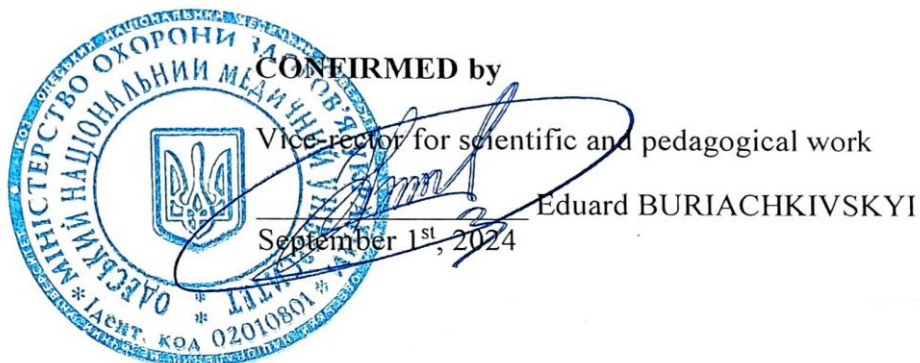


MINISTRY OF HEALTH OF UKRAINE
ODESA NATIONAL MEDICAL UNIVERSITY

Department of Medical Biology and Chemistry



WORKING PROGRAM IN THE DISCIPLINE
«BIOLOGICAL CHEMISTRY»

Level of higher education: second (master's degree)

Field of knowledge: 22 «Health care»

Specialty: 226 «Pharmacy, industrial pharmacy»

Educational and professional program: Pharmacy, industrial pharmacy

2024


The working program is compiled on the basis of the educational and professional program “Pharmacy, industrial pharmacy” for the training of specialists of the second (master’s) level of higher education in the specialty 226 “Pharmacy, industrial pharmacy” of the field of knowledge 22 “Health care”, approved by the Academic Council of ONMedU (minutes No. 10 dated 27.06.2024).

Authors:

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The working program is approved at the meeting of the Department of Medical Biology and Chemistry
Minutes No. 1 dated 26.08 2024.

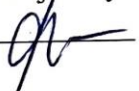
Head of the department


_____ Hennadii STEPANOV

Approved by the guarantor of
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_____ Liana UNHURIAN

Approved by the subject-cycle methodological commission for pharmaceutical disciplines of
ONMedU
Minutes No. 1 dated 30.08.2024

Head of the subject-cycle methodological commission for pharmaceutical disciplines of ONMedU

_____ Natalia FIZOR

Revised and approved at the meeting of _____
Minutes No. __ dated _____

Head of the department _____

Revised and approved at the meeting of _____
Minutes No. __ dated _____

Head of the department _____

Revised and approved at the meeting of _____
Minutes No. __ dated _____

Head of the department _____

1. Description of the discipline:

Name of indicators	Field of knowledge, specialty, specialization, level of higher education	Characteristics of the discipline
Total number:	Field of knowledge 22 «Health care»	<i>Full-time (day) education</i> <i>Compulsory discipline</i>
Credits of ECTS:5	Specialty 226 «Pharmacy, industrial pharmacy»	<i>Course: 3</i>
Hours: 150	Level of higher education second (master's degree)	<i>Semester: V-VI</i>
Content modules: 4		<i>Lectures (30 hours)</i>
		<i>Seminars (0 hours)</i>
		<i>Practical classes (70 hours)</i>
		<i>Laboratories (0 hours)</i>
		<i>Independent work (50 hours)</i>
		<i>including individual tasks (0 hours)</i>
		<i>Form of final control – Exam</i>

2. The purpose and tasks of the educational discipline, competencies, program learning outcomes

The purpose is to study of biomolecules and molecular organization of cellular structures, general laws of enzymatic catalysis and biochemical dynamics of transformation of the main classes of biomolecules (amino acids, carbohydrates, lipids, nucleotides, porphyrins, etc.), molecular biology and genetics of informative macromolecules (proteins and nucleic acids), i.e. molecular mechanisms of heredity and implementation of genetic information, hormonal regulation of metabolism and biological functions of cells, biochemistry of special physiological functions.

The tasks of the discipline are the following:

1. Acquisition of knowledge and skills to conduct biochemical research to identify normal and pathological components in biological fluids.
2. Analyze the results of biochemical research for the diagnosis of the most common human diseases.
3. To analyze the biochemical processes of metabolism and its regulation in ensuring the functioning of organs and systems of the human body.

The process of studying the discipline is aimed at forming elements of following competencies:

General competencies:

- GC 01. Ability to think abstractly, analyze and synthesize, learn and be modernly educated.
 GC 07. The ability to realize one's rights and responsibilities as a member of society; to realize the values of a civil (free democratic) society and the need for its sustainable development, the rule of law, the rights and freedoms of a person and a citizen in Ukraine.
 GC 10. The ability to act socially responsibly and consciously.
 GC 12. The desire to preserve the environment.
 GC 13. Ability to show initiative and entrepreneurship.
 GC 16. The ability to conduct experimental research at the appropriate level.

Special competencies are:

- SC 08. The ability to consult on prescription and non-prescription drugs and other products of the pharmacy assortment; pharmaceutical care during the selection and sale of medicinal products of natural and synthetic origin by assessing the risk/benefit ratio, compatibility, taking into account

biopharmaceutical, pharmacokinetic, pharmacodynamic and physicochemical and chemical features, indications/contraindications for use guided by data on the health status of a particular patient.

SC 09. Ability to provide pre-medical assistance to the sick and injured in extreme situations and emergencies.

SC 11. The ability to identify medicinal products, xenobiotics, toxins and their metabolites in biological fluids and tissues of the body, to conduct chemical and toxicological studies for the purpose of diagnosing acute poisoning, drug and alcohol intoxication.

SC 20. Ability to develop and evaluate methods of quality control of medicinal products of natural and synthetic origin, including active pharmaceutical ingredients, medicinal plant raw materials and auxiliary substances using physical, chemical, physico-chemical, biological, microbiological, pharmaco-technological methods; carry out standardization of medicinal products in accordance with current requirements.

