**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:** | Virology/Вирусология |
| **major:** | Biotechnology |
| **specialization:** | Biomedical Engineering/Биомедицинская инженерия |
| | Phystech School of Biological and Medical Physics |
| | Center for educational programs in bioinformatics |
| **term:** | 4 |
| **qualification:** | Bachelor |

Semester, form of interim assessment: 8 (spring) - Grading test

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

Independent work: 15 AH.

In total: 45 AH, credits in total: 1

Authors of the program:

A.S. Dukh, senior professor
A.S. Kuznetsov, teacher

The program was discussed at the Center for educational programs in bioinformatics 10.07.2023

**Annotation**

The student after mastering the course will understand the principles of viral genome replication, have knowledge of the formation of the host spectrum for various viruses, the mechanisms underlying the various strategies and cycles of viral reproduction, as well as the practically important areas in which viruses, viral genes and / or their products are used.

**1. Study objective**

**Purpose of the course**

Learning about the structure and functions of viruses.

**Tasks of the course**

1) Study of the diversity of viruses and their replication cycles.

2) The study of all stages of viral infection on the example of bacteriophages.

3) Gaining knowledge about the use of viruses in the molecular biological (genetic vectors) and medical (vaccines, oncolytic viruses) fields.

**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-2 Use modern IT and software tools to perform professional tasks in compliance with information security requirements | Gen.Pro.C-2.1 Apply modern computing tools and Internet services in professional settings |
| | Gen.Pro.C-2.2 Apply numerical mathematical methods and use software applications for scientific problem-solving in professional settings |
| | Gen.Pro.C-2.3 Fulfill basic information security requirements |
| Pro.C-2 Analyze research data and make scientific conclusions | Pro.C-2.1 Adopt methods of statistical process and scientific data analysis |
| | 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 |
| Pro.C-3 Select the necessary devices, tools, and research methods for problem-solving in a | Pro.C-3.1 Apply functional principles and operating ranges of scientific equipment |
| | Pro.C-3.2 Apply theory to evaluate the accuracy of analytical calculations |

| | |
|---|---|
| research methods for problem-solving in a selected subject area | Pro.C-3.3 Estimate the accuracy of numerical methods used on a computer, learn the computational complexity of the applied algorithms and the number of required computing resources |

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

As a result of studying the course the student should:

know:

1) Stages of virus reproduction cycles, their biological, ecological and evolutionary significance.
2) Molecular principles of replication and transcription of viral nucleic acids.
3) The main groups of viruses and the features of the corresponding virus systems.
4) Technologies for the preparation of various types of antiviral vaccines.
5) Approaches to the use of oncolytic viruses in anticancer therapy.

be able to:

1) Think in the context of virology problems.
2) Within the framework of the modern concept of the virus, clearly answer questions and formulate your thoughts.
3) Substantiate the practical significance of virological research.

master:

1) Knowledge about the diversity and classification of viruses, their reproduction cycles, principles of adsorption on the surface of a target cell, methods of virus penetration into a cell, features of viral genome replication, areas of application of viruses in synthetic biology and medicine.

**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 Virology | | 3 | | 2 |
| 2 | Variety and classification of viruses | | 3 | | 2 |
| 3 | Bacteriophages | | 3 | | |
| 4 | Viral genome | | 3 | | |
| 5 | Morphogenesis of viral particles | | 3 | | 2 |
| 6 | The release of the virus from the cell | | 3 | | |
| 7 | Viral ecology | | 3 | | 2 |
| 8 | Plant viruses | | 3 | | 2 |
| 9 | Viruses of humans and animals. Vaccines | | 2 | | |
| 10 | Viruses as tools of genetic engineering | | 2 | | 2 |
| 11 | Oncolytic viruses | | 2 | | 3 |
| AH in total | | | 30 | | 15 |
| Exam preparation | | 0 AH. | | | |
| Total complexity | | 45 AH., credits in total 1 | | | |

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

Semester: 8 (Spring)

1. Introduction to Virology

A virus is a transmissible genetic program. Principles of virus reproduction. The term "living objects". Stages of the viral reproduction cycle: adsorption, penetration, genome replication, synthesis of viral proteins, self-assembly and maturation of virions, release of viral progeny from the cell. A brief historical account of the formation and development of virology. Variety of viruses.

