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

APPROVED
Head of Landau Phystech-School of Physics & Research
A.V. Rogachev

Work program of the course (training module)

course:	Genomics of Microorganisms/Геномика микроорганизмов
major:	Applied Mathematics and Physics
specialization:	General and Applied Physics/Общая и прикладная физика
	Landau Phystech-School of Physics & Research
	Chair of Biophysics
term:	1
qualification:	Master

Semester, form of interim assessment: 1 (fall) - Exam

Academic hours: 30 AH in total, including:
lectures: 15 AH.
seminars: 15 AH.
laboratory practical: 0 AH.

Independent work: 30 AH.

Exam preparation: 30 AH.

In total: 90 AH, credits in total: 2

Number of course papers, tasks: 2

Author of the program: I.V. Manukhov, doctor of biological sciences

The program was discussed at the Chair of Biophysics 19.06.2023

Annotation

Genomics as a science originated in the 20th century. The focus of this discipline is the genome - the detailed blueprint by which all living things are built, and which provides a powerful tool for understanding and using them for the benefit of humanity. The main difficulty in establishing and understanding this plan is the problem of its enormous size. The 21st century has brought with it high-throughput sequencing techniques that enable the determination of nucleic acid sequences of great length and astonishing speed. Thus, the human genome can be “read” for as little as $ 1000. However, in order to fully take advantage of all the advantages of these methods, we need to understand in detail the rules for the organization and functioning of genomes (a kind of "operating system"), which remain far beyond the reach of both the human body and, in general, multicellular organisms, which have several levels organizations. At the other end of the difficulty scale are microbes: viruses, bacteria, and archaea. These seemingly simple organisms have a long evolutionary history that covers a significant part of the history of our planet, and, at the same time, they are the ancestors of most of the genetic diversity that is present on Earth today (including the human genome).

1. Study objective

Purpose of the course

The aim of the course is to familiarize students with modern methods and approaches to the analysis of genomes of microorganisms and the study of their biodiversity.

Tasks of the course

Provide an overview of the structure and function of genomes with an emphasis on prokaryotic microorganisms and the tools for their study (bioinformatics) required for processing large arrays of biological sequences. The course is divided into theoretical and practical (bioinformatics) lessons.

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 Use a systematic approach to critically analyze a problem,and develop an action plan	UC-1.1 Systematically analyze the problem situation, identify its components and the relations between them
	UC-1.2 Search for solutions by using available sources
	UC-1.3 Develop a step-by-step strategy for achieving a goal, foresee the result of each step, evaluate the overall impact on the planned activity and its participants
UC-4 Use modern communication tools in the academic and professional fields, including those in a foreign language	UC-4.1 Exchange business information in oral and written forms in Russian and at least one foreign language
	UC-4.2 Use the acquired skills to write, translate, and edit various academic texts (abstracts, essays, reviews, articles, etc.)
	UC-4.3 Present the results of academic and professional activities at various academic events, including international conferences
	UC-4.4 Use modern ICT tools for academic and professional collaboration
UC-6 Determine priorities and ways to improve performance through self-assessment	UC-6.1 Achieve personal growth and professional development, determine priorities and ways to improve performance
Gen.Pro.C-1 Gain fundamental scientific knowledge in the field of physical and mathematical sciences	Gen.Pro.C-1.1 Apply fundamental scientific knowledge in the field of physical and mathematical sciences
	Gen.Pro.C-1.2 Consolidate and critically assess professional experience and research findings
Gen.Pro.C-2 Acquire an understanding of current scientific and technological challenges	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
	Gen.Pro.C-2.2 Assess the relevance and practical importance of research in professional settings

in professional settings, and scientifically formulate professional objectives	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form within professional communication
Gen.Pro.C-3 Select and/or develop approaches to professional problem-solving with consideration to the limitations and specifics of different solution methods	Gen.Pro.C-3.1 Analyze problems, plan research strategy to achieve solution(s), propose, and combine solution approaches
	Gen.Pro.C-3.2 Employ research methods to solve new problems and apply knowledge from various fields of science (technology)
	Gen.Pro.C-3.3 Gain knowledge of analytical and computational methods of problem-solving, understand the limitations of the implementation of the obtained solutions in practice
Gen.Pro.C-4 Successfully perform a task, analyze the results, and present conclusions, apply knowledge and skills in the field of physical and mathematical sciences and ICTs	Gen.Pro.C-4.1 Apply ICT knowledge and skills to find and study scientific literature and use software products
	Gen.Pro.C-4.2 Apply knowledge in the field of physical and mathematical sciences to solve problems, make conclusions, and evaluate the obtained results
	Gen.Pro.C-4.3 Justify the chosen method of scientific research
Pro.C-1 Assign, formalize, and solve tasks, develop and research mathematical models of the studied phenomena and processes, systematically analyze scientific problems and obtain new scientific results	Pro.C-1.1 Locate, analyze, and summarize information on current research findings within the subject area
	Pro.C-1.2 Make hypotheses, build mathematical models of the studied phenomena and processes, evaluate the quality of the developed model
	Pro.C-1.3 Apply theoretical and/or experimental research methods to a specific scientific task and interpret the obtained results
Pro.C-3 Use research and testing equipment (devices and installations, specialized software) in a selected subject field	Pro.C-3.1 Understand the operating principles of the equipment and specialized software
	Pro.C-3.2 Conduct an experiment (simulation) using research equipment (software)
	Pro.C-3.3 Evaluate the accuracy of the experimental (numerical) results

