

<b>Name of the entrance exam</b>
Molecular and cellular biomedical technologies
<b>Field/fields of study</b>
12.04.04 Biotechnical systems and technologies
<b>Educational program/programs</b>
12.04.04 _01 Molecular and cellular biomedical technologies (international educational program)
<b>Abstract</b>
<p>The program contains a list of topics (questions) from the disciplines of the basic part of the professional cycle of the bachelor's degree curriculum in the field of study 12.03.04 "Biotechnical Systems and Technologies," which are included in the content of the test tasks for the entrance examinations to the master's program.</p> <p>The entrance examination is assessed on a 100-point scale and consists of an interdisciplinary exam based on the requirements set by state educational standards of higher education for the level of bachelor's training in the field corresponding to the master's program. The exam is conducted in person in written form or remotely (maximum score – 100). The minimum score confirming successful completion is established by the Admission Rules approved for the current academic year.</p> <p>The duration of the examination is 60 minutes.</p> <p>The entrance examination is conducted using remote technologies. The entrance examination is a test with single or multiple-choice answers. During the entrance examination, the use of writing materials and scratch paper is permitted.</p>
<b>Disciplines included in the program of entrance examinations for the Master's degree program</b>
<ol style="list-style-type: none"> <li>1. Physics</li> <li>2. Research experimental methods in biology</li> <li>3. Molecular biology and genetics</li> </ol>
<b>Content of academic disciplines</b>
<ol style="list-style-type: none"> <li>1. Physics <ol style="list-style-type: none"> <li>1. Physical foundations of mechanics Speed and acceleration of a material object. The law of conservation of momentum energy in mechanics. The law of conservation of angular momentum. Driving in the center field.</li> <li>2. Molecular physics, thermodynamics Variables of thermodynamics. Equations of state of ideal and real gases. Entropy. The beginnings of thermodynamics. Thermodynamic potentials. Free energy. Chemical potential, equilibrium constants. Activation barrier, Eyring-Arrhenius equation. Diffusion equation.</li> <li>3. Oscillations and waves Wave processes. Basic laws. Elastic wave equation. Wave equations. One-dimensional and multidimensional wave equation. The speed of propagation of an elastic wave. Doppler effect. Propagation of damped vibrations. Wave energy flow. Intensity concept. Harmonic (mechanical) and damped oscillations. Forced (mechanical) vibrations, resonance. Polarization by reflection and refraction of light. Spontaneous and stimulated emission. Planck's formula (radiation density under the condition of thermodynamic equilibrium).</li> <li>4. Electricity and magnetism Electric and magnetic fields. Electric and magnetic field of the system of charges. The movement of a charge in an electromagnetic field. The energy of the electromagnetic field. Stationary electric current, Ohm's and Joule-Lenz's laws. Electromagnetic waves in vacuum and matter, dispersion law. Polarization of an electromagnetic wave, polarization during reflection and refraction of light.</li> <li>5. Hydrodynamics Viscosity. Viscous fluid motion, velocity field. Newtonian fluids. Stationary motion of a viscous fluid between 2 parallel planes: moving relative to each other at a constant speed, in the presence of a longitudinal pressure gradient. Stationary motion of a viscous fluid in a pipe in the presence of a longitudinal pressure gradient of constant diameter with an annular constant cross-section. Stationary movement of a viscous fluid: between 2 coaxial cylinders with constant radii (the inner cylinder moves at a constant speed along the generatrix); with a constant thickness of the free surface above an inclined plane, forming a constant angle with the horizontal surface in the gravity field.</li> <li>6. Quantum mechanics and molecular spectroscopy Quantum-mechanical description of systems. Wave function. Hamilton operator. Schrödinger equation. The Heisenberg uncertainty relation. Quantum properties of electromagnetic radiation, photons. Spontaneous and stimulated emission. Equilibrium radiation, Planck's formula. Absorption. Bouguer-Lambert-Beer law. Amplification of light in a medium, inverse media, lasers. Harmonic and anharmonic oscillator model for molecular</li> </ol> </li> </ol>

vibrations. The spectrum of a polyatomic molecule (electronic, vibrational, rotational). Ranges of electromagnetic radiation.

## 2. Research experimental methods in biology

### 1. Solutions

Solutions, their quantitative characteristics: concentration, ionic strength, pH, colligative properties. Hydrophobic and hydrophilic. Acid-base equilibrium, pKa, buffer solutions. Osmosis.

### 2. Electrophoretic methods

The phenomenon of electrophoresis. Gel electrophoresis. Methods for the electrophoretic separation of proteins and nucleic acids. Isofocusing proteins.

### 3. Chromatography

Chromatography: the principle of separation of substances. Types of chromatography. Chromatograph. The most important chromatographic methods of analysis and isolation of biomolecules.

### 4. Sedimentation

Svedberg equation, sedimentation coefficient. Ultracentrifuge. Differential, zonal-speed and equilibrium centrifugation of cellular components.

### 5. Isolation of cellular components

Strategy for isolation of cellular components, goals and objectives. Classes of biomolecules, their physical and chemical properties. Detergents. Protein precipitation methods. Purification of proteins and nucleic acids

### 6. Spectral analysis methods

General scheme of the spectral experiment. Spectral bands and spectral lines. Ranges of electromagnetic radiation. Relationship of spectral properties of various ranges with the characteristics of biological objects.

### 7. Optical spectroscopy of solutions

Absorption spectrum, optical density, Beer's law. Chromophores. Spectrophotometer. Spectrophotometric determination of the concentration of biomolecules. Optical activity.

