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: Fundamentals of Cellular Biotechnology/Основы клеточных биотехнологий
major: Biotechnology
specialization: Biomedical Engineering/Биомедицинская инженерия
Phystech School of Biological and Medical Physics
Department of Molecular and Biological Physics
term: 3
qualification: Bachelor

Semesters, forms of interim assessment:
5 (fall) - Grading test
6 (spring) - Exam

Academic hours: 180 AH in total, including:
lectures: 60 AH.
seminars: 0 AH.
laboratory practical: 120 AH.

Independent work: 105 AH.

Exam preparation: 30 AH.

In total: 315 AH, credits in total: 7

Author of the program: E.V. Petersen, candidate of medical sciences

The program was discussed at the Department of Molecular and Biological Physics 28.04.2022

Annotation

The purpose of this discipline is to familiarize students with the achievements of the last decade in the study of the functioning of the eukaryotic cell in order to provide an interface between information and biological sciences. During the course, students will get acquainted with the following sections: eukaryotic cell organelles and their functions, cell division processes, mitosis and meiosis, karyotype, chromosomal abnormalities, cell cycle and its regulation in normal and tumor cells, fundamentals of embryology, structure of the cell nucleus, chromatin, chromatin packaging, epigenetic modifications of proteins and DNA, cell cultures as a model system for cell biology, the concept of pluripotent and multipotent stem cells, the concept of modern omix technologies.

1. Study objective

Purpose of the course

To acquaint students with the achievements of the last decade in the study of the functioning of the eukaryotic cell to provide an interface between information and biological sciences. Introduction to the main directions of cell technologies, methods and devices used in working with cells, a variety of areas of cell biotechnologies and prospects for their development in the coming decades. Acquisition of initial skills in the application of methods aimed at isolating individual cell types from various sources, their cultivation in order to increase the number and subsequent use of the waste products of these cells or the cells themselves for scientific or scientific-practical purposes using molecular genetic methods

Tasks of the course

- formation of basic knowledge about the biology of the eukaryotic cell;
- practical mastering by students of basic concepts used in modern cell biology;
- formation of students' basic skills in data retrieval and analytical processing of material for conducting independent research in the field of cell biology and genetics.

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
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-1.3 Determine the applicability limits of the obtained results
Gen.Pro.C-3 Write scientific and/or technical (technological, innovative) reports (publications, projects)	Gen.Pro.C-3.3 Visually and graphically present scientific (scientific and technical, innovative technological) outcomes in the form of reports, scientific publications
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-4.4 Use computer and network skills to obtain, store, and process scientific (technical, technological) information
Gen.Pro.C-6 Operate technological equipment, manage biotechnological processes, design technical and technological systems, technical facilities, biotechnological production processes by applying basic engineering and technological knowledge	Gen.Pro.C-6.1 Professionally operate modern experimental scientific research (measuring and analytical, technological) equipment in biotechnological research
	Gen.Pro.C-6.2 Evaluate, analyze, and interpret biotechnological data
	Gen.Pro.C-6.3 Possession of the skills to design new technological solutions for the scientific, technical, biotechnological task at hand
	Pro.C-1.1 Understand the fundamental concepts, laws, and theories of modern physics and biology

Pro.C-1 Plan and conduct scientific experiments (in a selected subject area) and/or theoretical (analytical and simulation) research	Pro.C-1.3 Proficiency in methods of observation, description, identifIcation and scientific classification of biological objects
	Pro.C-1.6 Safely use modern scientific tools and other experimental equipment
	Pro.C-1.7 Follow the basic rules of conduct in a modern scientific laboratory
	Pro.C-1.8 Estimate the time and resources required to conduct a scientific experiment
	Pro.C-1.11 Conducts experimental research with cells and cell cultures, conduct physical and chemical study of macromolecules, analyze and study life systems, apply mathematical methods to process biological research outcomes, understand and apply the basic concepts of bioengineering
	Pro.C-1.2 Gain in-depth knowledge and understanding of mathematical disciplines
	Pro.C-1.4 Set scientific objectives and build models of biotechnological objects and systems
	Pro.C-1.5 Build mathematical models used to describe and research various processes and phenomena in relevant scientific fields
	Pro.C-1.9 Use modern programming languages and software packages for scientific calculations
	Pro.C-1.10 Apply knowledge of leading scientific journals to select relevant publications in professional settings
Pro.C-2 Analyze research data and make scientific conclusions	Pro.C-2.2 Define key parameters of the studied phenomenon and make relevant numerical estimates
	Pro.C-2.3 Make scientific claims with supporting evidence for a professional audience in verbal and written form, state scientific problems and propose solutions

