ENTRANCE EXAMINATION PROGRAM

FOR LANDAU PHYSTECH SCHOOL OF PHYSICS AND RESEARCH BIOLOGICAL SCIENCES COMPETITIVE GROUP

FOR APPLICANTS ENTERING PHD PROGRAMS

At the entrance examination applicants will be asked questions on their final qualifying work and questions from the section corresponding to specialty of their future research activity.

Questions on the final qualifying work (master or specialist's degree):

1. Main provisions.
2. Novelty.
3. Relevance.

Biophysics Section

Theoretical Biophysics

1. Kinetics of biological processes.

The main features of the kinetics of biological processes. Description of the dynamics of biological processes in the language of chemical kinetics. Kinetics of enzymatic processes. Features of the mechanisms of enzymatic reactions. The concept of the physics of enzymatic catalysis. Kinetics of the simplest enzymatic reactions. Conditions for the implementation of stationarity. Michaelis-Menten equation. Influence of modifiers on the kinetics of enzymatic reactions. Application of the graph method to study the stationary kinetics of enzymatic reactions. General principles for the analysis of more complex enzymatic reactions. Effect of temperature on the rate of reactions in biological systems. Interrelation of kinetic and thermodynamic parameters. The role of conformational properties of biopolymers.

2. Thermodynamics of biological processes.

Classification of thermodynamic systems. The first and second laws of thermodynamics in biology. Heat capacity and compressibility of protein globules. Entropy change in open systems. Prigogine's postulate. Thermodynamic conditions for the implementation of a stationary state. Thermodynamic coupling of reactions and thermal effects in biological systems. Relationship between entropy and information in biological systems.

Molecular biophysics

1. Spatial organization of biopolymers.

Macromolecule as the basis for the organization of biostructures. Spatial configuration of biopolymers. Statistical nature of the conformation of biopolymers.

Conditions for the stability of the configuration of macromolecules. Phase transitions. Coil-globule transitions. Cooperative properties of macromolecules. Types of bulk interactions in protein macromolecules. Hydrogen bonds: Van der Waals forces; electrostatic interactions; rotational isomerism and energy of internal rotation.

Interaction of macromolecules with a solvent. State of water and hydrophobic interactions in biostructures. Spiral-tangle transitions.
Features of the spatial organization of proteins and nucleic acids. Models of fibrillar and globular proteins.

2. Dynamic properties of globular proteins.

Structural and energy factors that determine the dynamic mobility of proteins. Dynamic structure of oligopeptides and globular proteins; conformational mobility.
Methods for studying conformational mobility: isotope exchange, luminescent methods, EPR, gamma-resonance spectroscopy, high-resolution NMR, pulsed NMR methods, molecular dynamics methods. Auto- and cross-correlation functions of torsion angles and interatomic distances. Maps of free energy levels of peptides.
Results of the study of conformational mobility. Limited diffusion. Types of movement in proteins. Hierarchy of amplitudes and relaxation times of conformational movements. Relationship between characteristics of conformational mobility of proteins and their functional properties.
Dynamics of electronic conformational transitions. The role of water in protein dynamics. The role of conformational mobility in the formation of enzymes and transport proteins.

Cellular Biophysics
Membrane Biophysics

1. Structure and function of biological membranes.

Membrane as a universal component of biological systems. Development of ideas about the structural organization of membranes. Characterization of membrane proteins. Characterization of membrane lipids. Dynamics of the structural elements of the membrane. Protein-lipid interactions. Water as an integral element of biomembranes. Model membrane systems. Monolayer at the phase boundary. Bilayer membranes. Proteoliposomes.
Physico-chemical mechanisms of membrane stabilization. Features of phase transitions in membrane systems. Rotational and translational mobility of phospholipids, flip-flop transitions. Mobility of membrane proteins. Influence of external (environmental) factors on the structural and functional characteristics of biomembranes.
Surface charge of membrane systems; origin of the electrokinetic potential. The phenomenon of polarization in membranes. Dispersion of electrical conductivity, capacitance, permittivity. Dependence of dielectric losses on frequency. Structural features of living cells and tissues underlying their electrical properties.
Free radicals in chain reactions of lipid oxidation in membranes and other cellular structures. The formation of free radicals in tissues in normal and pathological processes. The role of reactive oxygen species. Antioxidants, the mechanism of their biological action. Natural tissue antioxidants and their biological role.

2. Biophysics of the transport processes of substances through biomembranes and bioelectrogenesis. Passive and active transport of substances through biomembranes.

Transport of nonelectrolytes. Membrane permeability to water. Simple diffusion. Limited diffusion. Connection of membrane permeability with the solubility of penetrating substances in lipids. Facilitated diffusion. Transport of sugars and amino acids across membranes with the participation of carriers. Pinocytosis.
Transport of electrolytes. Electrochemical potential. Ionic equilibrium at the membrane–solution interface. Profiles of the potential and concentration of ions in the electric double layer. Donnan equilibrium. Passive transport; driving forces for ion transport. Nernst–Planck electrodiffusion equation.
Resting potential, its origin. Active transport. Electrogenic ion transport. Participation of ATPases in the active ion transport through biological membranes. Ion channels. Ionophores: carriers and channeling agents. Ionic selectivity of membranes (thermodynamic and kinetic approaches).

