National Academy of Sciences of Ukraine
V.P. Kukhar Institute of Bioorganic Chemistry and Petrochemistry

PROGRAM
in biochemistry

for passing additional entrance exams to postgraduate studies
for studying at the third (educational and scientific) level of higher education
Doctor of Philosophy (PhD)
in the specialty E1 Biology and biochemistry

Kyiv - 2025

Approved by the Academic Council
Institute of Bioorganic Chemistry
and Naftochemistry V.P. Kukhar
NAS of Ukraine
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Protocol No. 6

Explanatory note

The Biochemistry program is designed for applicants entering postgraduate studies in the specialty E1 Biology and Biochemistry from another field of knowledge (specialty) indicated in their master's (specialist's) degree.

The purpose of the additional entrance examination for postgraduate studies in the specialty E1 Biology and Biochemistry is to determine the level of theoretical knowledge and practical skills of applicants acquired during their studies at the educational degree / specialist / master's level in order to form a rating list and competitive selection of applicants for the degree of Doctor of Philosophy in the specialty E1 Biology and Biochemistry within the license volume of the Institute.

Form of additional entrance exam

The additional entrance exam is held in writing, and applicants write the answers to the questions on the exam paper with the Institute's seal. The exam lasts 60 minutes.

Structure of the exam ticket

The ticket of the additional entrance exam contains 3 theoretical questions. The questions in the tickets are formed on the basis of this program.

Requirements for the applicant's answer

The questions assess the applicant's knowledge of biochemistry necessary for the correct expression of certain concepts, as well as for understanding a wide range of theoretical and practical tasks, and possession of skills required for professional activities within the program. The correctness of the tasks is assessed in accordance with the criteria for assessing knowledge.

criteria

The assessment of the applicant's response to the postgraduate program is based on the level of his/her preparedness for research and experimental activities in the field of biochemistry.

Each question is scored on a 100-point scale. The total score is determined as the arithmetic mean of the sum of the scores for all questions.

Scale of evaluation: national and ECTS

Total points for all types of learning activities	Evaluation ECTS	Score on the national scale
		for the exam, practice, differentiated test
90 - 100	**A**	excellent
82-89	**B**	well

74-81	**C**	
64-73	**D**	satisfactorily
60-63	**E**	
35-59	**FX**	unsatisfactory with the possibility of reassembly
0-34	**F**	unsatisfactory with mandatory re-study of the discipline

90-100 - "excellent". The applicant presents the program material in a reasoned and complete manner. In his answers, he relies on the research of scientists, uses the methods of comparative analysis, generalization, gives examples, proofs. Consciously, accurately, and fully presents the program material in writing; highlights the main points. Shows a creative approach to revealing the essence of phenomena. Skillfully combines the acquired knowledge, skills, abilities with practice. Excellent performance of the task with only a small number of errors

74-89 - "good". The entrant shows knowledge of the course content. Gives examples when reproducing the program material, but lacks a creative approach to solving the problem. Shows knowledge of the course content, but does not fully reveal the essence of the phenomena. Correctly uses knowledge, skills, abilities only in standard situations.

60-73 - "satisfactory". The applicant makes mistakes in the answers and has difficulties in eliminating them. The answers to the questions are not complete. Has difficulties in applying the acquired knowledge, skills and abilities in practice. In general, the program material is partially mastered.

0-59 - "unsatisfactory". Has difficulty in explaining the content of basic concepts. Makes a significant number of mistakes in the reproduction of program material. Has a poor command of basic concepts, reveals the essence of phenomena, concepts at the level of reproduction. Cannot combine the acquired knowledge with practice. Answers to questions are fragmentary, do not reflect the essence of the problem.

Program content

INTRODUCTION

The role and place of biochemistry in the system of natural sciences. The importance of biochemistry for the modern development of society

The subject of biochemistry. Structure and properties of basic macromolecules (carbohydrates, proteins, nucleic acids, lipids). Structure, general properties, classification of macromolecules. Metabolism and transformation of macromolecules in the body, key metabolic pathways, sequence of reactions, their regulation, biological role, energy balance. Physical and chemical methods of studying biological processes.