SC 21. The ability to ensure the rational use of prescription and non-prescription drugs in accordance with the physicochemical, pharmacological characteristics, biochemical, pathophysiological features of a particular disease and pharmacotherapeutic schemes of its treatment.

Program learning outcomes are:

PLO 01. Have and apply specialized conceptual knowledge in the field of pharmacy and related fields, taking into account modern scientific achievements.

PLO 03. Have specialized knowledge and skills/skills for solving professional problems and tasks, including for the purpose of further development of knowledge and procedures in the field of pharmacy.

PLO 09. Formulate, argue, clearly and concretely convey to specialists and non-specialists, including those seeking higher education, information based on one's own knowledge and professional experience, the main trends in the development of world pharmacy and related industries.

PLO 12. Provide pre-medical assistance to patients in emergency situations and victims in extreme situations.

PLO 21. Ensure competitive positions and effective development of pharmaceutical organizations, including taking into account the results of marketing research and market processes at the national and international levels.

PLO 22. Ensure and carry out quality control of medicinal products of natural and synthetic origin and document its results; draw up quality certificates and analysis certificates taking into account the requirements of the current edition of the State Pharmacopoeia of Ukraine, quality control methods, technological instructions, etc.; take measures to prevent the distribution of low-quality, falsified and unregistered medicinal products.

PLO 25. Adhere to the norms of the sanitary and hygienic regime and the requirements of safety equipment when carrying out professional activities.

As a result of studying the discipline, the higher education applicant has to

Know:

- The structure of bioorganic compounds and the functions they perform in the human body.
- The reactivity of the main classes of biomolecules, which ensures their functional properties and metabolic transformations in the body.
- Biochemical mechanisms of pathological processes in the human body.
- Peculiarities of diagnosing the physiological state of the body and the development of pathological processes based on biochemical studies.
- The relationship between the peculiarities of the structure and transformations in the body of bioorganic compounds as the basis of their pharmacological action as medicines.
- Basic mechanisms of biochemical action and principles of directed use of various classes of pharmacological agents.

- Biochemical and molecular bases of physiological functions of cells, organs and systems of the human body.
- Functioning of enzymatic processes occurring in membranes and organelles for the integration of metabolism in individual cells.
- Norms and changes in biochemical indicators used to diagnose the most common human diseases.
- The importance of biochemical processes of metabolism and its regulation in ensuring the functioning of organs, systems and the entire human body.

Be able:

- To analyze the correspondence of the structure of bioorganic compounds to the physiological functions they perform in the human body.
- Interpret the peculiarities of the physiological state of the body and the development of pathological processes on the basis of laboratory studies.
- To analyze the reactivity of carbohydrates, lipids, amino acids, which ensures their functional properties and metabolic transformations in the body.
- Interpret the peculiarities of the structure and transformations of bioorganic compounds in the body as the basis of their pharmacological action as medicines.
- Interpret the biochemical mechanisms of pathological processes in the human body and the principles of their correction.
- Explain the basic mechanisms of biochemical action and the principles of targeted use of various classes of pharmacological agents.
- To explain the biochemical and molecular basis of the physiological functions of cells, organs and systems of the human body.
- To classify the results of biochemical studies and changes in biochemical and enzymatic parameters used for the diagnosis of the most common human diseases.

3. The content of the educational discipline

Content module 1.

General patterns of metabolism

Theme 1. General characteristics, properties of enzymes.

General characteristics, properties of enzymes. The protein nature of enzymes. Active, allosteric enzyme centers. Regulation of enzyme activity. Enzyme activators and inhibitors. Coenzymes, their role in catalysis. Coenzyme functions of vitamins. International classification and nomenclature of enzymes. Proenzymes. Activation of proenzymes, role in metabolism. Demonstration-practical work: Determining the structure of enzymes by biuret reaction, Foll's reaction. Determination of amylase activity of saliva and urine in the presence of activator and inhibitor.

Theme 2. Mechanism of action of enzymes. Kinetics of catalysis.

Basic theories of biocatalysis. Kinetics of catalysis. Methods of qualitative and quantitative determination of enzymes. Intracellular localization of enzymes. Use of enzymes in the clinic (fundamentals of medical enzymology). Enzyme diagnostics and enzyme therapy. Enzymopathies. Demonstration of enzymograms. Demonstration-practical work: Observation of the kinetics of lipase action on milk fat. Effect of bile on lipase activity.

Theme 3. Citric acid cycle.

Specific and general pathways of catabolism. Citric acid cycle (CAC). Sequence of reactions and characteristics of enzymes. Biological significance of CAC. Bioenergetics of significance. Anaplerotic and amphibolic reactions of CAC. Demonstration-practical work: Detection of milk dehydrogenase. Detection of succinate dehydrogenase in muscles.

Theme 4. Molecular mechanisms of tissue respiration. Peroxide and microsomal

oxidation.

The structure of mitochondria. Molecular organization of Electron transport chain: components; their redox-potential, molecular complexes of the inner mitochondria membranes. Oxidative phosphorylation in the respiratory chain. High energy compounds. Peroxide and microsomal oxidation. Antioxidant system. Demonstration-practical work: Detection of oxidase (tyrosinase) in potatoes. Detection of peroxidase in horseradish extract. Detection of catalase in blood. Quantification of blood catalase (catalase number) according to Bach and Zubkova.

Content module 2.**Metabolism of carbohydrates, lipids, amino acids and its regulation. Molecular biology.****Theme 5. Intracellular catabolism of glucose.**

Intracellular catabolism of glucose. Glycolysis: reactions. Comparison of glycolysis and alcoholic fermentation. Glycogenolysis, regulation. Differences from glycolysis. Stages of aerobic oxidation of glucose: oxidative decarboxylation of pyruvate. Bioenergetics of the process. Demonstration-practical work: Simulation of the "in vitro" process of glycolysis, determination of end products. Alcoholic fermentation test. Determination of pyruvate content in blood serum.