Action potential. The role of Na and K ions in the generation of action potentials in nerve and muscle fibers; the role of Ca and Cl ions in the generation of action potentials in other objects. Kinetics of changes in ion fluxes during excitation. Channel activation and inactivation mechanisms.
Description of ion currents in the Hodgkin–Huxley model. Gate currents. Mathematical model of nonlinear processes of membrane transport. Voltage and conductivity fluctuations in model and biological membranes.
Spread of excitation. Cable properties of nerve fibers. Impulse conduction along unmyelinated and myelinated fibers. Mathematical models of the nerve impulse propagation process. Physicochemical processes in nerve fibers during the conduction of series of impulses (rhythmical excitation). Energy supply of excitation propagation processes.
Basic concepts of the theory of excitable media.

3. Molecular mechanisms of energy conjugation processes.

Relationship between ion transport and electron transfer process in chloroplasts and mitochondria. Localization of electron transport chains in the membrane; structural aspects of the functioning of membrane-bound carriers; membrane asymmetry.
The main provisions of Mitchell's theory; electrochemical gradient of protons; energized state of membranes; the role of the vector H+-ATPase.
Conjugating complexes, their localization in the membrane; functions of individual subunits; conformational rearrangements in the process of macroergic formation.
Proteoliposomes as a model for studying the mechanism of energy
conjugation. Bacteriorhodopsin as a molecular photoelectric generator. Physical aspects and models of energy conjugation.

4. Biophysics of contractile systems.

The main types of contractile and mobile systems. Molecular mechanisms of mobility of protein components of the contractile apparatus of muscles. Principles of energy conversion in mechanochemical systems. Thermodynamic, energy and power characteristics of contractile systems.
Functioning of the striated muscle of vertebrates. Models of Huxley, Deshcherevsky, Hill.
Molecular mechanisms of non-muscular mobility.

5. Biophysics of reception.

Hormonal reception. General patterns of interaction between ligands and receptors; equilibrium hormone binding. The role of the plasma membrane structure in the process of hormonal signal transmission. Receptor-mediated intracellular transport.
Photoreception. The structure of the visual cell. Molecular organization of the photoreceptor membrane; dynamics of the visual pigment molecule in the membrane. Visual pigments: classification, structure, spectral characteristics; photochemical transformations of rhodopsin. Early and late receptor potentials. Mechanisms of late receptor potential generation.

Biophysics of photobiological processes

1. Mechanisms of energy transformation in primary photobiological processes. Interaction of quanta with molecules. Wave packet evolution and results of femtosecond spectroscopy. Primary photochemical reactions.

The main stages of the photobiological process. Mechanisms of photobiological and photochemical stages. Kinetics of photobiological processes.
Features and mechanisms of photoenergetic reactions of bacteriorhodopsin and visual pigment rhodopsin.

2. Photoregulatory and photodestructive processes

The main types of photoregulatory reactions of plant and microbial organisms: photomorphogenesis, phototropism, phototaxis, photoinduced carotenogenesis. Action spectrum,

nature of photoreceptor systems, mechanisms of primary photoreactions. Photochemical reactions in proteins, lipids and nucleic acids. DNA as the main intracellular target in the lethal and mutagenic action of ultraviolet light. Photosensitized and two-quantum reactions in DNA damage. Mechanisms of photodynamic processes. Protection of DNA by some chemical compounds.
Effects of photorepair and photoprotection. Enzymatic character and molecular mechanism of photoreactivation. The role of photoinduced synthesis of biologically active compounds in the process of photoprotection.

Main references

1. Альбертс Б., Брей Д., Льюис Дж., и др. Молекулярная биология клетки. М., 2013.
2. Рубин А.Б. Биофизика. В 2-х кн. Учеб. для биол. спец. вузов. М., 2004

Additional literature

1. Антонов В.Ф. Липиды и ионная проницаемость мембран. М., 1982. 151с.
2. Биологические мембраны. Методы. Под ред. Дж. Финдел, У. Эванеса. М., 1990.
3. Болдырев А.А. и др. Биохимия активного транспорта ионов и транспортные АТФазы.М., 1983. 126 с.
4. Введение в мембранологию. М. 1990 208 с. (авторы Болдырев и др.)
5. Владимиров Ю.А. и др. Биофизика. М., 1983. 272 с.
6. Веселова Т.В., Веселовский В.А., Чернавский Д.С. Стресс у растений. Биофизическийподход. М. МГУ, 1993 144 с.
7. Волькенштейн М.В. Биофизика. М., 1981. 575 с.
8. Исмаилов Э.Ш., Захаров С.Д. Электромагнитные поля и излучения в природе, техникеи жизни человека. М., 1992. 159 с.
9. Кольс О.Р., Максимов Г.В., Раденович Ч.Н. Биофизика ритмического возбуждения М.1993. 302 с.
10. Рубин А.Б. Термодинамика биологических процессов. 2-е изд., перераб. и доп.М., 1984,285 с