Cells. Chemical composition of cells. Classification of methods of nutrition. Prokaryotic and eukaryotic plans of cell structure, their common and distinctive features. Hypotheses of the origin of eukaryotes. Primary and secondary endosymbioses. General cell structure plans of algae, higher plants and fungi. Variety of cell coatings: pellicle, amphiosm, periplasm, carapace, cell membrane. Variety of cell membrane types. Study of the principles of functioning of molecular biological

systems. Concept of intermolecular interactions and characterization of weak interactions (Van der Waals forces, hydrogen bonding, hydrophobic and electrostatic interactions).

Membranes. Membrane structures of the cell (nuclear, mitochondrial, lysosomal, endoplasmic reticulum), their features and identification. Membranes and intercellular interactions. Functions of membranes. Membrane transport. Structural organization of membranes. Intermolecular interactions in the membrane. Phase transitions in membranes. Dynamics of lipids and proteins in the membrane. Study of dynamic characteristics of membranes. Models of structural organization of membranes. Transport of substances through biomembranes. Mechanisms of passive and active transport across biomembranes.

Amino acids . Classification. Isomerism. Nomenclature. Natural amino acids. Their stereochemistry. Methods of preparation: by substitution of halogen in halogen-substituted carboxylic acids, by the action of ammonium cyanide on oxo compounds (Strecker, Zelinsky), by addition of ammonia to unsaturated acids, by the action of malonic acid and ammonia on aldehydes, from nitroacetic acid ester.

Physical and chemical properties of amino acids, their betaine-like structure. The concept of an isoelectric point. Amphotericity. Reactions of amino acids involving the carboxyl group (formation of salts, esters, halides) and the amino group (formation of salts with acids, acylation, alkylation). Specific properties of amino acids: formation of diketopiperazines of α-unsaturated acids, lactams, peptides, and complexes with metal salts. The most important representatives of aliphatic, aromatic, and heterocyclic amino acids, their preparation and use: α-amino acids - components of proteins (feed additives), aminocaproic acid (nylon), ethylenediaminetetraacetic acid (complexes).

Peptides and polypeptides. Proteins. Methods for the preparation of peptides and polypeptides from various amino acids. Protection of the amino group, activation of the carboxyl group. Methods for determining the composition and structure of polypeptides. Hydrolysis. Determination of N-, C-terminal groups of amino acids. Natural amino acids (aliphatic, aromatic and heterocyclic).

Proteins. Structure and properties of proteins. Primary structure of proteins. Amino acid residues - monomers of protein chains. Types of amino acids and their structure. Formation of a polypeptide chain, peptide bond. Methods of isolation and characterization of proteins and peptides.

Amino acid sequence determination strategy. Proteolytic and chemical cleavage, separation and identification of peptides. Automatic sequencing of peptides and proteins, reconstruction of amino acid sequences of proteins. Determination of nucleotide sequences of protein-coding genes and amino acid sequences from cDNA.

Mass spectrometry as a method of protein identification. The importance of studying the primary structure of proteins for solving the problem of evolution and systematics of organisms

Spatial structure of proteins. Main types of dipeptide unit conformation. Secondary structure of proteins. Helical and beta-structural regions in globular proteins. Curvature of beta-structural layers in globular proteins (right-handedness). Relation of the secondary structure to the amino acid sequence. Basic provisions of the stereochemical theory of the secondary structure of globular proteins. Statistical regularities in the distribution of amino acid residues in helical, beta-structural and non-regulatory regions of globular proteins. Experimental methods for studying the secondary

structure of proteins. Optical methods: circular dichroism method, infrared spectroscopy.

Tertiary structure of proteins. The nature of the forces that stabilize the three-dimensional structure of a protein. X-ray crystallographic analysis of globular proteins. Main structural characteristics of globular proteins with known spatial structure. Compact shape, presence of densely packed hydrophobic cores and polar shell. Domain structure.