Theme 6. Alternative pathways of monosaccharide metabolism.

Alternative pathways of monosaccharide metabolism. The pentose phosphate pathway of glucose oxidation: scheme, biological significance, features of functioning in various tissues. Metabolic pathways of fructose and galactose conversion: hereditary enzymopathies of their metabolism. Demonstration-practical work: Detection of fructose by the Selivanov reaction.

Theme 7. Gluconeogenesis. Glycogen biosynthesis. Regulation of carbohydrate metabolism.

Glucose biosynthesis: physiological significance, reactions, regulatory enzymes. Substrates of gluconeogenesis. Glucose-lactate and glucose-alanine cycles. Regulation of glucose metabolism. Glucosemia: normal state and its disorders. Glycogen biosynthesis. Regulation of carbohydrate metabolism. Genetic disorders of glycogen metabolism of (glycogen storage diseases). Demonstration-practical work: Determination of glucose content in the blood by the Hagedorn-Jenson method. Determination of glycogen in the liver.

Theme 8. The role of lipids in the structure and functions of biological membranes. Oxidation of fatty acids and glycerol.

The role of lipids in the structure and functions of biological membranes. Molecular mechanisms of lipolysis regulation. Tissue, intracellular metabolism of lipids. Oxidation of fatty acids and glycerol. Energy yield from fatty acid β -oxidation. Demonstration-practical work: Observation of the effect of bile on fat emulsification. Observation of the effect of pancreatic lipase on milk fat with and without bile.

Theme 9. Biosynthesis of glycerol, fatty acids, glycerides and phospholipids.

Biosynthesis of glycerol, fatty acids and glycerides. Formation of phospholipids. Demonstration-practical work: Determination of total lipids in blood serum by the method of Bang.

Theme 10. Cholesterol metabolism. Metabolism of acetoacetic acid.

Structure, biological role and metabolism of cholesterol. Cholesterol biosynthesis. Disorders of lipid metabolism. Lipoproteins, structure and functions. Metabolism of acetoacetic acid. Ketone bodies. Demonstration-practical work: Qualitative reactions to acetone (iodoformant, nitroprusside). Quantitative determination of acetone in urine by the Rudoy method. Qualitative response to the presence of cholesterol in the brain.

Theme 11. Ways of formation and maintenance of the pool of amino acids in the body. Deamination, decarboxylation, transamination of amino acids.

Ways of formation and maintenance of the pool of amino acids in the body. Transport of amino acids into cells. Deamination of amino acids. Mechanism of indirect deamination of L-

amino acids. Decarboxylation of amino acids: enzymes, physiological significance. Oxidation of biogenic amines. Transamination. Biochemical significance, mechanisms of action of aminotransferases. Diagnostic value of determination of aminotransferases in blood serum. Demonstration-practical work: Quantitative determination of nitrogen of ammonium salts in urine by the Model method. Detection of alanine aminotransferase (AlAT) in normal and pathological blood serum.

Theme 12. Ammonia metabolism in the human body.

Ammonia metabolism in the human body. Urea. Ways of ammonia formation. Ammonia toxicity and mechanisms of its neutralization. Transport forms of ammonia (glutamine and asparagine). Urea biosynthesis: enzyme reactions, genetic anomalies. Demonstration-practical work: Quantitative determination of urea in urine.

Theme 13. Amino acids nitrogen-free skeleton metabolism in the body. Hereditary enzymopathies of amino acid metabolism.

Ways of metabolism of the nitrogen-free skeleton of amino acids in the human body. Glycogenic and ketogenic amino acids. Special pathways of acyclic amino acids metabolism. Glutathione, its role in the metabolism of organic peroxides. Arginine metabolism, biological role of nitric oxide, NO-synthase. Metabolic features of branched-chain amino acid: participation of coenzyme forms of vitamin B12 in amino acid metabolism. Metabolic pathways of cyclic amino acids. Hereditary enzymopathies of cyclic and aliphatic amino acid metabolism. Demonstration-practical work: Determination of phenyl pyruvate (Fehling's test)

Theme 14. Catabolism of purine and pyrimidine nucleotides.

Nucleotides' metabolism in tissues: purine and pyrimidine nucleotides catabolism. Disorders of purine metabolism (gout). Demonstration-practical work: Quantitative determination of uric acid in urine.

Theme 15. Anabolism of purine and pyrimidine nucleotides.

Purine and pyrimidine nucleotides biosynthesis. Regulation of nucleotide biosynthesis. Deoxyribonucleotide biosynthesis. Formation of thymidine nucleotides: dTMP biosynthesis inhibitors as antitumor agents.

Theme 16. Biosynthesis of nucleic acids.

Biosynthesis of nucleic acids. Molecular mechanisms of DNA replication. Stages of synthesis of daughter chains of DNA molecules. Molecular mechanisms of transcription. RNA synthesis stages and enzymes. Processing as a post-transcriptional modification of RNA. Antibiotics as transcription inhibitors.

Theme 17. Protein biosynthesis in ribosomes.

Protein biosynthesis in ribosomes. Genetic code: triplet code structure, its properties. Post-translational modification of peptide chains. Regulation of translation. Regulation of gene expression. Mechanisms of DNA mutations and repairs. Obtaining recombinant DNA, transgenic proteins.

Theme 18. Fundamentals of Molecular Genetics.

Regulation of gene expression. Mechanisms of DNA mutations and repairs. Obtaining recombinant DNA, transgenic proteins.

Intermediate control for the semester.

Content module 3.

Biochemistry of intercellular communications.

Theme 19. Hormones general concept. Hypothalamus and pituitary gland hormones.

Hormones general concept. Classification, mechanisms of action of hormones on target cells. Hormones of the hypothalamus and pituitary gland hormones. Demonstration-practical work: Study of the nature of hormones using the biuret reaction.

