits in total: 4

Author of the program: A.V. Belikov, phd (candidate of biological sciences)

The program was discussed at the Center for educational programs in bioinformatics 04.06.2020

Annotation

The purpose of this discipline is to introduce students to the basic concepts of molecular biology. After completing the course, the student will understand the fundamental concepts and principles of molecular biology, the structure and function of proteins and nucleic acids, the mechanisms of DNA replication, repair and recombination, transcription and translation, as well as control of gene expression, intracellular compartments, cytoskeleton, intercellular junctions and extracellular matrix, mechanisms of membrane transport of small molecules, protein sorting and intracellular membrane transport, mechanisms of energy conversion by mitochondria and chloroplasts, cell signaling, cell cycle and death cells, stem cell functions and tissue renewal mechanisms.

1. Study objective

Purpose of the course

to introduce students to the basic concepts of molecular biology.

Tasks of the course

- mastering by students of basic terms and concepts of molecular biology;
- the acquisition by students of the ability to apply the acquired knowledge;
- providing advice and assistance to students in the course of mastering the material.

2. List of the planned results of the course (training module), correlated with the planned results of the mastering the educational program

Mastering the discipline is aimed at the formation of the following competencies:

Code and the name of the competence	Competency indicators
UC-1 Search and identify, critically assess, and synthesize information, apply a systematic approach to problem-solving	UC-1.1 Analyze problems, highlight the stages of their solution, plan the actions required to solve them
	UC-1.2 Find, critically assess, and select information required for the task in hand
	UC-1.3 Consider various options for solving a problem, assess the advantages and disadvantages of each option
	UC-1.4 Make competent judgments and estimates supported by logic and reasoning
	UC-1.5 Identify and evaluate practical consequences of possible solutions to a problem
Gen.Pro.C-1 Apply knowledge of mathematical, physical, chemical, biological laws, patterns, and interrelation to study, analyze, and utilize biological objects and processes	Gen.Pro.C-1.1 Analyze the task in hand, outline the ways to complete it
	Gen.Pro.C-1.2 Build mathematical models, make quantitative measurements and estimates
	Gen.Pro.C-1.3 Determine the applicability limits of the obtained results
Gen.Pro.C-4 Collect and process scientific and technical and/or technological data for fundamental and applied problem-solving	Gen.Pro.C-4.1 Apply scientific research and intellectual analysis methods for professional problem-solving
	Gen.Pro.C-4.2 Search for primary sources of scientific and technical and/or technological information in professional settings
	Gen.Pro.C-4.3 Prepare abstracts, reports, bibliographies, and reviews of information in professional settings
	Gen.Pro.C-4.4 Use computer and network skills to obtain, store, and process scientific (technical, technological) information
Gen.Pro.C-5 Participate in fundamental and applied research and development activities; independently develop new theoretical research methods (including mathematical research methods)	Gen.Pro.C-5.1 Perform tasks in the field of theoretical and experimental research and development activities
	Gen.Pro.C-5.2 Apply new knowledge through the study of literature, scientific articles, and other sources

3. List of the planned results of the course (training module)

As a result of studying the course the student should:

know:

- fundamental concepts and principles of molecular biology;
- structure and function of proteins and nucleic acids;
- mechanisms of DNA replication, repair and recombination, transcription and translation, as well as control of gene expression;
- mechanisms of membrane transport of small molecules, sorting of proteins and intracellular membrane transport;
- mechanisms of energy conversion by mitochondria and chloroplasts, signal transmission in the cell, cell cycle and cell death;
- functions of stem cells and mechanisms of tissue renewal.

be able to:

- to apply the acquired fundamental knowledge about molecular biology for planning scientific experiments;
- to apply the acquired fundamental knowledge about molecular biology to solve practical problems, including in biotechnology and medicine.

master:

- skills of mastering a large amount of information;
- skills of independent work;
- terminology, including sufficient technical terms.