2. Variety and classification of viruses

Classification of viruses. Classification of viruses according to Baltimore. I, II, III, IV, V, VI, VII groups. Types of viral genomic nucleic acid. dsDNA and ssDNA viruses. Features of the reproduction cycle of dsRNA viruses. ss(+)- and ss(-)-RNA viruses. Features of replication of retro- and pararetroviruses. Origin and evolution of viruses. Classification of ICTV viruses. Realms Adnaviria, Duplodnaviria, Varidnaviria, Monodnaviria, Riboviria, Ribozyviria. Using data on the fold of major viral proteins to determine the degree of relatedness of viruses. eukaryotic and prokaryotic viruses. Plant viruses: features of reproduction, spectrum of hosts, transport through the host organism. Animal viruses: features of reproduction, spectrum of hosts, transport through the host organism. Viruses of the protista. Giant acanthamoeba viruses. Pandoravirus.

3. Bacteriophages

Prokaryotic viruses: bacterial viruses and archaeal viruses. Bacterial viruses are bacteriophages (phages). Phages are the most common living objects. History of discovery and study of bacteriophages. Prerequisites for the discovery of bacteriophages. Works by Twort, d'Herelle, the Borde and Brunogh groups. Research of Wollmans and Lwoff. Discoveries of the Lederberg and Delbrück groups. Cycles of reproduction of bacteriophages: lytic (+ “chronic infection” of filamentous phages), lysogenic, “pseudo-lysogenic”. Lytic and lysogenic cycle in tailed phages. Stages of the lytic cycle of a tailed bacteriophage. Stages of the lysogenic cycle: prophage integration into the chromosome, lysogenic cultures, lysogen induction. Principles of adsorption of viral particles. Adhesin-receptor interaction. Methods of adsorption of different viruses. adsorption of bacteriophages. Adsorption of Gram-negative bacteria viruses. Mechanisms for contraction of myovirus tails. Delivery of the phage genome into the cell of gram-negative bacteria - the formation of a transperiplasmic channel and transport of viral DNA into the cell.

4. Viral genome

Features of the organization of the phage genome on the example of tailed bacteriophages. Expression of viral genomes. Switching of expression phases of the phage genome: early, middle and late genes. RNA polymerases used by phages: cellular, modified cellular, cellular with phage σ-factor, phage, virion. Expression control strategy using proteins - transcription regulators. Making a "lysogenic decision" in temperate phages using the λ phage as an example. Strategies using different sigma factors. Strategies using virus-encoded RNAP. Replication: the problem of the 3' ends of a linear replicon. Phage DNA packaging strategies. Practical application of enzymes of nucleic acid metabolism of phage origin

5. Morphogenesis of viral particles

Morphology of viral capsids. Spiral symmetry of capsids. Icosahedral symmetry of capsids. Theory of quasi-equivalent interactions, triangulation number. The structure of the tail processes of podoviruses, siphoviruses and myoviruses. Mechanisms for contraction of myovirus tails. Principles of morphogenesis control. Scheme of tailed bacteriophage assembly: capsid assembly, various scaffold variants, protein processing, capsid expansion, decorating proteins. Phage DNA packaging: terminases, packaging strategies and mechanisms. Morphogenesis of the tail processes. Tape measure proteins that limit the length of the tail tube.

6. The release of the virus from the cell

Ways of releasing virions from an infected cell in different viruses. Budding from the outer membrane associated with maturation of the virion (for example, alphaviruses, retroviruses). Release of viruses from vesicles (for example, herpesviruses). "Extrusion" (inoviruses). Lysis of the host cell (phages with an icosahedral capsid). Phagolysis of a bacterial cell. Evolutionary and ecological principles determining the timing of phage lysis. Mechanisms of cell lysis involving one phage protein: lysis protein E (phage ϕX174), lysis protein A2 (phage Qβ). Mechanisms of cell lysis involving several components: endolysins (classical and SAR lysines), cholines (canonical or pincholines), "lysis timer" - anticholines, spanins

