Ministry of Science and Higher Education of the Russian Federation
"Peter the Great St. Petersburg Polytechnic University"

INSTITUTE OF BIOMEDICAL SYSTEMS AND BIOTECHNOLOGIES

APPROVED

IBSiB Director

_____ Vasin A.V.

«20» 09 2024 г.

Program

entrance test for applicants to the master's degree program

12.04.04 "Biotechnical systems and technologies"
12.04.04 _01 Molecular and cellular biomedical technologies
(international educational program)"

Code and name of the field of study / educational program

St. Petersburg
2024

ANNOTATION

The program contains a list of topics (questions) based on the professional discipline cycle for training bachelors in the fields of biomedical systems and molecular biology.

The program was composed and approved for entrance test for the 12.**04.04 "Biotechnical systems and technologies"**, in particular the international educational program **12.04.04 _01 Molecular and cellular biomedical technologies** ".

The entrance examination is conducted in person in written form and/or using distance technologies (subject to identification of applicants when they take the entrance examinations).

The entrance exam is interdisciplinary test, performed in distant online format. The test is assessed on a **100-point scale** and consists of 24 short-test questions for choosing right answer. The minimum number of points confirming the successful completion of the interdisciplinary exam is **50 points (50%)**.

Head of the educational program 12.04.01 _____ / Bolshakova A.V./

Authors:

Director of
HS Biomedical systems and technologies _____ / Vlasova O.L./

Head of the educational program
Associate professor _____ / Bolshakova A.V./

Head of the bachelor program 12.03.04
Associate professor _____ / Bolshakova A.V./

The program was reviewed and recommended for publication at meeting №2 of the Higher School of Biomedical Systems and Technologies, IBSiB (Protocol №. 2 of September 20, 2024).

1. DISCIPLINES INCLUDED IN THE PROGRAM FOR ENTRY TESTS FOR THE MASTER'S DEGREE

1.1. Physics

1.2. Research experimental methods

1.3. Molecular biology and genetics

2. DISCIPLINES and TOPICs

2.1. "Physics"

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.

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.

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).

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.

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.

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

2.2 "Research experimental methods (biophysical)"

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. 7. Optical spectroscopy of solutions

2.3 "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.

3. Test example

Peter the Great St. Petersburg Polytechnic University
Institute Of Biomedical Systems and Biotechnologies

APPROVED

Head of the educational program 12.04.04_01

_____ Bolshakova A.V.

«20» 05 2024 г.

ENTRANCE TEST

for

12.04.04 "Biotechnical systems and technologies"
12.04.04 _01 Molecular and cellular biomedical technologies
(international educational program)"

Question examples

1 **Physics**

A moving particle is elastically scattered by a stationary particle of the same mass. Which statement is true in the most general case?

a) **the velocity vectors of the particles after scattering are perpendicularto each other**

b) the velocity of the first particle after collision is equal to zero

c) the velocities of the particles after collision are directed in opposite directions

d) particle velocities after collision are equal in modulus

2 **Molecular biology and genetics**

What is maximum size of polypeptide encoded by mRNA consist of 1232 nucleotides?

a) 3696 amino acids

b) 410 amino acids

c) 411 amino acids

d) 400 amino acids

3 **Experimental methods**

Which wave length is usually used to measure photometrical the concentration of proteins by their own absorption?

a) 280 nm

b) 350 nm

c) 595 nm

d) 254 nm