### 8. Fluorescence

The phenomenon of photoluminescence. Quantitative characteristics and their measurement. Quantum model of fluorescence. Fluorescence of biomolecules. Fluorescent labels and probes. FRET. Fluorescence microscopy.

### 9. Methods for studying enzymatic activity

Catalysis. Enzymes. Michaelis-Menten equation. Experimental determination of parameters. Inhibition of enzymatic reactions.

### 10. Immunological methods

Antibodies and antigens, structure of IgG molecules, specificity of antibodies. Obtaining and using antibodies in practical molecular biology. Immunoblotting.

### 11. Measurements and statistical analysis

Uncertainty in the measurement of physical and chemical quantities. Random variables, properties. Parameters. The most important distributions (normal, chi-square, Poisson). Samples. Point and interval estimation of parameters. Statistical tests.

## 3. Molecular biology and genetics

### 1. Molecular basis of heredity

The theory of heredity. The laws of inheritance are their molecular basis. The main structural elements of DNA and RNA. Primary structure of nucleic acids. Watson-Crick model, DNA forms, DNA topoisomers. Supercoiling and its meaning.

### 2. Organization of genes and genomes

Gene and genome concepts. Genes in populations. Gene expression. Features of the structure and expression of genes of prokaryotes and eukaryotes. Model objects of molecular genetics.

### 3. Horizontal transfer of genetic information

Plasmids and bacteriophages. Sex and conjugation in bacteria. The stages of the conjugation process.

Transformation. Molecular mechanisms of transduction. Transducing phages. Mapping of bacterial chromosomes using conjugation, transduction and transformation. Genetic map of E. coli. Mobile genetic elements. Horizontal gene transfer in eukaryotes.

### 4. Transcription

Generalized structure of the prokaryotic gene. Transcription stages, RNA polymerase, its structure and functions. Initiation of transcription, promoter, mechanisms of recognition of the promoter by RNA polymerase. Termination and antitermination of transcription. Eukaryotic mRNA processing.

### 5. Translation, genetic code

Ribosomes, composition and function. Initiation of translation in prokaryotes. tRNA and rRNA encoding their genes. Genetic code. Start and stop codons, reading frames, open and closed frames. Aminoacylation of tRNA, accuracy and energy consumption in protein synthesis.

### 6. Replication

DNA replication mechanism, matrix synthesis. Replicon concept, replication fork. Replication mechanisms of prokaryotic chromosomes, plasmids. Enzymes involved in replication. Replication accuracy. The problem of underreplication of linear DNA.

## 7. Mutagenesis and repair

Mutations, classification of mutations. Spontaneous and induced mutagenesis. Mechanisms of action of mutagens (UV, radiation, base analogs, alkylating agents). The repair system, its branches (direct, excisional, post-replicative; correction of unpaired bases). SOS answer.

## 8. Regulation of gene expression

Gene expression levels. The classical scheme of the operon according to Jacob and Monod. Induction and repression of enzyme synthesis (lactose operon). Repressors and activators. Catabolic repression.

## 9. Recombination

The phenomenon of genetic recombination, its types. Molecular mechanism of recombination. General (homologous) recombination. Heteroduplexes. Holliday junction. Gene conversion. Site-specific recombination. The role of recombination in evolution.

## 10. Recombinant DNA method

Genetic vectors. Genetic engineering enzymes. Molecular cloning. Polymerase chain reaction, real-time PCR. DNA sequencing. Vectors for cloning. Production of recombinant proteins.

## 11. Organization and functioning of the core

Chromosomes. Cell division. Cell cycle. Periods of the cell cycle. Replication patterns. Mitosis. Meiosis as the basis of the sexual process.

### Literature:

1. Zhdanov, L.S. Physics for the technician / Zhdanov L.S. ; Transl. from the Rus. by M. Samokhvalov Moskva : Mir, 1980 640 p. : il.
2. Freeman, Ira M. Physics / I. M. Freeman London : , [1972] 272 p.()
3. MBN Explorer: dynamics biomolecular systems and self-organization : version 1.2 (June 1, 2015) : [tutorial] / Ilia A. Solov'yov [et al.] ; MBN Research Center St. Petersburg : Polytechnic University, 2015 106 p. : ill. ; 21 cm (MBN Explorer tutorials ; vol. 2) ISBN 978-5-7422-4894-1
4. Alberts B. et al. Molecular Biology of the Cell. 2nd ed. Vol. 1-3. Moscow: Mir, 2015.
5. Cells. Edited by B. Lewin et al. Moscow: Binom Publishing House, 2017.
6. Koryakov D.E., Zhimulev I.F. Chromosomes. Structure and Functions. Novosibirsk: Siberian Branch of Russian Academy of Sciences Publishing House, 2009.
7. Faller J.M., Shields D. Molecular Cell Biology. Moscow: Binom Publishing House, 2003.
8. Chentsov Yu.S. General Cell Biology. Moscow: Akademkniga ICC, 2004.

### Entrance exam assessment criteria

The entrance examination consists of a set of closed-ended (multiple-choice) test questions, in which the applicant must select one or more correct answers from the options provided.

The total number of questions in the test is 24. Each question carries a weighted score.

The total sum of points is 100 points.

### Assigned group

Chair of the Subject Examination Board:

HS BS&T O.L. Vlasova

Compiled by:

Prof. HS BS&T Y.N. Orlov

Prof. HS BS&T A.N. Skvorzov

Senior Lecturer HS BS&T A.V. Brodskaya

Senior Lecturer HS BS&T A.V. Bolshakova