Federal State Autonomous Educational Institution of Higher Education
PEOPLES' FRIENDSHIP UNIVERSITY OF RUSSIA
RUDN University

Institute of Pharmacy and Biotechnology
educational division (faculty/institute/academy) as higher education programme developer

COURSE SYLLABUS

INTRODUCTION TO BIOINFORMATICS
course title

Recommended by the Didactic Council for the Education Field of:

04.04.01 CHEMISTRY
field of studies / speciality code and title

The course instruction is implemented within the professional education programme of higher education:

BIOCHEMICAL TECHNOLOGIES AND NANOTECHNOLOGIES

higher education programme profile/specialisation title

2025

1. COURSE GOAL(s)

Possible wording

A. The goal of the course "**Introduction to Bioinformatics**" is to study the fundamentals of bioinformatics, modern methods of analyzing biological sequences, protein structures, gene expression data, and regulatory elements of genomes.

B. The course aims to equip students with the knowledge and skills necessary to use bioinformatics tools and methods for analyzing biological data, understanding molecular processes, and gaining insight into genomic, proteomic, and transcriptomic information. By the end of the course, students should be able to apply bioinformatics methodologies to solve research questions, interpret biological data, and make informed decisions in relevant knowledge areas.

2. REQUIREMENTS FOR LEARNING OUTCOMES

Possible wording

1) Mastering the course "Introduction to Bioinformatics" is aimed at the development of the following competences /competences in part:

Table 2.1. List of competences that students acquire through the course study

Competence code	**Competence descriptor**	**Competence formation indicators** (within this course)
PC-3	Ability to evaluate the prospects of practical application and continuation of work in the chosen field of chemistry, chemical technology or sciences related to chemistry based on critical analysis of R&D results	PC-3.1 Studies and analyzes specialized literature, methodical and regulatory documents related to objects and subjects of professional activity

3.COURSE IN HIGHER EDUCATION PROGRAMME STRUCTURE

The course refers to the core/variable/elective* component of (B1) block of the higher educational programme curriculum.

* - Underline whatever applicable.

Within the higher education programme students also master other (modules) and / or internships that contribute to the achievement of the expected learning outcomes as results of the course study.

Table 3.1. The list of the higher education programme components/disciplines that contribute to the achievement of the expected learning outcomes as the course study results

Competence code	**Competence descriptor**	**Previous courses/modules***	**Subsequent courses/modules***
PC-3	Ability to evaluate the prospects of practical application and continuation of work in the chosen field of chemistry, chemical technology or sciences	Nanotechnology in medicine; Product safety assessment of nanoindustry**; Industrial microbiology**; Industrial toxicology**; Introduction to	Pre-graduation internship; Protection of intellectual property; Current challenges in modern chemistry**; Application of polymers in biomedical technology and

Competence code	Competence descriptor	Previous courses/modules*	Subsequent courses/modules*
	related to chemistry based on critical analysis of R&D results	nanotechnology**	nanotechnology**

* To be filled in according to the competence matrix of the higher education programme., ** Elective disciplines/practices

4. COURSE WORKLOAD AND ACADEMIC ACTIVITIES

Possible wording

1)The total workload of the course "Introduction to Bioinformatics" is 3 credits (108 academic hours).

*Table 4.1. Types of academic activities during the periods of higher education programme mastering (**full-time training**)**

Type of academic activities		Total academic hours	Semesters/training modules
			3
Contact academic hours		*32*	*32*
including:			
Lectures (LC)		16	16
Lab work (LW)		8	8
Seminars (workshops/tutorials) (S)		8	8
Self-studies		*58*	*58*
Evaluation and assessment (exam/passing/failing grade)		*18*	*18*
Course workload	academic hours_	**108**	**108**
	credits	**3**	**3**

*Table 4.2. Types of academic activities during the periods of higher education programme mastering (**part-time training**)**

Type of academic activities		Total academic hours	Semesters/training modules
			3
Contact academic hours		*32*	*32*
including:			
Lectures (LC)		16	16
Lab work (LW)		8	8
Seminars (workshops/tutorials) (S)		8	8
Self-studies		*58*	*58*
Evaluation and assessment (exam/passing/failing grade)		*18*	*18*
Course workload	academic hours_	**108**	**108**
	credits	**3**	**3**

* To be filled in regarding the higher education programme part-time training mode.