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

As a result of studying the course the student should:

know:

- the structure of eukaryotic cells - organelles and their functions;
- cell division, mitosis and meiosis, karyotype, chromosomal abnormalities. The cell cycle and its regulation in normal and tumor cells. Fundamentals of Embryology;
- the structure of the cell nucleus. Chromatin, chromatin packing. Epigenetic modifications of proteins and DNA;
- cell cultures as a model system for cell biology. The concept of stem cells Pluripotent and multipotent stem cells;
- the concept of modern omics technologies.

be able to:

- to use the literature and find the necessary information on cell biology.

master:

- categories and concepts used in cell biology;
- ideas about modern methods used in the study of cells;
- ideas about methods requiring bioinformatics analysis in cell biology.

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

		Types of training sessions, including independent work

№	Topic (section) of the course	Lectures	Seminars	Laboratory practical	Independent work
1	Cell structure, functions, cell cycle	2		4	3
2	Stem cells, tissue specialization, epigenetic regulation	2		4	3
3	The concept of a stem cell niche. The role of components in the formation of cellular response	2		4	3
4	Cell culture. Cell-based test systems	2		4	3
5	Methods for assessing the specific effects of pharmacological substances	2		4	3
6	A method of flow cytofluorimetry	2		4	3
7	Microscopy in cell research	2		4	3
8	Polymerase chain reaction	2		4	3
9	Principles of sequencing	2		4	3
10	Next-generation sequencing	2		4	3
11	Third generation sequencing	2		4	3
12	The concept of cell reprogramming	2		4	3
13	Embryonic stem cells	2		4	3
14	Induced pluripotent cells	2		4	3
15	Types of methods for genetic editing	2		4	3
16	Solutions for transcriptome sequencing	2		4	4
17	The use of reprogrammed cells to study the mechanisms of diseases	2		4	4
18	Cellular vaccines, application in medicine	2		4	4
19	Modeling of diseases in vitro	2		4	4
20	Methods of large-scale cell cultivation	2		4	4
21	Genetic engineering methods for obtaining modified cell lines, selection and screening	2		4	4
22	Methods for manufacturing of biopharmaceutical products	2		4	4
23	Food biotechnology	2		4	4
24	Agrobiotechnologies	2		4	4
25	Biotechnology of soil	2		4	4
26	Regenerative medicine. Tissue engineering	2		4	4
27	Bioprinting technologies. Methods for growing humanized organs in animals	2		4	4
28	Modern concept of nanorobots	2		4	4
29	The concept of synthetic biology. Synthetic cells	2		4	4
30	Technologies using biopolymers and implantable electronics and sensors	2		4	4
AH in total		60		120	105
Exam preparation		30 AH.			
Total complexity		315 AH., credits in total 7			

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

Semester: 5 (Fall)

1. Cell structure, functions, cell cycle

Prokaryotes and eukaryotes. The structure of the eukaryotic cell. Organelles and their functions. Cell nucleus. Cell division. Mitosis and meiosis. Karyotype and chromosomal abnormalities.

2. Stem cells, tissue specialization, epigenetic regulation

Stem cells. Epigenetics. Early embryogenesis and its stages. Genes that determines embryonic development and tissue specialization. The concept of epigenetics, chromatin, epigenetic modifications of histones and DNA. Methods of research.

3. The concept of a stem cell niche. The role of components in the formation of cellular response

Cell niches. Determination of specificity depending on the type of tissue and cellular differentiation. Components of the cell niches and their effect on cells in in-vitro models.

4. Cell culture. Cell-based test systems

Cell cultures. Cell culture techniques. Cell-based test systems in pharmacology and biomedicine. Screening methods - survival, MTT, LD50.

5. Methods for assessing the specific effects of pharmacological substances

Methods for assessing the specific effects of pharmacological substances. Kinetics, exposure, physiological activity, assessment of the activity of signaling cascades.

6. A method of flow cytofluorimetry

Flow cytofluorimeter. The principle of operation. Areas of application. Cell type identification using surface markers. Requirements for selection of antibodies.