Theme 20. Thyroid and parathyroid glands hormones. Regulation of phosphorus-calcium metabolism.

Thyroid and parathyroid glands hormones. Structure and synthesis of thyroid hormones. Thyroid gland pathology. Regulation of phosphorus-calcium metabolism. Metabolic disorders of calcium homeostasis.

Demonstration-practical work: Determination of iodine in the thyroid gland.

Theme 21. Steroid hormones.

Steroid hormones. Hormones of the adrenal cortex and gonads. Their structure and biochemical mechanisms of action. Demonstration-practical work: Refractometric determination of protein in blood serum.

Theme 22. Pancreas and adrenal medulla hormones. Local hormones.

Pancreas and adrenal medulla hormones. Chemical structure and mechanism of action. Hormonal regulation of blood sugar. Local hormones, their structure, biological role. Hormones of the digestive tract. Demonstration-practical work: Determination of the level of sugar in the blood of animals after the introduction of hormones. Determination of sugar in urine with Felling's reagent.

Content module 4.

Biochemistry of tissues and physiological functions.

Theme 23. Digestion of carbohydrates, lipids, proteins, nucleoproteins in the gastrointestinal tract.

Digestion of carbohydrates, lipids, proteins, nucleoproteins in the gastrointestinal tract. Enzymes, biochemical mechanisms. Chemical composition of gastric and intestinal juice. Hereditary disturbances of digestion.

Demonstration-practical work: Determination of all forms of gastric juice acidity.

Theme 24. Water-soluble vitamins B1, B2, B6, PP.

Biochemical characteristics and classification of vitamins. Water-soluble vitamins B1, B2, B6, PP. Their coenzyme role and symptoms of hypovitaminosis.

Demonstration-practical work: Qualitative reactions to vitamins B1, B2, B6, PP

Theme 25. Water-soluble vitamins C, biotin, folic acid, B12, pantothenic acid.

Water-soluble vitamins C, biotin, folic acid, B12, pantothenic acid. Structure, biological role and symptoms of hypovitaminosis.

Demonstration-practical work: Quantitative determination of vitamin C in products by the Tillmans method.

Theme 26. Fat-soluble vitamins.

Fat-soluble vitamins. Vitamins of groups A, D, E, K. Structure, biological role. Hypo- and hypervitaminosis manifestation.

Demonstration-practical work: Qualitative reactions to fat-soluble vitamins A, D, E, K (Vikasol).

Theme 27. Biochemical characteristics and functions of blood. Blood respiratory function.

Biochemical characteristics and functions of blood. Biochemical composition of blood plasma. Characteristics of protein fractions of blood. Characteristics of non-protein substances of blood plasma. Residual nitrogen of blood, its components. Diagnostic value of residual nitrogen determination in blood. Lipid transport forms - plasma lipoproteins. Types of hyperlipoproteinemia. The role of lipoproteins in the development of atherosclerosis. Osmotic pressure and acid-base state of blood. Blood buffer systems, hormonal regulation mechanisms, lung and kidney function. Blood respiratory function. Hemoglobin, structure, synthesis in the body. Role in the transport of oxygen and carbon dioxide. Abnormal hemoglobin.

Demonstration-practical work: Quantitative determination of blood proteins by biuret and refractometric methods. Serum protein fractionation by the "salting out" method. Determination of hemoglobin content in blood.

Theme 28. Biochemistry of coagulation, anticoagulation and fibrinolytic blood systems.

Biochemistry of coagulation, anticoagulation and fibrinolytic blood systems. Functional and biochemical characteristics of the homeostasis system in the human body: coagulation and vascular-platelet hemostasis. Blood coagulation system, characteristics of individual components (coagulation factors). Mechanisms of coagulation. The anticoagulation system of blood, anticoagulants. The role of vitamin K in coagulation reactions. Hereditary disorders of the blood coagulation system.

Demonstration-practical work: Determination of fibrinogen concentration in blood plasma. Determination of prothrombin time. Determination of plasma recalcification.

Theme 29. Biochemical functions of the liver. The role of the liver in the metabolism of bile pigments. Detoxification function of the liver.

Biochemical functions of the liver, its role in the metabolism of carbohydrates, lipids, and proteins. The role of the liver in the metabolism of bile pigments. Hemoglobin catabolism. Pathobiochemistry of jaundice, hereditary (enzymatic) jaundice. Detoxification function of the liver: biotransformation of xenobiotics and endogenous toxins. Types of biotransformations of xenobiotics. Reaction of microsomal oxidation, inducers and inhibitors of microsomal monooxidases. Conjugation reactions in hepatocytes: biochemical mechanisms, functional significance.

Demonstration-practical work: Determination of total, direct and indirect bilirubin in blood serum. Determination of hippuric acid and indican in urine.

Theme 30. Muscle biochemistry. Biochemistry of nervous tissue.

Muscle biochemistry. Features of the chemical composition and metabolism in muscles. Molecular mechanisms of muscle contraction. Bioenergetics of muscle tissue: sources of ATP in muscles. Features of the biochemical composition and metabolism of the nervous system. Biochemical composition of the brain. Energy metabolism of the human brain, the value of aerobic oxidation of glucose. Neurotransmitters: acetylcholine, norepinephrine, dopamine, serotonin. Molecular basis of bioelectrical processes on neuron membranes. Demonstration-practical work: Determination of creatinine and creatine levels in blood and urine.

Theme 31. Kidney biochemistry.

Kidney role in body fluids electrolyte composition and pH regulation. Biochemical mechanisms of the urine formation of the kidneys. Pathobiochemistry of kidneys. Biochemical composition of human urine in normal conditions and under conditions of pathological processes, nephrolithiasis. Clinical and diagnostic significance of urine composition analysis. Demonstration-practical work: Qualitative determination of protein in urine (heating and acid precipitation). Quantitative determination of protein by the Branderg-Stolnikov method. Quantitative determination of glucose in urine using a polarimeter.

Intermediate control for the semester.