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

As a result of studying the course the student should:

know:

the main rules and patterns that determine the structure of genomes and their relationship with the vital activity of microorganisms.

be able to:

1) Work with large arrays of biological sequences.
2) Use programs for identifying and annotating genes, assembling genomes and metagenomes, and analyzing raw sequences.
3) Highlight and systematize the main ideas in scientific texts;
4) Critically evaluate any incoming information, regardless of the source;
5) Generate new ideas and methodological solutions;
6) Carry out the design of their scientific activities;
7) Present your scientific results in oral reports.

master:

1) Methods of theoretical and experimental research;
2) Skills of search (including using information systems and databases), processing, analysis and systematization of information;
3) Skills of critical analysis and assessment of modern scientific achievements.

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	Introduction to Microbiology	2	2		4
2	Structure and Functioning of Bacterial Genomes	2	2		4
3	Comparative genomics	2	2		4
4	Phylogenetics and Evolution	2	2		4
5	Community sequencing: metagenomics	2	2		4
6	Transcriptomics and proteomics	2	2		4
7	Genomes of viruses and protists	3	3		6
AH in total		15	15		30
Exam preparation		30 AH.			
Total complexity		90 AH., credits in total 2			

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

Semester: 1 (Fall)

1. Introduction to Microbiology

A brief overview of the biology of bacteria and archaea, classification of microorganisms.

2. Structure and Functioning of Bacterial Genomes

General features of the organization of bacterial replicons, including types, topology, general properties and parameters, etc.

3. Comparative genomics

Intraspecific diversity of genomes: pangenome. Cow genome. Homology. Gene clusters. Annotation of genomes.

4. Phylogenetics and Evolution

Using sequences as molecular chronometers. Phylogeny concept. Synthetic theory of evolution. Population genetics and genomics. Vertical and horizontal inheritance.

5. Community sequencing: metagenomics

Methodological foundations of metagenomics. Basic principles of microbial ecology. Sequencing and assembly of metagenomes. Biological diversity of microbial communities.

6. Transcriptomics and proteomics

Genotype and phenotype of bacteria. Regulation mechanisms. Methodological foundations for studying gene expression in microorganisms and their communities.

7. Genomes of viruses and protists

Classification of viruses. Phage genomes as replicons. Viruses of animals and plants. Introduction to eukaryotic cell cytology. Classification of protists.

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

1. Classroom with a media projector and screen, Internet access.
2. Required software.
3. Providing independent work - databases on logs.

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

Main literature

1.Structure and Function of the Bacterial Genome, Charles J. Dorman. 2020 John Wiley & Sons, Inc.
2.Sequence, Evolution, Function, Koonin and Galperin, Kluwer Academic Publishers, 3003.

Additional literature

1.Computing for Comparative Genomics, Ussery. Springer 2008.

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)

When preparing and conducting lectures, the Internet is used.
In addition, Libre Office is used, as well as the Ink Scape graphics package.

9. Guidelines for students to master the course

A student studying the discipline must, on the one hand, master the 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 must know the basic definitions and concepts, be able to apply the knowledge gained to solve various problems.
Successful completion of the course requires:
- attendance of all classes provided for by the curriculum for the discipline;
- keeping a synopsis of classes;
- student's intense independent work.

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

An indicator of mastery of the material is the ability to answer questions on the topics of the discipline without a synopsis.
It is important to achieve an understanding of the material being studied, not its mechanical memorization. If a student finds it difficult to study certain topics, questions, he/she should seek advice from a teacher.
Intermediate control of students' knowledge is possible in the form of solving problems in accordance with the topic of classes.