4. Content of the course (training module), structured by topics (sections), indicating the number of allocated academic hours and types of training sessions

4.1. The sections of the course (training module) and the complexity of the types of training sessions

№	Topic (section) of the course	Types of training sessions, including independent work			
		Lectures	Seminars	Laboratory practical	Independent work
1	Cells and Genomes. Biochemistry and Bioenergy		6		15
2	Proteins. DNA, chromosomes and genomes		8		15
3	Replication, repair and recombination of DNA. How cells read the genome		8		15
4	Control of gene expression		8		15
5	Membrane structure. Membrane transport of small molecules and electrical properties of membranes	5	5		5
6	Intracellular compartments and protein sorting. Intracellular membrane transport	5	5		5
7	Cytoskeleton. Intercellular junctions and extracellular matrix	5	5		5
8	Energy conversion: mitochondria and chloroplasts. Signaling in a cell	5	5		5
9	The cell cycle. Cell death	5	5		5
10	Stem cells and tissue renewal	5	5		5
AH in total		30	60		90
Exam preparation		0 AH.			

Total complexity	180 AH., credits in total 4

4.2. Content of the course (training module), structured by topics (sections)

Semester: 5 (Fall)

1. Cells and Genomes. Biochemistry and Bioenergy

Universal features of cells on Earth. Diversity of genomes and the tree of life. Genetic information in eukaryotes. Chemical components of the cell. Catalysis and energy use by cells. How cells get energy from food.

2. Proteins. DNA, chromosomes and genomes

Chemical components of the cell. Catalysis and energy use by cells. How cells get energy from food. DNA structure and function. Chromosomal DNA and its packaging in chromatin fiber. Chromatin structure and function. The global structure of chromosomes. How genomes evolve.

3. Replication, repair and recombination of DNA. How cells read the genome

Maintaining DNA sequences. DNA replication mechanisms. Initiation and completion of DNA replication in chromosomes. DNA repair. Homologous recombination. Transposition and Conservative Site-Specific Recombination. From DNA to Protein. From DNA to RNA. From RNA to Protein. The world of RNA and the origins of life.

4. Control of gene expression

Gene control overview. Control of transcription using sequence-specific DNA-binding proteins. Transcriptional regulators turn genes on and off. Molecular genetic mechanisms that create and maintain specialized cell types. Mechanisms that enhance cellular memory in plants and animals. Post-transcriptional control. Regulation of gene expression by non-coding RNA.

Semester: 6 (Spring)

5. Membrane structure. Membrane transport of small molecules and electrical properties of membranes

Lipid bilayer. Membrane proteins. The principles of membrane transport. Conveyors and active membrane transport. Channels and electrical properties of membranes.

6. Intracellular compartments and protein sorting. Intracellular membrane transport

Cell compartmentalization. Transport of molecules between the nucleus and the cytosol. Transport of proteins to mitochondria and chloroplasts. Peroxisomes. Endoplasmic reticulum. Molecular mechanisms of membrane transport and maintenance of compartment diversity. Transport from the ER through the Golgi apparatus. Transport from the trans-Golgi network to lysosomes. Transport into the cell from the plasma membrane: endocytosis. Transport from the trans-Golgi network to the extracellular space: exocytosis.

7. Cytoskeleton. Intercellular junctions and extracellular matrix

Function and origin of the cytoskeleton. Actin and actin-binding proteins. Myosin and actin. Microtubules. Intermediate fibers and septins. Cell polarization and migration. Intercellular connections. Extracellular matrix of animals. Cell-matrix compounds. Plant cell wall.

8. Energy conversion: mitochondria and chloroplasts. Signaling in a cell

Mitochondria. Proton pumps of the electron transport chain. ATP production in mitochondria. Chloroplasts and photosynthesis. Genetic systems of mitochondria and chloroplasts. Principles of cell signaling. Signaling through g-protein coupled receptors. Signaling through enzymatic receptors. Alternative signaling pathways in gene regulation. Transmission of signals in plants.

9. The cell cycle. Cell death

Cell cycle overview. Cell cycle control system. S phase. Mitosis. Cytokinesis. Meiosis. Control of cell division and cell growth.

10. Stem cells and tissue renewal

Stem cells and epithelial tissue renewal. Fibroblasts and their transformations: a family of connective tissue cells. Genesis and regeneration of skeletal muscles. Blood vessels, lymph vessels, and endothelial cells. The hierarchical system of stem cells: the formation of blood cells. Regeneration and repair. Cell reprogramming and pluripotent stem cells.

5. Description of the material and technical facilities that are necessary for the implementation of the educational process of the course (training module)

- classrooms for lecture / seminar classes;
- computer and multimedia equipment (projector, sound system);
- individual computing facilities of students (personal computers) for homework.