4. The structure of the educational discipline

Themes	Number of hours					
	Total	including				
		lectures	seminars	practical classes	laboratories	Independent work
Content module 1. General patterns of metabolism						
Theme 1. General characteristics, properties of enzymes.	5	1	0	2	0	2
Theme 2. Mechanism of	5	1	0	2	0	2

action of enzymes. Kinetics of catalysis.						
Theme 3. Citric acid cycle.	5	1	0	2	0	2
Theme 4. Molecular mechanisms of tissue respiration. Peroxide and microsomal oxidation.	5	1	0	2	0	2
<i>Total by content module 1</i>	20	4	0	8	0	8
Content module 2. Metabolism of carbohydrates, lipids, amino acids and its regulation. Molecular biology.						
Theme 5. Intracellular catabolism of glucose.	5	1	0	2	0	2
Theme 6. Alternative pathways of monosaccharide metabolism.	5	1	0	2	0	2
Theme 7. Gluconeogenesis. Glycogen biosynthesis. Regulation of carbohydrate metabolism.	6	2	0	2	0	2
Theme 8. The role of lipids in the structure and functions of biological membranes. Oxidation of fatty acids and glycerol.	6	2	0	2	0	2
Theme 9. Biosynthesis of glycerol, fatty acids, glycerides and phospholipids.	4	1	0	2	0	1
Theme 10. Cholesterol metabolism. Metabolism of acetoacetic acid.	4	1	0	2	0	1
Theme 11. Ways of	4	1	0	2	0	1

formation and maintenance of the pool of amino acids in the body. Deamination, decarboxylation, transamination of amino acids.						
Theme 12. Ammonia metabolism in the human body.	4	1	0	2	0	1
Theme 13. Amino acids nitrogen-free skeleton metabolism in the body. Hereditary enzymopathies of amino acid metabolism.	4	1	0	2	0	1
Theme 14. Catabolism of purine and pyrimidine nucleotides.	4	1	0	2	0	1
Theme 15. Anabolism of purine and pyrimidine nucleotides.	4	1	0	2	0	1
Theme 16. Biosynthesis of nucleic acids.	4	1	0	2	0	1
Theme 17. Protein biosynthesis in ribosomes.	4	1	0	2	0	1
Theme 18. Fundamentals of molecular genetics	4	1	0	2	0	1
Intermediate control for the semester	8	0	0	4	0	4
<i>Total by content module 2</i>	70	16	0	32	0	22
Content module 3.						
Biochemistry of intercellular communications						
Theme 19. Hormones general concept. Hypothalamus and pituitary gland hormones.	5	1	0	2	0	2

Theme 20. Thyroid and parathyroid glands hormones. Regulation of phosphorus-calcium metabolism.	5	1	0	2	0	2
Theme 21. Steroid hormones.	5	1	0	2	0	2
Theme 22. Pancreas and adrenal medulla hormones. Local hormones.	5	1	0	2	0	2
<i>Total by content module 3</i>	20	4	0	8	0	8
Content module 4.						
Biochemistry of tissues and physiological functions						
Theme 23. Digestion of carbohydrates, lipids, proteins, nucleoproteins in the gastrointestinal tract. Water-soluble vitamins B1, B2, B6, PP.	4	1	0	2	0	1
Theme 24. Water-soluble vitamins B1, B2, B6, PP.	4	1	0	2	0	1
Theme 25. Water-soluble vitamins C, biotin, folic acid, B12, pantothenic acid.	3	0	0	2	0	1
Theme 26. Fat-soluble vitamins.	4	1	0	2	0	1
Theme 27. Biochemical characteristics and functions of blood. Blood respiratory function.	4	1	0	2	0	1
Theme 28. Biochemistry of coagulation, anticoagulation and fibrinolytic blood systems.	5	2	0	2	0	1
Theme 29. Biochemical functions of the	3	0	0	2	0	1

liver. The role of the liver in the metabolism of bile pigments. Detoxification function of the liver.						
Theme 30. Muscle biochemistry. Biochemistry of nervous tissue.	3	0	0	2	0	1
Theme 31. Kidney biochemistry.	2	0	0	2	0	0
Intermediate control for the semester	8	0	0	4	0	4
<i>Total by content module 4</i>	40	6	0	22	0	12
<i>Individual task</i>	0	0	0	0	0	0
Total hours	150	30	0	70	0	50

5. Themes of lectures / seminars / practical classes / laboratories

5.1. Themes of lectures

No	Theme	Hours
1.	Biochemistry as a science: biomolecules; metabolic pathways. Enzymes: structure, properties, classification and nomenclature. Kinetics and regulation of enzymatic reactions. Regulatory enzymes. Cofactors and coenzymes. Medical enzymology.	2
2.	Bioenergetics: general pathways of catabolism of carbohydrates, lipids, amino acids. Citric acid cycle. Biological oxidation and oxidative phosphorylation. Electron transport chain in mitochondria.	2
3.	Carbohydrate metabolism: glycolysis, glycogenolysis, oxidative decarboxylation of pyruvate, interconversion of monosaccharides, metabolism of fructose, galactose.	2
4.	Carbohydrate metabolism: Glycogen biosynthesis, pentose phosphate pathway, gluconeogenesis. Enzymopathies of carbohydrate metabolism (glycogen storage diseases). Diabetes mellitus.	2
5.	Lipid metabolism. Catabolism of triacylglycerols: oxidation of fatty acids and glycerol; ketogenesis.	2
6.	Lipid metabolism. Lipogenesis. Cholesterol metabolism. Regulation and pathology of lipid metabolism: obesity, atherosclerosis.	2
7.	Amino acid metabolism. General pathways of amino acid transformation (deamination, transamination, decarboxylation). Ammonia metabolism: urea biosynthesis and its disorders. Special pathways of amino acid transformation; hereditary enzymopathies of amino acid metabolism.	2
8.	Biosynthesis and catabolism of purine and pyrimidine nucleotides.	2
9.	Biosynthesis of nucleic acids: DNA replication; RNA transcription. Protein synthesis in ribosomes. Regulation of protein biosynthesis.	2