SUPPLEMENT

Assessment funds for course (training module)

major:	Applied Mathematics and Physics
specialization:	General and Applied Physics/Общая и прикладная физика Landau Phystech-School of Physics & Research Chair of Biophysics
term:	1
qualification:	Master

Semester, form of interim assessment: 1 (fall) - Exam

Author: I.V. Manukhov, doctor of biological sciences

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
UC-1 Use a systematic approach to critically analyze a problem,and develop an action plan	UC-1.1 Systematically analyze the problem situation, identify its components and the relations between them
	UC-1.2 Search for solutions by using available sources
	UC-1.3 Develop a step-by-step strategy for achieving a goal, foresee the result of each step, evaluate the overall impact on the planned activity and its participants
UC-4 Use modern communication tools in the academic and professional fields, including those in a foreign language	UC-4.1 Exchange business information in oral and written forms in Russian and at least one foreign language
	UC-4.2 Use the acquired skills to write, translate, and edit various academic texts (abstracts, essays, reviews, articles, etc.)
	UC-4.3 Present the results of academic and professional activities at various academic events, including international conferences
	UC-4.4 Use modern ICT tools for academic and professional collaboration
UC-6 Determine priorities and ways to improve performance through self-assessment	UC-6.1 Achieve personal growth and professional development, determine priorities and ways to improve performance
Gen.Pro.C-1 Gain fundamental scientific knowledge in the field of physical and mathematical sciences	Gen.Pro.C-1.1 Apply fundamental scientific knowledge in the field of physical and mathematical sciences
	Gen.Pro.C-1.2 Consolidate and critically assess professional experience and research findings
Gen.Pro.C-2 Acquire an understanding of current scientific and technological challenges in professional settings, and scientifically formulate professional objectives	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
	Gen.Pro.C-2.2 Assess the relevance and practical importance of research in professional settings
	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form within professional communication
Gen.Pro.C-3 Select and/or develop approaches to professional problem-solving with consideration to the limitations and specifics of different solution methods	Gen.Pro.C-3.1 Analyze problems, plan research strategy to achieve solution(s), propose, and combine solution approaches
	Gen.Pro.C-3.2 Employ research methods to solve new problems and apply knowledge from various fields of science (technology)
	Gen.Pro.C-3.3 Gain knowledge of analytical and computational methods of problem-solving, understand the limitations of the implementation of the obtained solutions in practice
Gen.Pro.C-4 Successfully perform a task, analyze the results, and present conclusions, apply knowledge and skills in the field of physical and mathematical sciences and ICTs	Gen.Pro.C-4.1 Apply ICT knowledge and skills to find and study scientific literature and use software products
	Gen.Pro.C-4.2 Apply knowledge in the field of physical and mathematical sciences to solve problems, make conclusions, and evaluate the obtained results
	Gen.Pro.C-4.3 Justify the chosen method of scientific research
Pro.C-1 Assign, formalize, and solve tasks, develop and research mathematical models of the studied phenomena and processes, systematically analyze scientific problems and	Pro.C-1.1 Locate, analyze, and summarize information on current research findings within the subject area
	Pro.C-1.2 Make hypotheses, build mathematical models of the studied phenomena and processes, evaluate the quality of the developed model

systematically analyze scientific problems and obtain new scientific results	Pro.C-1.3 Apply theoretical and/or experimental research methods to a specific scientific task and interpret the obtained results
Pro.C-3 Use research and testing equipment (devices and installations, specialized software) in a selected subject field	Pro.C-3.1 Understand the operating principles of the equipment and specialized software
	Pro.C-3.2 Conduct an experiment (simulation) using research equipment (software)
	Pro.C-3.3 Evaluate the accuracy of the experimental (numerical) results

2. Competency assessment indicators

As a result of studying the course the student should:

know:

the main rules and patterns that determine the structure of genomes and their relationship with the vital activity of microorganisms.

be able to:

1) Work with large arrays of biological sequences.
2) Use programs for identifying and annotating genes, assembling genomes and metagenomes, and analyzing raw sequences.
3) Highlight and systematize the main ideas in scientific texts;
4) Critically evaluate any incoming information, regardless of the source;
5) Generate new ideas and methodological solutions;
6) Carry out the design of their scientific activities;
7) Present your scientific results in oral reports.

master:

1) Methods of theoretical and experimental research;
2) Skills of search (including using information systems and databases), processing, analysis and systematization of information;
3) Skills of critical analysis and assessment of modern scientific achievements.

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

Examples of topics of individual courseworks/reports:

1. Intraspecific diversity of genomes.
2. Phylogeny concept. Synthetic theory of evolution. Population genetics and genomics.
3. Methodological foundations of metagenomics.
4. Methodological foundations for studying gene expression in microorganisms and their communities.
5. Viruses of animals and plants.