7. Viral ecology

The prevalence of viruses in nature. Virosphere. The role of viruses in ecological processes. Giant acanthamoeba viruses. Phages are the most widespread and numerous group of viruses. Phage host spectrum and its ecological role. Mechanisms of adsorption stability of a bacterial cell. Lysogeny as an ecological factor. Integration of temperate phages into the bacterial genome. Defective prophages. lysogenic conversion. Examples, significance for pathogenic microorganisms. Lytic conversion by temperate phages (Stx producing enteropathogenic E. coli). The prevalence of phages in nature. Global function of phage infection on the example of the ecology of aquatic systems. Marine bacteriophages, their impact on the ecosystem. Methods for measuring phage production and the contribution of phage infection to cell death in aquatic systems. Significance of phage infection for the functioning of the microbial loop. Mechanisms of coexistence of phages and bacteria in nature. Shelter concept. The “Kill the winner” principle and underlying mechanisms. The role of phages in maintaining microbial diversity in natural ecosystems. Phages in symbiotic microbial ecosystems. Viromes of the body of animals and humans.

8. Plant viruses

Characteristics of plant viruses, main groups. Types of nucleic acids used by plant viruses. Transmission of viruses from plant to plant and transport of the virus through the infected plant. Examples of plant viruses and related diseases, their economic importance. Viroids, their features of replication.

9. Viruses of humans and animals. Vaccines

Mammalian viruses, types of nucleic acids, features of reproduction cycles. Herpesviruses and adenoviruses causing diseases. Parvoviruses, "The Fifth Disease". Reoviruses, rotavirus infections. Orthomyxoviruses, influenza. Rabdoviruses, vesicular stomatitis and rabies. Filoviruses, Ebola virus. Coronaviruses, COVID-19. Arboviruses: tick-borne encephalitis virus, yellow fever virus, dengue virus, etc. Bunyaviruses, Rift Valley fever. Arenaviruses, Lassa fever. Vaccines. The main types of vaccines and methods for their production. Vaccines based on inactivated virus. Live attenuated vaccines. subunit vaccines. RNA vaccines. Viral vector based vaccines.

10. Viruses as tools of genetic engineering

Use of bacteriophages for selection of mutants. Phage display. lysogenic conversion. Recombination using bacteriophages. Phage transduction. Lentiviral vectors as a tool for editing the eukaryotic genome.

11. Oncolytic viruses

History of the study of oncolytic viruses. Principles of viral oncolysis. Extracellular and intracellular "selectivity" of oncolytic viruses. Oncolytic action of rabodoviruses and parvoviruses. Application as oncolytic agents of adenoviruses, paramyxoviruses, reoviruses, herpesviruses. Problems of modern viral therapy of cancer.

**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 equipment (projector, sound system).

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

Main literature

Основная литература (книги предоставляются базовой кафедрой):

1. Карпова О. В., Градова Н. Б. Основы вирусологии для биотехнологов. – 2012.
2. Летаров А. В. Современные концепции биологии бактериофагов //М.: ТД ДеЛи. – 2019.
3. Соловьев А.Г. Структура икосаэдрических вирусов. - 2021

Additional literature

Предоставляется базовой кафедрой

1. Аграновский А.А. Репликация вирусных РНК. - 2019.
2. Каттер Э., Сулаквелидзе А. (ред). Бактериофаги. Биология и практическое применение - 2012
3. Заридзе Д.Г. Канцерогенез. - 2004
4. Зверева В.В. Бойченко М.Н. Медицинская микробиология, вирусология и иммунология. - 2016

**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)**

Internet access. For some of the lessons, you 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<br>Phystech School of Biological and Medical Physics<br>Center for educational programs in bioinformatics |
| **term:** | 4 |
| **qualification:** | Bachelor |

Semester, form of interim assessment: 8 (spring) - Grading test

**Authors:**

A.S. Dukh, senior professor
A.S. Kuznetsov, teacher

**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 |
| | 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-2 Use modern IT and software tools to perform professional tasks in compliance with information security requirements | Gen.Pro.C-2.1 Apply modern computing tools and Internet services in professional settings |
| | Gen.Pro.C-2.2 Apply numerical mathematical methods and use software applications for scientific problem-solving in professional settings |
| | Gen.Pro.C-2.3 Fulfill basic information security requirements |
| Pro.C-2 Analyze research data and make scientific conclusions | Pro.C-2.1 Adopt methods of statistical process and scientific data analysis |
| | 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 |
| Pro.C-3 Select the necessary devices, tools, and research methods for problem-solving in a selected subject area | Pro.C-3.1 Apply functional principles and operating ranges of scientific equipment |
| | Pro.C-3.2 Apply theory to evaluate the accuracy of analytical calculations |
| | Pro.C-3.3 Estimate the accuracy of numerical methods used on a computer, learn the computational complexity of the applied algorithms and the number of required computing resources |