10.	Biochemical and molecular biological mechanisms of hormone action; hierarchy of hormones. Hormones of protein-peptide nature.	2
11.	Hormones and bioregulators - derivatives of amino acids; hormones and physiologically active compounds of lipid nature. Local hormones.	2
12.	Biochemistry of human nutrition. Vitamins and micro elements as components of human nutrition. Water-soluble vitamins.	2
13.	Fat-soluble vitamins, bioantioxidants. Exogenous and endogenous hypo- and avitaminosis, hypervitaminosis	2
14.	Chemical composition and functions of blood. Transport of gases by blood. Biochemistry and pathobiochemistry of hemoglobins. Biosynthesis of porphyrins, heme catabolism. Metabolism of bile pigments.	2
15.	Biochemistry of coagulation, anticoagulation and fibrinolytic systems. Violation of coagulation homeostasis	2
	Total	30

5.2. Themes of seminars

Seminars are not provided.

5.3. Themes of practical classes

No	Theme	Hours
1.	Practical class 1. General characteristics, properties of enzymes. The protein nature of enzymes. Active, allosteric enzyme centers. Regulation of enzyme activity. Enzyme activators and inhibitors. Coenzymes, their role in catalysis. Coenzyme functions of vitamins. International classification and nomenclature of enzymes. Proenzymes. Activation of proenzymes, role in metabolism. <i>Determining the structure of enzymes by biuret reaction, Foll's reaction.</i> <i>Determination of amylase activity of saliva and urine in the presence of activator and inhibitor.</i>	2
2.	Practical class 2. Basic theories of biocatalysis. Kinetics of catalysis. Methods of qualitative and quantitative determination of enzymes. Intracellular localization of enzymes. Use of enzymes in the clinic (fundamentals of medical enzymology). Enzyme diagnostics and enzyme therapy. Enzymopathies. <i>Demonstration of enzymograms.</i> <i>Observation of the kinetics of lipase action on milk fat.</i> <i>Effect of bile on lipase activity.</i>	2
3.	Practical class 3. Specific and general pathways of catabolism. Citric acid cycle (CAC). Sequence of reactions and characteristics of enzymes. Biological significance of CAC. Bioenergetics of significance. Anaplerotic and amphibolic reactions of CAC. <i>Detection of milk dehydrogenase.</i> <i>Detection of succinate dehydrogenase in muscles.</i>	2
4.	Practical class 4. The structure of mitochondria. Molecular organization of Electron transport chain: components; their redox-potential, molecular complexes of the inner mitochondria membranes. Oxidative phosphorylation in the respiratory chain. High energy compounds. Peroxide and microsomal oxidation. Antioxidant system. <i>Detection of oxidase (tyrosinase) in potatoes.</i> <i>Detection of peroxidase in horseradish extract.</i> <i>Detection of catalase in blood.</i>	2

	<i>Quantification of blood catalase (catalase number) according to Bach and Zubkova.</i>	
5.	Practical class 5. Intracellular catabolism of glucose. Glycolysis: reactions. Comparison of glycolysis and alcoholic fermentation. Glycogenolysis, regulation. Differences from glycolysis. Stages of aerobic oxidation of glucose: oxidative decarboxylation of pyruvate. Bioenergetics of the process. <i>Simulation of the "in vitro" process of glycolysis, determination of end products.</i> <i>Alcoholic fermentation test.</i> <i>Determination of pyruvate content in blood serum.</i>	2
6.	Practical class 6. Alternative pathways of monosaccharide metabolism. The pentose phosphate pathway of glucose oxidation: scheme, biological significance, features of functioning in various tissues. Metabolic pathways of fructose and galactose conversion: hereditary enzymopathies of their metabolism. <i>Detection of fructose by the Selivanov reaction.</i>	2
7.	Practical class 7. Glucose biosynthesis: physiological significance, reactions, regulatory enzymes. Substrates of gluconeogenesis. Glucose-lactate and glucose-alanine cycles. Regulation of glucose metabolism. Glucosemia: normal state and its disorders. Glycogen biosynthesis. Regulation of carbohydrate metabolism. Genetic disorders of glycogen metabolism of (glycogen storage diseases). <i>Determination of glucose content in the blood by the Hagedorn-Jenson method.</i> <i>Determination of glycogen in the liver.</i>	2
8.	Practical class 8. The role of lipids in the structure and functions of biological membranes. Molecular mechanisms of lipolysis regulation. Tissue, intracellular metabolism of lipids. Oxidation of fatty acids and glycerol. Energy yield from fatty acid β -oxidation. <i>Observation of the effect of bile on fat emulsification.</i> <i>Observation of the effect of pancreatic lipase on milk fat with and without bile.</i>	2
9.	Practical class 9. Biosynthesis of glycerol, fatty acids and glycerides. Formation of phospholipids. <i>Determination of total lipids in blood serum by the method of Bang.</i>	2
10.	Practical class 10. Structure, biological role and metabolism of cholesterol. Cholesterol biosynthesis. Disorders of lipid metabolism. Lipoproteins, structure and functions. Metabolism of acetoacetic acid. Ketone bodies. <i>Qualitative reactions to acetone (iodoformant, nitroprusside).</i> <i>Quantitative determination of acetone in urine by the Rudoy method.</i> <i>Qualitative response to the presence of cholesterol in the brain.</i>	2
11.	Practical class 11. Ways of formation and maintenance of the pool of amino acids in the body. Transport of amino acids into cells. Deamination of amino acids. Mechanism of indirect deamination of L-amino acids. Decarboxylation of amino acids: enzymes, physiological significance. Oxidation of biogenic amines. Transamination. Biochemical significance, mechanisms of action of aminotransferases. Diagnostic value of determination of aminotransferases in blood serum. <i>Quantitative determination of nitrogen of ammonium salts in urine by the Model method.</i> <i>Detection of alanine aminotransferase (AIAT) in normal and pathological blood serum.</i>	2
12.	Practical class 12. Ammonia metabolism in the human body. Urea. Ways of	2