4. Evaluation criteria

Checking questions:

1. List approaches to determine the origin of replication in a bacterial chromosome
2. Describe the different topologies of bacterial replicons
3. Define the pangenome and explain approaches to describe it
4. What degree of conservation of synteny would you expect when comparing two bacterial species of the same genus when referring to: complete genome, operons, location of tRNAs, location of IS elements
5. What algorithms can you use to do a phylogenetic tree of 16S rRNA? What is a phylogenomic tree? How do you define coverage?
6. Define and give examples of horizontal gene transfer
7. What is the use of fosmid libraries in modern metagenomics if any
8. Describe the steps to assemble a genome from a metagenome
9. Advantages and disadvantages of single amplified genomes

10. How can you determine of the transcription start site of a gene?

Examples of exam question papers:

Question paper 1.

1.What degree of conservation of synteny would you expect when comparing two bacterial species of the same genus when referring to: complete genome, operons, location of tRNAs, location of IS elements

2. Describe the steps to assemble a genome from a metagenome

Question paper 2.

1. Define and give examples of horizontal gene transfer

2. Define the pangenome and explain approaches to describe it

Question paper 3.

1. Describe the different topologies of bacterial replicons

2. Advantages and disadvantages of single amplified genomes

Assessment “excellent (10)” is given to a student who has displayed comprehensive, systematic and deep knowledge of the educational program material, has independently performed all the tasks stipulated by the program, has deeply studied the basic and additional literature recommended by the program, has been actively working in the classroom, and understands the basic scientific concepts on studied discipline, who showed creativity and scientific approach in understanding and presenting educational program material, whose answer is characterized by using rich and adequate terms, and by the consistent and logical presentation of the material;

Assessment “excellent (9)” is given to a student who has displayed comprehensive, systematic knowledge of the educational program material, has independently performed all the tasks provided by the program, has deeply mastered the basic literature and is familiar with the additional literature recommended by the program, has been actively working in the classroom, has shown the systematic nature of knowledge on discipline sufficient for further study, as well as the ability to amplify it on one’s own, whose answer is distinguished by the accuracy of the terms used, and the presentation of the material in it is consistent and logical;

Assessment “excellent (8)” is given to a student who has displayed complete knowledge of the educational program material, does not allow significant inaccuracies in his answer, has independently performed all the tasks stipulated by the program, studied the basic literature recommended by the program, worked actively in the classroom, showed systematic character of his knowledge of the discipline, which is sufficient for further study, as well as the ability to amplify it on his own;

Assessment “good (7)” is given to a student who has displayed a sufficiently complete knowledge of the educational program material, does not allow significant inaccuracies in the answer, has independently performed all the tasks provided by the program, studied the basic literature recommended by the program, worked actively in the classroom, showed systematic character of his knowledge of the discipline, which is sufficient for further study, as well as the ability to amplify it on his own;

Assessment “good (6)” is given to a student who has displayed a sufficiently complete knowledge of the educational program material, does not allow significant inaccuracies in his answer, has independently carried out the main tasks stipulated by the program, studied the basic literature recommended by the program, showed systematic character of his knowledge of the discipline, which is sufficient for further study;

Assessment “good (5)” is given to a student who has displayed knowledge of the basic educational program material in the amount necessary for further study and future work in the profession, who while not being sufficiently active in the classroom, has nevertheless independently carried out the main tasks stipulated by the program, mastered the basic literature recommended by the program, made some errors in their implementation and in his answer during the test, but has the necessary knowledge for correcting these errors by himself;

Assessment “satisfactory (4)” is given to a student who has discovered knowledge of the basic educational program material in the amount necessary for further study and future work in the profession, who while not being sufficiently active in the classroom, has nevertheless independently carried out the main tasks stipulated by the program, learned the main literature but allowed some errors in their implementation and in his answer during the test, but has the necessary knowledge for correcting these errors under the guidance of a teacher;

Assessment “satisfactory (3)” is given to a student who has displayed knowledge of the basic educational program material in the amount necessary for further study and future work in the profession, not showed activity in the classroom, independently fulfilled the main tasks envisaged by the program, but allowed errors in their implementation and in the answer during the test, but possessing necessary knowledge for elimination under the guidance of the teacher of the most essential errors;

Assessment “unsatisfactory (2)” is given to a student who showed gaps in knowledge or lack of knowledge on a significant part of the basic educational program material, who has not performed independently the main tasks demanded by the program, made fundamental errors in the fulfillment of the tasks stipulated by the program, who is not able to continue his studies or start professional activities without additional training in the discipline in question;

Assessment “unsatisfactory (1)” is given to a student when there is no answer (refusal to answer), or when the submitted answer does not correspond at all to the essence of the questions contained in the task.

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

The course is graded at a credit. The questioning starts with a random task assigned to each student and time given for completion of the task. No aids are allowed. The student then proceeds to a chat with the examiner, at which he/she presents his/her solution to the assigned task. The examiner then asks the student several questions that evenly cover the course content. A final grade is assigned based on the quality of answers and demonstrated level of understanding.