5. COURSE CONTENTS

Table 5.1. Course contents and academic activities types

Course module title	Course module contents (topics)	Academic activities types
Module 1: Introduction to bioinformatics and NCBI databases	Topic 1.1. Overview of NCBI resources, structure and interconnection of various databases	LC, LW, S
	Topic 1.2. Information search in NCBI databases (GQuery/NCBI Search)	LC, LW, S
	Topic 1.3. Sequence search using BLAST	LC, LW, S
	Topic 1.4. GenBank record structure, sequence representation formats	LC, LW, S
	Topic 1.5. Concepts of homology, orthology, and paralogy	LC, LW, S
Module 2: Advanced BLAST capabilities and comparative genomics	Topic 2.1. Different types of BLAST search (BlastP, PSI-Blast, Translated Blast)	LC, LW, S
	Topic 2.2. Substitution matrices, their selection and construction principles	LC, LW, S
	Topic 2.3. Dot matrices for sequence comparison	LC, LW, S
	Topic 2.4. Genome browsers and identification of orthologous genes	LC, LW, S
	Topic 2.5. The concept of synteny and its significance in comparative genomics	LC, LW, S
Module 3: Multiple sequence alignment	Topic 3.1. Methods of multiple alignment construction: Clustal, MUSCLE, MAFFT	LC, LW, S
	Topic 3.2. Analysis of conserved and variable regions in alignments	LC, LW, S
	Topic 3.3. Practical application of multiple alignments	LC, LW, S
Module 4: Phylogenetic analysis	Topic 4.1. Terminology and basic concepts of phylogenetic trees	LC, LW, S
	Topic 4.2. Tree construction methods: distance-based and character-based	LC, LW, S
	Topic 4.3. Sequence evolution models	LC, LW, S
	Topic 4.4. Construction of phylogenetic trees using neighbor-joining and maximum likelihood methods	LC, LW, S
Module 5: Selection pressure analysis	Topic 5.1. Types of selection pressure and their biological significance	LC, LW, S
	Topic 5.2. Calculation and interpretation of dN/dS values	LC, LW, S

	Topic 5.3. Identification of sites under positive, negative, and neutral selection using DataMonkey	LC, LW, S
Module 6: RNA-Seq data analysis and metagenomics	Topic 6.1. Next-generation sequencing (NGS) technologies	LC, LW, S
	Topic 6.2. Principles of RNA-Seq data assembly and analysis	LC, LW, S
	Topic 6.3. Analysis of gene expression and alternative splicing	LC, LW, S
	Topic 6.4. Fundamentals of metagenomics and its application for analyzing microbial communities	LC, LW, S
Module 7: Protein motif analysis	Topic 7.1. Conserved regions of protein families and their significance	LC, LW, S
	Topic 7.2. Ways to describe conserved regions: regular expressions, profiles, hidden Markov models	LC, LW, S
	Topic 7.3. Using CDD, CDART, SMART, Pfam, InterProScan databases for functional domain identification	LC, LW, S
Module 8: Protein-protein interactions	Topic 8.1. Experimental methods for determining protein-protein interactions	LC, LW, S
	Topic 8.2. Protein-protein interaction databases (DIP, BioGRID)	LC, LW, S
	Topic 8.3. Visualization and analysis of interaction networks using Cytoscape	LC, LW, S
	Topic 8.4. Gene Ontology category enrichment	LC, LW, S
Module 9: Structural bioinformatics	Topic 9.1. Basic methods for determining protein structures	LC, LW, S
	Topic 9.2. Working with Protein Data Bank (PDB)	LC, LW, S
	Topic 9.3. Searching for structural similarity using VAST	LC, LW, S
	Topic 9.4. Visualization and analysis of protein structures using PyMOL	LC, LW, S
Module 10: Gene expression analysis	Topic 10.1. Technologies for generating gene expression data	LC, LW, S
	Topic 10.2. Normalization and analysis of gene expression data	LC, LW, S
	Topic 10.3. Clustering and identification of co-expressed genes	LC, LW, S
	Topic 10.4. Using expression databases and online tools	LC, LW, S