7. Microscopy in cell research

Microscopy in cell research. Fluorescence microscopy. High-resolution microscopy. Confocal microscopy. Screening methods. Optical mapping.

8. Polymerase chain reaction

Polymerase chain reaction. The principle of operation. Types of PCR. Areas of application. Selection of primers. Verification of PCR products, electrophoresis. Analysis of the results.

9. Principles of sequencing

Polymerase chain reaction. The principle of operation. Types of PCR. Areas of application. Selection of primers. Verification of PCR products, electrophoresis. Analysis of the results

10. Next-generation sequencing

Next-generation sequencing - NGS. Types and features of NGS. Areas of application. Sample preparation. Analysis of the results. Usage of databases.

11. Third generation sequencing

Nanopore sequencing. Sequencing of single cells. Features of the method. Areas of application. Processing of raw data, bioinformatic analysis. Cluster analysis of the results.

12. The concept of cell reprogramming

Genetic and epigenetic features of reprogrammed somatic cells and methods of their analysis. Methods for the genetic modification of organisms. Transgenesis

13. Embryonic stem cells

Embryonic stem cells. Genetic knockout technology. Nucleus transfer, genetic knockout. The concept of pluripotency.

14. Induced pluripotent cells

Cell reprogramming. Induced pluripotent cells. Pluripotency transcription factors. Reprogramming to a pluripotent state - methods of reprogramming, methods of analysis, significance for biomedicine. Direct Reprogramming and the Epigenetic Landscape.

15. Types of methods for genetic editing

Types of methods for genetic editing (transformation, transfection, transduction). Advantages and disadvantages of the most commonly used methods of genetic editing: CRISPRcas9, TALEN, ZFN.

Semester: 6 (Spring)

16. Solutions for transcriptome sequencing

Quantitative analysis of gene expression. Solutions for transcriptome sequencing. miRNA expression analysis. Biomarkers. Areas of application.

17. The use of reprogrammed cells to study the mechanisms of diseases

The use of reprogrammed cells to study the mechanisms of diseases and for the search for new therapeutic methods. Usage of bioinformatics methods to develop criteria for reprogramming

18. Cellular vaccines, application in medicine

Immunotherapy. Cellular vaccines, application in medicine. Cancer treatment with modified cells on the example of CAR-T. Prospects for the treatment of genetic pathologies.

19. Modeling of diseases in vitro

Modeling of diseases in vitro, correction of mutations using TALEN and CRISPR / CAS systems. Usage of bioinformatic methods for the development of criteria for reprogramming.

20. Methods of large-scale cell cultivation

Cell niches. Determination of specificity depending on the type of tissue and cellular differentiation. Components of the cell niches and their effect on cells in in-vitro models.

21. Genetic engineering methods for obtaining modified cell lines, selection and screening

Products of biopharmaceutical technologies. Genetic engineering methods for obtaining modified cell lines, selection and screening.

22. Methods for manufacturing of biopharmaceutical products

Biopharmaceutical technologies. Methods for manufacturing of vaccines, antibodies, enzymes. Scaling up of laboratory methods. Standardization of technologies. Preclinical and clinical studies.

23. Food biotechnology

Food biotechnology. Manufacturing of probiotics. Modification of technological processes.

24. Agrobiotechnologies

Agrobiotechnologies. Microclonal reproduction. The use of molecular genetic methods for obtaining new varieties of agricultural plants.

25. Biotechnology of soil

Biotechnology of soil. The use of microorganisms in remediation. Formation of remediation biocenoses. Improvement of soil fertility

26. Regenerative medicine. Tissue engineering

Regenerative medicine. Tissue engineering. Areas of application. Tissue bioreactors. Safety requirements. Legal aspects.

27. Bioprinting technologies. Methods for growing humanized organs in animals

Bioprinting technologies. Types of bioprinters. Methods for growing humanized organs in animals. Current challenges in bioprinting.

28. Modern concept of nanorobots

Nanorobots. Theory and biomedical application. Requirements for biosafety and efficiency. Differences from nanoparticles.

29. The concept of synthetic biology. Synthetic cells

Synthetic cells, ethics and legal aspects.

30. Technologies using biopolymers and implantable electronics and sensors

Biocompatible polymers. Implantable electronics and sensors. Prosthetics for the conductive pathways. Functional 3D biopolymer structures.