**2. Competency assessment indicators**

As a result of studying the course the student should:

**know:**

1) Stages of virus reproduction cycles, their biological, ecological and evolutionary significance.
2) Molecular principles of replication and transcription of viral nucleic acids.
3) The main groups of viruses and the features of the corresponding virus systems.
4) Technologies for the preparation of various types of antiviral vaccines.
5) Approaches to the use of oncolytic viruses in anticancer therapy.

**be able to:**

1) Think in the context of virology problems.
2) Within the framework of the modern concept of the virus, clearly answer questions and formulate your thoughts.
3) Substantiate the practical significance of virological research.

**master:**

1) Knowledge about the diversity and classification of viruses, their reproduction cycles, principles of adsorption on the surface of a target cell, methods of virus penetration into a cell, features of viral genome replication, areas of application of viruses in synthetic biology and medicine.

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

1. Classification of ICTV viruses.
2. Prerequisites for the discovery of bacteriophages.
3. Adhesin-receptor interaction. Methods of adsorption of different viruses.
4. Expression of viral genomes. Switching of expression phases of the phage genome.
5. Spiral symmetry of capsids. Icosahedral symmetry of capsids.
6. Mechanisms for contraction of myovirus tails.
7. Principles of morphogenesis control.
8. Scheme of the assembly of tailed bacteriophages.
9. Evolutionary and ecological principles determining the timing of phage lysis.
10. Global function of phage infection on the example of the ecology of aquatic systems.

**4. Evaluation criteria**

1. A virus is a transmissible genetic program. Principles of virus reproduction. The term "living objects". stages of the viral reproduction cycle.
2. Classification of viruses. Classification of viruses according to Baltimore. I, II, III, IV, V, VI, VII groups. Types of viral genomic nucleic acid.
3. dsDNA and ssDNA viruses. Features of the reproduction cycle of dsRNA viruses.
4. ss(+)- and ss(-)-RNA viruses. Features of replication of retro- and pararetroviruses.
5. Origin and evolution of viruses. Classification of ICTV viruses. Realms Adnaviria, Duplodnaviria, Varidnaviria, Monodnaviria, Riboviria, Ribozyviria. eukaryotic and prokaryotic viruses.
6. Plant viruses: features of reproduction, spectrum of hosts, transport through the host organism.
7. Animal viruses: features of reproduction, spectrum of hosts, transport through the host organism. Viruses of the simplest. Giant acanthamoeba viruses.
8. History of discovery and study of bacteriophages. Prerequisites for the discovery of bacteriophages. Works by Twort, d'Herelle, the Borde and Brunogh groups. Research of Wollmans and Lwoff. Discoveries of the Lederberg and Delbrück groups.
9. Cycles of reproduction of bacteriophages: lytic (+ “chronic infection” of filamentous phages), lysogenic, “pseudo-lysogenic”. Lytic and lysogenic cycle in tailed phages. Stages of the lytic cycle of a tailed bacteriophage. Stages of the lysogenic cycle: prophage integration into the chromosome, lysogenic cultures, lysogen induction.
10. Principles of adsorption of viral particles. Adhesin-receptor interaction. Methods of adsorption of different viruses. adsorption of bacteriophages. Adsorption of Gram-negative bacteria viruses. Mechanisms for contraction of myovirus tails. Delivery of the phage genome into the cell of gram-negative bacteria.
11. Organization of the viral genome. Features of the organization of the phage genome on the example of tailed bacteriophages. Expression of viral genomes. Switching of expression phases of the phage genome.
12. RNA polymerases used by phages: cellular, modified cellular, cellular with phage σ-factor, phage, virion. Expression control strategy using proteins - transcription regulators. Making a "lysogenic decision" in temperate phages using the λ phage as an example.
13. Strategies for controlling the expression of phage genes using different sigma factors. Strategies using virus-encoded RNAP.
14. Replication of phage DNA genomes: the problem of the 3' ends of the linear replicon. Phage DNA packaging strategies.
15. Morphology of viral capsids. Spiral symmetry of capsids. Icosahedral symmetry of capsids. Theory of quasi-equivalent interactions, triangulation number.