Module 11: Regulatory elements in genomes	Topic 11.1. Cis-regulatory elements and their role in gene expression regulation	LC, LW, S
	Topic 11.2. Methods for identifying known cis-elements	LC, LW, S
	Topic 11.3. Prediction of new regulatory elements	LC, LW, S

* - to be filled in only for **full** -time training: *LC - lectures; LW - lab work; S - seminars.*

6. CLASSROOM EQUIPMENT AND TECHNOLOGY SUPPORT REQUIREMENTS

Table 6.1. Classroom equipment and technology support requirements

Type of academic activities	**Classroom equipment**	**Specialised educational / laboratory equipment, software, and materials for course study** (if necessary)
Lecture	A lecture hall for lecture-type classes, equipped with a set of specialised furniture; board (screen) and technical means of multimedia presentations.	Classroom for conducting lectures, practical classes, group and individual consultations, current control and interim attestation. Set of specialized furniture; technical equipment: Multimedia projector Everycom, Lenovo Thinkpad L530 Intel Core i3-2370M_2.4GHz/DDR3 4 GB laptop, Internet access provided.
Lab work	A classroom for laboratory work, individual consultations, current and mid-term assessment; equipped with a set of specialised furniture and machinery.	Classroom for conducting lectures, practical classes, group and individual consultations, current control and interim attestation. Set of specialized furniture; technical equipment: Multimedia projector Everycom, Lenovo Thinkpad L530 Intel Core i3-2370M_2.4GHz/DDR3 4 GB laptop, Internet access provided.
Seminar	A classroom for conducting seminars, group and individual consultations, current and mid-term assessment; equipped with a set of specialised furniture and technical means for multimedia presentations.	Classroom for conducting lectures, practical classes, group and individual consultations, current control and interim attestation. Set of specialized furniture; technical equipment: Multimedia projector

Type of academic activities	Classroom equipment	Specialised educational / laboratory equipment, software, and materials for course study (if necessary)
		Everycom, Lenovo Thinkpad L530 Intel Core i3-2370M_2.4GHz/DDR3 4 GB laptop, Internet access provided.
Computer Lab	A classroom for conducting classes, group and individual consultations, current and mid-term assessment, equipped with personal computers (in the amount of ____pcs), a board (screen) and technical means of multimedia presentations.	List of specialised software installed on computers for mastering the discipline
Self-studies	A classroom for independent work of students (can be used for seminars and consultations), equipped with a set of specialised furniture and computers with access to the electronic information and educational environment.	Classroom for conducting lectures, practical classes, group and individual consultations, current control and interim attestation. Set of specialized furniture; technical equipment: Multimedia projector Everycom, Lenovo Thinkpad L530 Intel Core i3-2370M_2.4GHz/DDR3 4 GB laptop, Internet access provided.

* The premises for students' self-studies are subject to **MANDATORY** mention

7. RESOURCES RECOMMENDED FOR COURSE STUDY

Main readings:

1. Compo, F., Pevzner, P. (2023). Algorithms for Bioinformatics. Moscow: DMK Press. ISBN 978-5-93700-175-7. Text: electronic // Lan: electronic library system. URL: https://e.lanbook.com/book/314972

2. Chasovskikh, N. Yu. (2020). Bioinformatics: textbook. Moscow: GEOTAR-Media. 352 p.: ill.
URL: https://lib.rudn.ru/MegaPro/UserEntry?Action=Link_FindDoc&id=497943&idb=0

Additional readings:

1. Chasovskikh, N. Yu. (2019). Bioinformatics Practicum: tutorial. Part 1. Tomsk: SibGMU. 135 p. ISBN 978-5-98591-145-9. Text: electronic // Lan: electronic library system. URL: https://e.lanbook.com/book/138707

2. Chasovskikh, N. Yu. (2019). Bioinformatics Practicum: tutorial. Part 2. Tomsk: SibGMU. 126 p. ISBN 978-5-98591-147-3. Text: electronic // Lan: electronic library system. URL: https://e.lanbook.com/book/138708

3. Lesk, A. (2009). Introduction to Bioinformatics. Translated from English, edited by A.A. Mironov, V.K. Shvyadasa. Moscow: BINOM. Laboratory of Knowledge. 318 p.: ill. ISBN 978-5-94774-501-6.