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

Equipment needed for lectures and seminars: computer and multimedia eqipment (projector, sound system).
Applied Genetics Resource Facility of MIPT

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

Main literature

Literature is provided at the department:

1. Animal Cell Culture: A Practical Approach. / R.I. Freshney (ed.). Moscow: Laboratory of Knowledge, 2018.

Additional literature

Recommended literature for self-study

1. Molecular biology of the cell / B. Alberts, A. Johnson, J. Lewis [et al.] ; with problems by J. Wilson, T. Hunt. - 6th edition. - New York : Garland science, 2015. - 1342 p.

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

Not used

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

MS Office software package: MS Word, MS PowerPoint, MS Excel. Acrobat Reader, DJVU Reader. ImageJ software package. Some classes may require Zoom. Google or Yandex Drive are required to access the course materials. To participate in interactive exercises / surveys, it is advisable to have access to the Internet on a laptop or smartphone.

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
	Department of Molecular and Biological Physics
term:	3
qualification:	Bachelor

Semesters, forms of interim assessment:

5 (fall) - Grading test

6 (spring) - Exam

Author: E.V. Petersen, candidate of medical sciences

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
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-1.3 Determine the applicability limits of the obtained results
Gen.Pro.C-3 Write scientific and/or technical (technological, innovative) reports (publications, projects)	Gen.Pro.C-3.3 Visually and graphically present scientific (scientific and technical, innovative technological) outcomes in the form of reports, scientific publications
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-4.4 Use computer and network skills to obtain, store, and process scientific (technical, technological) information
Gen.Pro.C-6 Operate technological equipment, manage biotechnological processes, design technical and technological systems, technical facilities, biotechnological production processes by applying basic engineering and technological knowledge	Gen.Pro.C-6.1 Professionally operate modern experimental scientific research (measuring and analytical, technological) equipment in biotechnological research
	Gen.Pro.C-6.2 Evaluate, analyze, and interpret biotechnological data
	Gen.Pro.C-6.3 Possession of the skills to design new technological solutions for the scientific, technical, biotechnological task at hand
Pro.C-1 Plan and conduct scientific experiments (in a selected subject area) and/or theoretical (analytical and simulation) research	Pro.C-1.1 Understand the fundamental concepts, laws, and theories of modern physics and biology
	Pro.C-1.3 Proficiency in methods of observation, description, identifIcation and scientific classification of biological objects
	Pro.C-1.6 Safely use modern scientific tools and other experimental equipment
	Pro.C-1.7 Follow the basic rules of conduct in a modern scientific laboratory
	Pro.C-1.8 Estimate the time and resources required to conduct a scientific experiment
	Pro.C-1.11 Conducts experimental research with cells and cell cultures, conduct physical and chemical study of macromolecules, analyze and study life systems, apply mathematical methods to process biological research outcomes, understand and apply the basic concepts of bioengineering
	Pro.C-1.2 Gain in-depth knowledge and understanding of mathematical disciplines
	Pro.C-1.4 Set scientific objectives and build models of biotechnological objects and systems
	Pro.C-1.5 Build mathematical models used to describe and research various processes and phenomena in relevant scientific fields
	Pro.C-1.9 Use modern programming languages and software packages for scientific calculations
	Pro.C-1.10 Apply knowledge of leading scientific journals to select relevant publications in professional settings
Pro.C-2 Analyze research data and make	Pro.C-2.2 Define key parameters of the studied phenomenon and make relevant numerical estimates

Pro.C-2 Analyze research data and make scientific conclusions	Pro.C-2.3 Make scientific claims with supporting evidence for a professional audience in verbal and written form, state scientific problems and propose solutions

2. Competency assessment indicators

As a result of studying the course the student should:

know:

- the structure of eukaryotic cells - organelles and their functions;
- cell division, mitosis and meiosis, karyotype, chromosomal abnormalities. The cell cycle and its regulation in normal and tumor cells. Fundamentals of Embryology;
- the structure of the cell nucleus. Chromatin, chromatin packing. Epigenetic modifications of proteins and DNA;
- cell cultures as a model system for cell biology. The concept of stem cells Pluripotent and multipotent stem cells;
- the concept of modern omics technologies.

be able to:

- to use the literature and find the necessary information on cell biology.

master:

- categories and concepts used in cell biology;
- ideas about modern methods used in the study of cells;
- ideas about methods requiring bioinformatics analysis in cell biology.