6. List of the main and additional literature, that is necessary for the course (training module) mastering

Main literature

Provided at the department:
Molecular biology of the cell / Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts, Peter Walter ; with problems by John Wilson, Tim Hunt. - Sixth edition. Published by Garland Science, Taylor & Francis Group, LLC

Additional literature

Provided at the department:
Molecular cell biology / Harvey Lodish, Arnold Berk, Chris A. Kaiser, Monty Krieger, Anthony Bretscher, Hidde Ploegh, Angelika Amon, Kelsey C. Martin. - Eighth edition. Published by W. H. Freeman and Company, Macmillan Learning

7. List of web resources that are necessary for the course (training module) mastering

https://scholar.google.com/
https://www.ncbi.nlm.nih.gov

8. List of information technologies used for implementation of the educational process, including a list of software and information reference systems (if necessary)

For some of the lessons, you will need Zoom. Google Drive to access course materials. The presence of smartphones / laptops during classes is encouraged to participate in interactive exercises.

9. Guidelines for students to master the course

A student who studies discipline must, on the one hand, master a general conceptual apparatus, and on the other hand, must learn to apply theoretical knowledge in practice.

As a result of studying the discipline, the student should know the basic definitions of the discipline, be able to apply this knowledge to solve various problems.

Successful learning requires:
- visits to all classes provided by the curriculum for the discipline;
- conducting the abstract of occupations;
- intense independent work of the student.

Independent work includes:
- reading recommended literature;
- study of educational material, preparation of answers to questions intended for self-study;
- solving problems offered to students in the classroom;
- preparation for performance of tasks of the current and intermediate certification.

An indicator of possession of the material is the ability to answer questions on discipline topics without an outline.

It is important to achieve an understanding of the material being studied, and not its mechanical memorization. If it is difficult to study individual
topics, questions, you should seek advice from the teacher.

Intermediate control of students' knowledge in the form of problem solving in accordance with the subject of classes is possible

SUPPLEMENT

Assessment funds for course (training module)

major:	Biotechnology
specialization:	Biomedical Engineering/Биомедицинская инженерия Phystech School of Biological and Medical Physics Center for educational programs in bioinformatics
term:	3
qualification:	Bachelor

Semesters, forms of interim assessment:

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Author: A.V. Belikov, phd (candidate of biological sciences)

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
UC-1 Search and identify, critically assess, and synthesize information, apply a systematic approach to problem-solving	UC-1.1 Analyze problems, highlight the stages of their solution, plan the actions required to solve them
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Gen.Pro.C-1 Apply knowledge of mathematical, physical, chemical, biological laws, patterns, and interrelation to study, analyze, and utilize biological objects and processes	Gen.Pro.C-1.1 Analyze the task in hand, outline the ways to complete it
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	Gen.Pro.C-1.3 Determine the applicability limits of the obtained results
Gen.Pro.C-4 Collect and process scientific and technical and/or technological data for fundamental and applied problem-solving	Gen.Pro.C-4.1 Apply scientific research and intellectual analysis methods for professional problem-solving
	Gen.Pro.C-4.2 Search for primary sources of scientific and technical and/or technological information in professional settings
	Gen.Pro.C-4.3 Prepare abstracts, reports, bibliographies, and reviews of information in professional settings
	Gen.Pro.C-4.4 Use computer and network skills to obtain, store, and process scientific (technical, technological) information
Gen.Pro.C-5 Participate in fundamental and applied research and development activities; independently develop new theoretical research methods (including mathematical research methods)	Gen.Pro.C-5.1 Perform tasks in the field of theoretical and experimental research and development activities
	Gen.Pro.C-5.2 Apply new knowledge through the study of literature, scientific articles, and other sources

2. Competency assessment indicators

As a result of studying the course the student should:

know:

- fundamental concepts and principles of molecular biology;
- structure and function of proteins and nucleic acids;
- mechanisms of DNA replication, repair and recombination, transcription and translation, as well as control of gene expression;
- mechanisms of membrane transport of small molecules, sorting of proteins and intracellular membrane transport;
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- functions of stem cells and mechanisms of tissue renewal.

be able to:

- to apply the acquired fundamental knowledge about molecular biology for planning scientific experiments;
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master:

- skills of mastering a large amount of information;
- skills of independent work;
- terminology, including sufficient technical terms.