Internet sources

1. Electronic libraries (EL) of RUDN University and other institutions, to which university students have access on the basis of concluded agreements:

- RUDN Electronic Library System (RUDN ELS) http://lib.rudn.ru/MegaPro/Web
- EL "University Library Online" http://www.biblioclub.ru
- EL "Yurayt" http://www.biblio-online.ru
- EL "Student Consultant" www.studentlibrary.ru
- EL "Lan" http://e.lanbook.com/
- EL "Trinity Bridge"

2.Databases and search engines:

- electronic foundation of legal and normative-technical documentation http://docs.cntd.ru/
- Yandex search engine https:// www .yandex.ru/
- Google search engine https://www.google.ru/
- Scopus abstract database http://www.elsevierscience.ru/products/scopus/

*Training toolkit for self- studies to master the course *:*

1. The set of lectures on the course "Introduction to Bioinformatics"

* The training toolkit for self- studies to master the course is placed on the course page in the university telecommunication training and information system under the set procedure.

DEVELOPERS:

Associate Professor	**Kezimana Parfait**
position, department	name and surname

HEAD OF EDUCATIONAL DEPARTMENT:

name of department	name and surname

HEAD
OF HIGHER EDUCATION PROGRAMME:

Director of Institute of Pharmacy and Biotechnology	**Romashchenko Victoria Alexandrovna**
position, department	name and surname

Federal State Autonomous Educational Institution of Higher Education
PEOPLES' FRIENDSHIP UNIVERSITY OF RUSSIA
RUDN University

Institute of Pharmacy and Biotechnology
educational division (faculty/institute/academy) as higher education programme developer

ASSESSMENT MATERIALS FOR THE COURSE

INTRODUCTION TO BIOINFORMATICS
course title

Recommended by the Didactic Council for the Education Field of:

04.04.01 CHEMISTRY
field of studies / speciality code and title

The course instruction is implemented within the professional education programme of higher education:

BIOCHEMICAL TECHNOLOGIES AND NANOTECHNOLOGIES

higher education programme profile/specialisation title

2025

Description of the Point-Rating System

Work during the semester

Maximum number of points earned in the semester – 100

Type of assignment	Number of assignments	Points per assignment	Total points
Practical assignments (seminars)	8	5	40
Essay	1	20	20
Tests	2	10	20
Final assessment (credit)	1	20	20
TOTAL			**100**

Correspondence of grading systems

(Previously used grades for final academic performance, ECTS grades and point-rating system (PRS) grades for current performance) (In accordance with the Rector's Order No. 996 of December 27, 2006):

PRS Points	Traditional grades in RF	Points for grade conversion	Grades	ECTS Grades
86 - 100	5	95 - 100	5+	A
		86 - 94	5	B
69 - 85	4	69 - 85	4	C
51 - 68	3	61 - 68	3+	D
		51 - 60	3	E
0 - 50	2	31 - 50	2+	FX
		0 - 30	2	F

The schedule for written tests is formed in accordance with the course calendar plan.

Students are required to submit all assignments by the deadlines set by the instructor.

Students are allowed to retake a test once if they received less than half of the planned points for it, in which case the previously received points for this test are annulled. The retake deadline is established by the instructor. The final test cannot be retaken.

The use of sources (including lecture notes and lab materials) during a written test is possible only with the instructor's permission.

The time allotted to a student for completing a written assignment (control test) is established by the instructor. Upon completion of the allotted time, the student must submit the work to the instructor, regardless of whether it is completed or not.

A delay in retaking tests and submitting homework is considered valid only in case of student illness, which is confirmed by a medical certificate. In this case, the completion of tests is carried out within the timeframe specified by the instructor.

A student is admitted to the final test with any number of points earned during the semester, provided that the student has a theoretical possibility of obtaining at least 31 points.