16. Arrangement of tail processes of podoviruses, siphoviruses and myoviruses. Mechanisms for contraction of myovirus tails. Principles of morphogenesis control. Scheme of the assembly of tailed bacteriophages. Phage DNA packaging: terminases, packaging strategies and mechanisms. Morphogenesis of the tail processes. Proteins are "rulers" that limit the length of the tail tube.

17. Methods for releasing virions from an infected cell in different viruses. Budding from the outer membrane associated with the maturation of the virion. Release of viruses from vesicles. "Extrusion". Lysis of the host cell.

18. Phagolysis of a bacterial cell. Evolutionary and ecological principles determining the timing of phage lysis. Mechanisms of cell lysis involving one phage protein. Mechanisms of bacterial cell lysis involving several components.

19. The prevalence of viruses in nature. Virosphere. The role of viruses in ecological processes. Giant acanthamoeba viruses. Phages are the most widespread and numerous group of viruses. Phage host spectrum and its ecological role. Mechanisms of adsorption stability of a bacterial cell.

20. Lysogeny as an ecological factor. Integration of temperate phages into the bacterial genome. lysogenic conversion. Examples, significance for pathogenic microorganisms. Lytic conversion by temperate phages.

21. The prevalence of phages in nature. Global function of phage infection on the example of the ecology of aquatic systems. Marine bacteriophages, their impact on the ecosystem. Methods for measuring phage production and the contribution of phage infection to cell death in aquatic systems. Significance of phage infection for the functioning of the microbial loop.

22. Mechanisms of coexistence of phages and bacteria in nature. Shelter concept. The “Kill the winner” principle and underlying mechanisms. The role of phages in maintaining microbial diversity in natural ecosystems. Phages in symbiotic microbial ecosystems. Viromes of the body of animals and humans.

23. Herpesviruses and adenoviruses causing diseases. Parvoviruses, "The Fifth Disease". Reoviruses, rotavirus infections. Orthomyxoviruses, influenza. Rabdoviruses, vesicular stomatitis and rabies. Filoviruses, Ebola virus. Coronaviruses, COVID-19. Arboviruses: tick-borne encephalitis virus, yellow fever virus, dengue virus, etc. Bunyaviruses, Rift Valley fever. Arenaviruses, Lassa fever.

24. Vaccines. The main types of vaccines and methods for their production. Vaccines based on inactivated virus. Live attenuated vaccines. subunit vaccines. RNA vaccines. Vaccines based on viral vector.

25. Use of bacteriophages for selection of mutants. Phage display. lysogenic conversion. Recombination using bacteriophages. Phage transduction. Lentiviral vectors as a tool for editing the eukaryotic genome.

26. Principles of viral oncolysis. Extracellular and intracellular "selectivity" of oncolytic viruses. Oncolytic action of rabodoviruses and parvoviruses. Application as oncolytic agents of adenoviruses, paramyxoviruses, reoviruses, herpesviruses. Problems of modern viral therapy of cancer.

Ticket 1:

1. RNA polymerases used by phages: cellular, modified cellular, cellular with phage σ-factor, phage, virion. Expression control strategy using proteins - transcription regulators. Making a "lysogenic decision" in temperate phages using the λ phage as an example.

2. Vaccines. The main types of vaccines and methods for their production. Vaccines based on inactivated virus. Live attenuated vaccines. subunit vaccines. RNA vaccines. Vaccines based on viral vector.

Ticket 2:

1. Lysogeny as an ecological factor. Integration of temperate phages into the bacterial genome. lysogenic conversion. Examples, significance for pathogenic microorganisms. Lytic conversion by temperate phages.

2. Principles of viral oncolysis. Extracellular and intracellular "selectivity" of oncolytic viruses. Oncolytic action of rabodoviruses and parvoviruses. Application as oncolytic agents of adenoviruses, paramyxoviruses, reoviruses, herpesviruses. Problems of modern viral therapy of cancer.

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.

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

The student is given 60 minutes to prepare. Interview with a student on a differential oral test should not exceed one astronomical hour.