Quaternary structure of proteins. Types of interactions between subunits in oligomeric proteins. Symmetrical oligomeric structures of identical subunits. Functional advantages of a subunit protein over a monomer. Macromolecular complexes of proteins. Fibrillar protein structures.

Denaturation of proteins: disruption of the native conformation of proteins by changes in temperature, pH, and organic denaturants.

Self-organization of protein structures. Self-organization of the secondary structure of proteins, Levinthal's paradox. Thermodynamics and kinetics of polypeptide chain folding, intermediate states. "Molten globule" as an intermediate of protein folding. Molecular chaperones, their role in protein folding. Types of chaperones and their characteristics. Chaperones of bacteria and eukaryotes. Stress proteins as chaperones. Chaperonins and ATP-dependent protein folding. Structure and mechanism of GroEL chaperonin functioning.

Naturally unstructured proteins are native proteins with a partially unfolded conformation. Revision of the structure-function relationship paradigm in proteins. Experimental methods for studying unstructured proteins. Unstructured domains in the processes of transcription, molecular recognition, membrane transport, signal transduction.

Functions of proteins: enzymes, transfer proteins, reserve proteins, contractile proteins, blood defense proteins, toxins, hormones, structural proteins.

Lipids. Structure and classification of lipids. Physical and chemical properties, role in a living organism. Neutral lipids. Biological functions of lipids. Definition and classification of lipids. Simple lipids. Triacylglycerols (triglycerides, neutral fats): structure, chemical properties, physiological significance. Fatty acids. Free fatty acids. Biological activity of free fatty acids. Higher fatty acids: palmitic, stearic, oleic, linoleic, linolenic, arachidonic.

Carbohydrates. Monosaccharides are polyoxyaldehydes and polyoxyketones. Classification of monosaccharides: by the number of carbon atoms - pentoses, hexoses with the presence of aldehyde or ketone groups - aldoses and ketoses. Stereochemistry of monoses. Absolute and relative configurations. D- and L- series, their stereochemical relationship with glycerol aldehyde. Stereochemical series of monoses, the most important representatives. Ring-chain tautomerism. Pyranose and furanose forms of Howors. Conformations of hexoses.

Mutual transformations of cyclic and open forms. The phenomenon of mutation, a- and ß-stereoisomers (anomers). Special properties of glucoside hydroxyl (formation of glucosides and their hydrolysis). Determination of the size of the monosaccharide cycle by exhaustive methylation and sequential oxidation. Chemical properties of monosaccharides: acylation, alkylation, formation of sugars, oxidation, reduction, interaction with hydrocyanic acid, hydroxylamine, phenylhydrazine (ozones and ozones). Epimerization under the influence of alkalis. Methods of shortening and extending the carbon chain of monosaccharides. Proof of stereochemical affinity of monosaccharides on the example of arabinose, glucose and fructose, as well as glucose, mannose

and fructose. Conversion of pentoses and hexoses into furfural derivatives. Specific properties of monoses that are incompatible with the notion of the Fischer chain formula for these compounds.

Disaccharides. Classification. Nomenclature. Structure. Reducing and non-reducing disaccharides. Maltose, cellobiose, lactose, sucrose. Methods for determining the structure of disaccharides. Inversion of the optical activity of sucrose during hydrolysis. Chemical properties of disaccharides. Amino sugars. Chitin. Structure. Biological significance.

Polysaccharides. Starch, glycogen, fiber (cellulose), their distribution in nature, importance. Structure of polysaccharides. Cellulose ethers and esters: methyl, ethyl, acetyl cellulose nitrocellulose, celluloid, cellophane. Artificial fibers based on cellulose. Acetate silk. Fiber xanthonate. Viscose.