QUESTIONS FOR CREDIT PREPARATION

1. Modern biology as an interdisciplinary science. The place of biology in the system of natural sciences.
2. Scientific method in biological research. Basic principles of experiment planning.
3. Fundamentals of systems biology. Integration of data from various "-omics" technologies.
4. Ecological interactions in nature and their significance for biotechnology.

5. The concept of sustainable development in the context of biotechnological and pharmaceutical industries.
6. Biomimetics: using natural principles in developing new technologies.
7. Cell bioenergetics. Main pathways of energy conversion in living systems.
8. Metabolic pathways and their regulation at the molecular level.
9. Enzymatic systems and their biotechnological applications.
10. Principles of metabolic engineering and their application in biotechnology.
11. Modern understanding of cell structure and functions.
12. Cell cycle and mechanisms of its regulation. Cell cycle disorders in pathologies.
13. Stem cells and their potential for regenerative medicine.
14. Cell cultures and their application in biotechnology and pharmaceutical production.
15. Genome structure and organization of genetic information. Comparative genomics.
16. Mechanisms of gene expression and their regulation at various levels.
17. Modern methods of genome editing (CRISPR/Cas, etc.) and their applications.
18. Genomics, transcriptomics, proteomics: a systems approach to studying the cell.
19. Epigenetic mechanisms of gene activity regulation and their role in organism development.
20. Genetic basis of individual variability in response to drugs.
21. Modern evolutionary theory and its significance for biotechnological developments.
22. Molecular basis of evolution. Evolution of genes and genomes.
23. Biodiversity as a source of innovations for biotechnology and pharmaceutics.
24. Phylogenetic analysis and its application in biopharmaceutical research.
25. Main directions of modern biotechnology. Classification of biotechnological processes.
26. Recombinant technologies and their application in the production of biopharmaceutical products.
27. Synthetic biology: principles of designing biological systems with specified properties.
28. Promising directions for biotechnology development in the context of personalized medicine.
29. Biological basis for drug development. Targets for drug action.
30. Biopharmaceutical aspects of creating and producing drugs.

TOPICS FOR PRACTICAL CLASSES (SEMINARS)

1. **Scientific method in modern biology**
    - Critical analysis of scientific publications
    - Discussion of modern myths and misconceptions in biology
    - Methodology for testing scientific hypotheses
2. **Ecological aspects of biotechnology**
    - Analysis of environmental consequences of biotechnological innovations
    - Principles of sustainable development in biotechnological and pharmaceutical industries
    - Biological safety of modern biotechnologies
3. **Bioenergetics and metabolic engineering**
    - Analysis of metabolic pathways from the perspective of their biotechnological use
    - Promising directions for optimizing bioenergetic processes
    - Enzymatic systems as tools for biotechnology
4. **Modern cell technologies**

- Analysis of cell technology applications in biopharmaceutics
- Discussion of ethical aspects of stem cell use
- Prospects for tissue engineering development

5. **Genome editing and its applications**
   - Analysis of modern genome editing technologies
   - Discussion of potential applications of CRISPR/Cas systems in biotechnology and medicine
   - Ethical aspects of human genetic engineering
6. **Personalized medicine and pharmacogenomics**
   - Case studies of genetic tests application for therapy personalization
   - Prospects for pharmacogenomics development
   - Bioinformatic approaches in personalized medicine
7. **Evolutionary approaches in biotechnology**
   - Analysis of evolutionary principles application in biotechnology
   - Discussion of biodiversity significance for developing new drugs
   - Directed evolution as a biotechnology tool
8. **Prospects for biopharmaceutics development**
   - Analysis of current trends in the biopharmaceutical industry
   - Discussion of regulatory aspects of biopharmaceutical production
   - Integration of biology and pharmaceutics: current state and prospects

Methodological recommendations for organizing practical classes

Practical classes are conducted in an interactive format using the following methods:

- Group discussions
- Analysis of scientific publications
- Case studies
- Student presentations followed by discussion

For practical classes, students should first familiarize themselves with the recommended literature and prepare materials for discussion according to the instructor's assignment. Active participation in discussions and completion of assignments are mandatory conditions for earning points for practical classes.