	ammonia formation. Ammonia toxicity and mechanisms of its neutralization. Transport forms of ammonia (glutamine and asparagine). Urea biosynthesis: enzyme reactions, genetic anomalies. <i>Quantitative determination of urea in urine.</i>	
13.	Practical class 13. Ways of metabolism of the nitrogen-free skeleton of amino acids in the human body. Glycogenic and ketogenic amino acids. Special pathways of acyclic amino acids metabolism. Glutathione, its role in the metabolism of organic peroxides. Arginine metabolism, biological role of nitric oxide, NO-synthase. Metabolic features of branched-chain amino acid: participation of coenzyme forms of vitamin B12 in amino acid metabolism. Metabolic pathways of cyclic amino acids. Hereditary enzymopathies of cyclic and aliphatic amino acid metabolism. <i>Determination of phenyl pyruvate (Fehling's test)</i>	2
14.	Practical class 14. Nucleotides' metabolism in tissues: purine and pyrimidine nucleotides catabolism. Disorders of purine metabolism (gout). Demonstration-practical work: Quantitative determination of uric acid in urine.	2
15.	Practical class 15. Purine and pyrimidine nucleotides biosynthesis. Regulation of nucleotide biosynthesis. Deoxyribonucleotide biosynthesis. Formation of thymidine nucleotides: dTMF biosynthesis inhibitors as antitumor agents.	2
16.	Practical class 16. Biosynthesis of nucleic acids. Molecular mechanisms of DNA replication. Stages of synthesis of daughter chains of DNA molecules. Molecular mechanisms of transcription. RNA synthesis stages and enzymes. Processing as a post-transcriptional modification of RNA. Antibiotics as transcription inhibitors.	2
17.	Practical class 17. Protein biosynthesis in ribosomes. Genetic code: triplet code structure, its properties. Post-translational modification of peptide chains. Regulation of translation.	2
18.	Practical class 18. Regulation of gene expression. Mechanisms of DNA mutations and repairs. Obtaining recombinant DNA, transgenic proteins.	2
19.	Practical class 19. Intermediate control for the semester (part 1)	2
20.	Practical class 20. Intermediate control for the semester (part 2)	2
21.	Practical class 21. Hormones general concept. Classification, mechanisms of action of hormones on target cells. Hormones of the hypothalamus and pituitary gland hormones. Demonstration-practical work: Study of the nature of hormones using the biuret reaction.	2
22.	Practical class 22. Thyroid and parathyroid glands hormones. Structure and synthesis of thyroid hormones. Thyroid gland pathology. Regulation of phosphorus-calcium metabolism. Metabolic disorders of calcium homeostasis. Demonstration-practical work: Determination of iodine in the thyroid gland.	2
23.	Practical class 23. Steroid hormones. Hormones of the adrenal cortex and gonads. Their structure and biochemical mechanisms of action. Demonstration-practical work: Refractometric determination of protein in blood serum.	2
24.	Practical class 24. Pancreas and adrenal medulla hormones. Chemical structure and mechanism of action. Hormonal regulation of blood sugar. Local hormones, their structure, biological role. Hormones of the digestive tract. Demonstration-practical work: Determination of the level of sugar in the blood of animals after the introduction of hormones. Determination of sugar in urine with Felling's reagent.	2
25.	Practical class 25. Digestion of carbohydrates, lipids, proteins, nucleoproteins	2

	in the gastrointestinal tract. Enzymes, biochemical mechanisms. Chemical composition of gastric and intestinal juice. Hereditary disturbances of digestion. Demonstration-practical work: Determination of all forms of gastric juice acidity.	
26.	Practical class 26. Biochemical characteristics and classification of vitamins. Water-soluble vitamins B1, B2, B6, PP. Their coenzyme role and symptoms of hypovitaminosis. Demonstration-practical work: Determination of all forms of gastric juice acidity. Qualitative reactions to vitamins B1, B2, B6, PP	2
27.	Practical class 27. Water-soluble vitamins C, biotin, folic acid, B12, pantothenic acid. Structure, biological role and symptoms of hypovitaminosis. Demonstration-practical work: Quantitative determination of vitamin C in products by the Tillmans method.	2
28.	Practical class 28. Fat-soluble vitamins. Vitamins of groups A, D, E, K. Structure, biological role. Hypo- and hypervitaminosis manifestation. Demonstration-practical work: Qualitative reactions to fat-soluble vitamins A, D, E, K (Vikasol).	2
29.	Practical class 29. Biochemical characteristics and functions of blood. Biochemical composition of blood plasma. Characteristics of protein fractions of blood. Characteristics of non-protein substances of blood plasma. Residual nitrogen of blood, its components. Diagnostic value of residual nitrogen determination in blood. Lipid transport forms - plasma lipoproteins. Types of hyperlipoproteinemia. The role of lipoproteins in the development of atherosclerosis. Osmotic pressure and acid-base state of blood. Blood buffer systems, hormonal regulation mechanisms, lung and kidney function. Blood respiratory function. Hemoglobin, structure, synthesis in the body. Role in the transport of oxygen and carbon dioxide. Abnormal hemoglobin. Demonstration-practical work: Quantitative determination of blood proteins by biuret and refractometric methods. Determination of erythrocytes osmotic resistance. Determination of hemoglobin content in blood	2
30.	Practical class 30. Biochemistry of coagulation, anticoagulation and fibrinolytic blood systems. Functional and biochemical characteristics of the homeostasis system in the human body: coagulation and vascular-platelet hemostasis. Blood coagulation system, characteristics of individual components (coagulation factors). Mechanisms of coagulation. The anticoagulation system of blood, anticoagulants. The role of vitamin K in coagulation reactions. Hereditary disorders of the blood coagulation system. Demonstration-practical work: Determination of fibrinogen concentration in blood plasma. Determination of prothrombin time. Determination of plasma recalcification.	2
31.	Practical class 31. Biochemical functions of the liver, its role in the metabolism of carbohydrates, lipids, and proteins. The role of the liver in the metabolism of bile pigments. Hemoglobin catabolism. Pathobiochemistry of jaundice, hereditary (enzymatic) jaundice. Detoxification function of the liver: biotransformation of xenobiotics and endogenous toxins. Types of biotransformations of xenobiotics. Reaction of microsomal oxidation, inducers and inhibitors of microsomal monooxidases. Conjugation reactions in hepatocytes: biochemical mechanisms, functional significance. Demonstration-practical work: Determination of total, direct and indirect bilirubin in blood serum. Determination of hippuric acid and indican in urine.	2
32.	Practical class 32. Muscle biochemistry. Features of the chemical composition and metabolism in muscles. Molecular mechanisms of muscle contraction. Bioenergetics of muscle tissue: sources of ATP in muscles. Features of the	2