3. List of typical control tasks used to evaluate knowledge and skills

During the current control, the student should be able to answer the following questions:

1) Cells and genomes. Biochemistry and Bioenergy
2) Proteins. DNA, chromosomes and genomes
3) Replication, repair and DNA recombination. How cells read the genome
4) Control of gene expression
5) The structure of the membrane. Membrane transport of small molecules and electrical properties of membranes
6) Intracellular compartments and protein sorting. Intracellular membrane transport
7) Cytoskeleton. Intercellular junctions and extracellular matrix
8) Energy conversion: mitochondria and chloroplasts. Signaling in a cell
9) Cell cycle. Cell death
10) Stem cells and tissue renewal

During the lesson, you can conduct interactive discussions in the course chats, which is a homework assignment. It is possible to perform patent search as an independent task. Successful completion of all tasks of the course and completion of the control fragments of knowledge gives an advantage in the differential credit.

4. Evaluation criteria

1) Cells and genomes. Biochemistry and Bioenergy
2) Proteins. DNA, chromosomes and genomes
3) Replication, repair and DNA recombination. How cells read the genome
4) Control of gene expression
5) The structure of the membrane. Membrane transport of small molecules and electrical properties of membranes
6) Intracellular compartments and protein sorting. Intracellular membrane transport
7) Cytoskeleton. Intercellular junctions and extracellular matrix
8) Energy conversion: mitochondria and chloroplasts. Signaling in a cell
9) Cell cycle. Cell death
10) Stem cells and tissue renewal

The mark is excellent (10 points) - it is given to a student who has shown comprehensive, systematic, deep knowledge of the curriculum of the discipline, who has an interest in this subject area, has demonstrated the ability to confidently and creatively put them into practice in solving specific problems, and a free and proper substantiation of decisions.

The mark is excellent (9 points) - it is given to a student who has shown comprehensive, systematic, in-depth knowledge of the curriculum of the discipline and the ability to confidently put them into practice in solving specific problems, free and proper substantiation of the decisions made.

The mark is excellent (8 points) - given to a student who has shown comprehensive, systematic, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice in solving specific problems, correct justification of decisions made, with some shortcomings.

A mark is good (7 points) - it is put up for a student, if he knows the material firmly, sets it up competently and in essence, knows how to apply the knowledge gained in practice, but does not competently substantiate the results obtained.

Evaluation is good (6 points) - it is put up to a student, if he knows the material firmly, sets it up correctly and in essence, knows how to apply this knowledge in practice, but admits some inaccuracies in the answer or in solving problems.

A mark is good (5 points) - it is given to a student, if he basically knows the material, correctly and essentially sets it out, knows how to apply this knowledge in practice, but allows a sufficiently large number of inaccuracies to answer or solve problems.

Grade satisfactorily (4 points) is given to a student who has shown the fragmented, fragmented nature of knowledge, insufficiently correct formulations of basic concepts, violations of the logical sequence in the presentation of program material, but at the same time he has mastered the main sections of the curriculum necessary for further education and can apply knowledge is modeled in a standard situation.

Grade satisfactorily (3 points) - given to a student who showed the fragmented, scattered nature of knowledge, making mistakes in formulating basic concepts, disrupting the logical sequence in presenting program material, poorly masters the main sections of the curriculum required for further education and even applies the knowledge gained in a standard situation.

The rating is unsatisfactory (2 points) - is given to a student who does not know most of the main content of the curriculum of the discipline, makes gross mistakes in the wording of the basic principles and does not know how to use this knowledge when solving typical tasks.

Unsatisfactory mark (1 point) - is given to a student who does not know the main content of the discipline's curriculum, makes gross errors in the wording of the basic concepts of the discipline and does not have any skills to solve typical practical problems.

The mark "passed" - is given when the correct answer to the questions for the test,
The mark "not passed" is given if the answer is incorrect.

5. Methodological materials defining the procedures for the assessment of knowledge, skills, abilities and/or experience

During oral differential credit, the student is given 30 minutes to prepare. Interview with a student on a differential oral test should not exceed one astronomical hour.
During the test, students can use the discipline program.