ESSAY TOPICS

1. Synthetic biology: current state and development prospects
2. CRISPR/Cas systems and their application in biotechnology and medicine
3. Stem cells and regenerative medicine
4. Molecular pharmacology: new approaches to drug development
5. Systems biology and its role in drug development
6. Epigenetics and its influence on organism development
7. Biomimetics as a source of innovations in biotechnology
8. Metagenomics and its application in biotechnology and medicine
9. Modern approaches to vaccine development
10. Antimicrobial resistance: mechanisms and ways to overcome
11. Bioinformatics and its role in modern biology
12. Biofilms: structure, formation, and significance for medicine
13. Aptamers as an alternative to antibodies in biotechnology and diagnostics
14. Nanobiotechnology: current state and development prospects
15. Genetically modified organisms in biotechnology and agriculture
16. Molecular mechanisms of aging and approaches to increasing life expectancy
17. Human microbiome and its role in health and disease

18. Metabolic engineering of microorganisms for the production of biologically active substances
19. Biosensors: operating principles and applications in medicine and biotechnology
20. Photosynthesis and possibilities for its biotechnological optimization

Methodological recommendations for essay preparation

The essay represents an analytical review of scientific literature on the chosen topic. The essay volume should be 15-20 pages (Times New Roman, 14 pt, 1.5 spacing). The essay structure should include:

- Title page
- Table of contents
- Introduction (topic relevance, purpose, and objectives)
- Main part (divided into logical subsections)
- Conclusion (main findings)
- Bibliography (at least 10 sources, including a minimum of 5 in English)

When preparing the essay, it is necessary to use modern scientific literature (publications from the last 5 years), including articles from peer-reviewed journals. The essay should contain an analysis of the current state of the problem, various approaches and perspectives of scientists, as well as the author's own assessments and conclusions. Direct copying of text from sources is not allowed. Citations should be accompanied by references to the source.

The defense of the essay is carried out in the form of an oral presentation with slides (7-10 minutes) followed by a discussion.

ESSAY EVALUATION CRITERIA

Criterion	**Maximum points**
Relevance and comprehensiveness of topic coverage	5
Use of modern scientific literature	5
Critical analysis of information	5
Quality of formatting and presentation	3
Answers to questions during discussion	2
Total	**20**

TEST EXAMPLES

Test 1: "Molecular and cellular foundations of modern biology"

1. Which of the listed methods belong to systems biology? (select all correct answers) a. Genomics b. Transcriptomics c. Proteomics d. Metabolomics e. Electron microscopy
2. Which characteristics define stem cells? (select all correct answers) a. Self-renewal capacity b. Differentiation potential c. Phagocytosis capability d. Presence of specific surface markers e. Unlimited cell cycle
3. What are epigenetic modifications? a. Changes in DNA sequence b. Reversible changes affecting gene expression without changing DNA sequence c. Mutations accumulating during aging d. DNA replication errors
4. Which processes are related to post-transcriptional regulation of gene expression? (select all correct answers) a. RNA splicing b. DNA methylation c. RNA modification d. mRNA stability regulation e. Heterochromatin formation
5. What is the principle of CRISPR/Cas9 technology? a. Application of RNA interference to suppress gene expression b. Use of nucleases for directed double-stranded DNA break with subsequent repair c. Introduction of genes using viral vectors d. Amplification of DNA segments using polymerase chain reaction