Vitamins. The history of the discovery of vitamins and their role in the functioning of human and animal organisms. Water-soluble and fat-soluble vitamins. Vitamins and coenzymes. Vitamin A. Structure, biological role and isomerization in the process of functioning. Vitamin B1, thiamine monophosphate and cocarboxylase; their role in the decarboxylation of α-keto acids and the treatment of beriberi disease. Vitamin B2 (riboflavin) and flavin coenzymes, participation in oxidase and dehydrogenase systems. Vitamin B3 (pantothenic acid), coenzyme A and its biosynthetic role. Vitamin B5 (niacin) and niacinamide, its coenzymes (NAD and NADP) and their role in oxidoreductases, niacin biosynthesis. Vitamin B6 (adermine), pyridoxine, pyridoxal and pyridoxamine. Vitamin B9 (folic acid), its conjugates with glutamic acid and tetrahydrofolic acid. Treatment of anemia and radiation sickness. Folic acid antagonists for the treatment of leukemia and leukemia. The history of the discovery and use of sulfamide drugs as the first chemotherapeutic agents to combat infectious diseases. Vitamin B12 (oxycobalamin), its biological role and use in the fight against diseases of the hematopoietic system. Vitamin C (ascorbic acid): structure, reactivity, tautomerism and biological role. Methods of industrial production. Vitamins D and their provitamins. Mechanism of biosynthesis. Active forms. Biological role. Vitamins E (tocopherols) and the consequences of E-vitaminosis. Vitamin H (biotin). Vitamins K and normalization of blood clotting. Vitamins Q (ubiquinone) in the regulation of electron transport and oxidative phosphorylation.

Enzymes. Regulatory macromolecules of the body. Chemical nature and properties of these compounds, classification and nomenclature. Kinetics of enzymatic catalysis. Enzyme - substrate interactions. The principle of cooperativity as a mechanism of membrane biogenesis, reception of enzymatic activity.

Mitochondria. Structure. Organization of the outer and inner membrane. Ways of obtaining energy by cells. Mitochondrial DNA. Energy transformation in mitochondrial membranes. Spatial localization of electron transport chains in mitochondrial membranes. Structure of the mitochondrial electron transport chain. The role of succinate dehydrogenase (SDH) in the functioning of the respiratory electron transport chain. Redox potentials of electron carriers. Oxidative phosphorylation. Structural organization of ATP synthetase and its localization. Mechanism of the mitochondrial ATP synthase complex. Mitchell's chemiosmotic theory. Coding of subunits of the electron transport chain of organelles in the mitochondrial and nuclear genome of cells

Photosynthesis. Structural and functional diversity of the main photosynthetic pigments - chlorophylls, carotenoids. Plastids. Organization of the chloroplast. Light and dark reactions of

photosynthesis. Biochemistry of photosynthesis. The main stages of the photobiological process. Laws of light absorption. Pigment molecules and their spectral characteristics. Photosynthetic unit. Light absorption and mechanisms of energy migration in light-harvesting pigment-protein (antenna) complexes. Basic laws of photochemistry. Spectra of photochemical reactions. Bacterial photosynthesis. Molecular mechanisms and methods of bioluminescence registration. Hypotheses of the autonomous origin of mitochondria and chloroplasts. Photosynthetic and mitochondrial apparatus

Hormones. Hormonal regulation as a mechanism of metabolic coordination. Biochemical receptor systems of the cell. Neurotransmitters. Molecular mechanisms of regulatory signaling. Genome organization and gene structure. Features of the organization of prokaryotic, chloroplastic, mitochondrial, nuclear genomes. The principle of structural and functional organization in biology on the example of regulation of genome expression and enzyme. Molecular mechanisms of DNA replication. Molecular mechanisms of DNA repair and recombination. The principle of complementarity on the example of DNA structure, mechanisms of transcription and translation. Cytoskeleton and regulation of genome expression.

Recommended reading:

1. Gubsky Y.I. Biochemistry - Vinnytsia: Nova Knyha, 2009. - 664 p.
2. Kucherenko M.E., Babeniuk Y.D., Vasiliev O.M. et al. Biochemistry // Kyiv: Kyiv University, 2002. 480 c.
3. Syvolob A.V. Molecular Biology - Kyiv: Kyiv University Press, 2008. - 384 c.
4. Kopylchuk G.P. Functional biochemistry: a textbook - Chernivtsi: Yuriy Fedkovych Chernivtsi National University, 2018. 344 c.

The recommended list of references is indicative and does not exclude the applicants' own initiatives in their selection and use.