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. Cell theory. Modern postulates of cell theory.
2. The concept of stem cells. Embryonic stem cells.
3. Epigenetics of stem cells.
4. Technology of genetic knockout.
5. Cell reprogramming.
6. Induced pluripotent cells.
7. Genetic and epigenetic features of reprogrammed somatic cells.
8. Application of reprogramming technology to study the mechanisms of diseases and search for new methods of therapy.
9. Use of bioinformatics methods to develop criteria for reprogramming.
10. Cell cycle.
11. Methods of cell biology and histology.
12. Potential of differentiation of stem and somatic cells.
13. Cell structure of mammals
14. Functions of eukaryotic cell organelles
15. Mitosis and meiosis.

4. Evaluation criteria

Differentiated test:

1. Describe the theoretical and methodological approaches to cell culture. Describe the main types of cell cultures.
2. Describe the main methods using cell lines to test the effects of new drugs.
3. Describe the differences between totipotent stem cells and unipotent ones. Define the term tissue-specific stem cells. Describe the role of tissue-specific cells in the mechanism of carcinogenesis.
4. Give examples of stem cells of various types of tissues, their localization in the body, their role in in vitro cultivation.

5. Describe the principle of the polymerase chain reaction. What methods are based on this principle, give an example and describe the differences.

Exam:

1. Describe the features of industrial cell cultivation. What types of bioreactors do you know, what are their differences?
2. What are cell vaccines? How are they created? What areas of their application are known to you?
3. Give examples of the use of regenerative cell technologies in the treatment of various pathologies: skin therapy; therapy of the cardiovascular system; defects of bone and cartilage tissues; therapy of the endocrine glands.
4. Describe the principle of the polymerase chain reaction. What methods are based on this principle, give an example and describe the differences.

Ticket 1

1. Give examples of the use of regenerative cell technologies in the treatment of various pathologies: skin therapy; therapy of the cardiovascular system; defects of bone and cartilage tissues; therapy of the endocrine glands.
2. Describe the principle of the polymerase chain reaction. What methods are based on this principle, give an example and describe the differences

Assessment excellent 10 points-exposed to the student who showed a comprehensive, systematic, in-depth knowledge of the curriculum discipline, showing interest in the subject area, demonstrated the ability to confidently and creatively apply them in practice in solving specific problems, free and correct justification of decisions.

Assessment excellent 9 points-exposed to the student, who showed a comprehensive, systematic, in-depth knowledge of the curriculum discipline and the ability to confidently apply them in practice in solving specific problems, free and correct justification of decisions.

Assessment is excellent 8 points-exposed to the student, who showed a comprehensive, systematic, in-depth knowledge of the curriculum discipline and the ability to confidently apply them in practice when solving specific problems, the correct justification of the decisions, with some shortcomings.

Score well 7 points is assigned to the student if he knows the material, competently, and essentially presents it, is able to apply the acquired knowledge in practice, but has not been properly justifies the results obtained.

Score well 6 points is assigned to the student if he knows the material, competently, and essentially presents it, is able to apply the acquired knowledge in practice, but admits in the answer or in the task some inaccuracies.

Score well 5 points is assigned to the student if he basically knows the material, competently, and essentially presents it, is able to apply the acquired knowledge in practice, but admits in the answer or in the task of quite a number of inaccuracies.

The satisfactory rating of 4 points is assigned to the student who showed the fragmented, piecemeal nature of the knowledge is not enough for the correct formulation of the basic concepts, disorders of logical sequence in the presentation of program material, but he mastered parts of the curriculum necessary for further learning, and can apply the knowledge modeled in the standard situation.

Rating satisfactory 3 points - is given for student, who showed the fragmented, piecemeal nature of knowledge makes a mistake in the formulation of the basic concepts of violation of logical sequence in the presentation of program material, has little major parts of the curriculum necessary for further studies and work applies the knowledge gained even in the standard situation.

Assessment unsatisfactory 2 points-exposed to the student who does not know most of the basic content of the curriculum discipline, makes blunders in the wording of the basic principles and does not know how to use the knowledge in solving typical problems.

Assessment unsatisfactory 1 point-exposed to the student who does not know the basic content of the curriculum discipline, makes gross errors in the wording of the basic concepts of discipline and does not have the skills to solve typical practical problems.

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

When conducting a differentiated test or examination, the student is given 40 minutes to prepare. The student's ticket survey should not exceed one astronomical hour.