6. Which characteristics define metabolic pathways in the cell? (select all correct answers) a. Sequence of enzymatic reactions b. Regulatory mechanisms c. Energy balance d. Cellular localization e. Phylogenetic origin
7. What are induced pluripotent stem cells (iPSCs)? a. Embryonic stem cells b. Somatic cells reprogrammed to pluripotent state c. Stem cells obtained from bone marrow d. Teratoma cells
8. Which methods are used to study protein structure? (select all correct answers) a. X-ray crystallography b. Nuclear magnetic resonance (NMR) c. Cryo-electron microscopy d. Polymerase chain reaction e. Mass spectrometry
9. What are "omics" in modern biology? a. Systems for classification of living organisms b. Complex of technologies for global study of biological systems at different levels c. Methods of statistical processing of biological data d. Algorithms for modeling biological processes
10. Which properties are characteristic of enzymes? (select all correct answers) a. Specificity of action b. Catalytic activity c. Regulability d. Thermostability e. Irreversibility of action
11. What main stages does the gene expression process include in eukaryotes? a. Transcription, translation b. Transcription, RNA processing, RNA export from nucleus, translation c. Replication, transcription, translation d. Replication, transcription, RNA processing, translation
12. What does metabolomics study? a. The totality of all metabolites in a biological sample b. Metabolic pathways in the cell c. Enzyme activity d. Energy metabolism
13. What DNA repair mechanisms exist in the cell? (select all correct answers) a. Base excision repair b. Nucleotide excision repair c. Double-strand break repair d. Photoreactivation e. Homologous recombination
14. What is alternative splicing? a. The process of removing introns from pre-mRNA b. The process by which different mRNAs and, consequently, different proteins can be formed from one gene c. A method for studying gene expression d. A type of mutation leading to changes in protein sequence
15. What components are necessary for the CRISPR/Cas9 system to work? (select all correct answers) a. Cas9 nuclease b. Guide RNA (sgRNA) c. Target DNA with PAM sequence d. DNA polymerase e. Restriction enzyme

Test 2: "Modern directions of biotechnology and their applications"

1. Which of the listed directions belong to modern biotechnology? (select all correct answers) a. Genetic engineering b. Cell engineering c. Protein engineering d. Metabolic engineering e. Quantum physics
2. What advantages do recombinant proteins have compared to proteins isolated from natural sources? (select all correct answers) a. Higher degree of purity b. Absence of pathogen contamination risk c. Possibility of obtaining in large quantities d. Higher biological activity e. Absence of immunogenicity
3. What are biosimilars? a. Generic versions of chemical drugs b. Biological products similar in quality, safety, and efficacy to already approved biological products c. Analogs of natural biologically active substances d. Simulated models of biological systems
4. Which cells are used for recombinant protein production? (select all correct answers) a. Bacterial cells (E. coli) b. Yeast c. Insect cells d. Mammalian cells e. Plant cells
5. What is pharmacogenomics? a. A section of genomics studying the influence of genetic factors on drug efficacy and toxicity b. Creating drugs based on genetic

information c. A method of disease diagnostics based on genetic markers d. A direction of genetics studying hereditary diseases

6. Which methods are used for directed protein evolution? (select all correct answers) a. Random mutagenesis b. Gene recombination c. Screening or selection of variants according to specified properties d. Rational design e. Animal cloning
7. What is synthetic biology? a. Creation of artificial biological systems with specified properties b. Synthesis of biologically active substances c. Production of synthetic polymers d. Computer modeling of biological processes
8. Which approaches are used in regenerative medicine? (select all correct answers) a. Tissue engineering b. Use of stem cells c. Stimulation of the organism's own regenerative mechanisms d. Organ transplantation e. Gene therapy
9. What is bioremediation? a. Use of living organisms to clean the environment from pollution b. Restoration of damaged tissues and organs c. A method of sterilization in pharmaceutical production d. Processing of biological waste
10. Which factors affect the efficiency of biopharmaceutical production? (select all correct answers) a. Choice of expression system b. Cultivation conditions c. Product purification methods d. Final product stability e. Marketing strategy
11. What is targeted therapy? a. Treatment directed at specific molecular targets that play a key role in disease development b. Diagnostic method using molecular markers c. Method of drug delivery to specific organs d. Personalized dose selection
12. Which methods are used to detect protein-protein interactions? (select all correct answers) a. Yeast two-hybrid system b. Immunoprecipitation c. Fluorescence resonance energy transfer (FRET) d. Mass spectrometry e. Polymerase chain reaction
13. What is nanobiotechnology? a. A section of biotechnology using nanomaterials and nanotechnologies for biological and medical applications b. Technology for creating nanoscale biological objects c. Method for visualizing biological structures with nanometer resolution d. Technology for producing nanoparticles of biological origin
14. Which genetic material delivery methods are used in gene therapy? (select all correct answers) a. Viral vectors b. Liposomes c. Nanoparticles d. Electroporation e. Magnetofection
15. What problems exist in the development of biopharmaceutical products? (select all correct answers) a. Immunogenicity b. Complexity of production and quality assurance c. High cost d. Product stability e. Production scaling difficulties