	biochemical composition and metabolism of the nervous system. Biochemical composition of the brain. Energy metabolism of the human brain, the value of aerobic oxidation of glucose. Neurotransmitters: acetylcholine, norepinephrine, dopamine, serotonin. Molecular basis of bioelectrical processes on neuron membranes. Demonstration-practical work: Determination of creatinine and creatine levels in blood and urine.	
33.	Practical class 33. Kidney role in body fluids electrolyte composition and pH regulation. Biochemical mechanisms of the urine formation of the kidneys. Pathobiochemistry of kidneys. Biochemical composition of human urine in normal conditions and under conditions of pathological processes, nephrolithiasis. Clinical and diagnostic significance of urine composition analysis. Demonstration-practical work: Qualitative determination of protein in urine (heating and acid precipitation). Quantitative determination of protein by the Branderg-Stolnikov method. Quantitative determination of glucose in urine using a polarimeter.	2
34.	Practical class 34. Intermediate control for the semester (part 1)	2
35.	Practical class 35. Intermediate control for the semester (part 2)	2
	Total	70

5.4. Themes of laboratories

Laboratories are not provided.

6. Independent work of the higher education applicant

No	Theme	Hours
1.	Theme 1. Preparation for practical class 1	2
2.	Theme 2. Preparation for practical class 2	2
3.	Theme 3. Preparation for practical class 3	2
4.	Theme 4. Preparation for practical class 4	2
5.	Theme 5. Preparation for practical class 5	2
6.	Theme 6. Preparation for practical class 6	2
7.	Theme 7. Preparation for practical class 7	2
8.	Theme 8. Preparation for practical class 8	2
9.	Theme 9. Preparation for practical class 9	1
10.	Theme 10. Preparation for practical class 10	1
11.	Theme 11. Preparation for practical class 11	1
12.	Theme 12. Preparation for practical class 12	1
13.	Theme 13. Preparation for practical class 13	1
14.	Theme 14. Preparation for practical class 14	1
15.	Theme 15. Preparation for practical class 15	1
16.	Theme 16. Preparation for practical class 16	1
17.	Theme 17. Preparation for practical class 17	1
18.	Theme 18. Preparation for practical class 18	1
19.	Preparation for practical class 19	2
20.	Preparation for practical class 20	2
21.	Theme 19. Preparation for practical class 21	2
22.	Theme 20. Preparation for practical class 22	2
23.	Theme 21. Preparation for practical class 23	2
24.	Theme 22. Preparation for practical class 24	2
25.	Theme 23. Preparation for practical class 25	1
26.	Theme 24. Preparation for practical class 26	1

27.	Theme 25. Preparation for practical class 27	1
28.	Theme 26. Preparation for practical class 28	1
29.	Theme 27. Preparation for practical class 29	1
30.	Theme 28. Preparation for practical class 30	1
31.	Theme 29. Preparation for practical class 31	1
32.	Theme 30. Preparation for practical class 32	1
33.	Theme 31. Preparation for practical class 33	0
34.	Preparation for practical class 34	2
35.	Preparation for practical class 35	2
	Total	50

7. Teaching methods

Lecture classes: lectures using multimedia presentations.

Practical classes: conversation, explanation, discussion, discussion of the acute issues; illustration (including multimedia presentations); testing, solving situational tasks and test tasks Krok-1.

Independent work:

independent work with recommended basic and additional literature, with electronic information resources, preparation for practical classes; independent work with the bank of test tasks Krok -1.

8. Forms of control and evaluation methods (including criteria for evaluating learning outcomes)

Current control: oral survey, testing, assessment of class activity.

Final control: exam.

Evaluation of the current educational activity in a practical lesson:

1. Evaluation of theoretical knowledge on the subject of the lesson:

- methods: survey, written work, solving a situational problem, solving test tasks;
- maximum score - 5, minimum score - 3, unsatisfactory score - 2.

2. Evaluation of intermediate control:

- methods: survey, written work, solving a situational problem, solving test problems;
- maximum score - 5, minimum score - 3, unsatisfactory score - 2.

The grade for one practical lesson is the arithmetic average of all components and can only have a whole value (5, 4, 3, 2), which is rounded according to the statistical method.

Current evaluation criteria for practical class:

Score	Evaluation criteria
Excellent «5»	The higher education applicant is fluent in the material, takes an active part in discussing and solving the situational problem, knows how to write the main biochemical reactions that occur in the body, determine the main biochemical indicators in biological objects and give them a medical (medico-biological)
Good «4»	The higher education applicant has a good command of the material, participates in the discussion and solution of the situational problem, knows how to write the main biochemical reactions, determine the main biochemical indicators in biological objects and give them a medical and biological evaluation, but allows some insignificant mistakes (inaccuracies) in answering questions.

Satisfactory «3»	The higher education applicant does not have sufficient knowledge of the material, is unsure of participating in the discussion and solution of the situational problem, makes mistakes when writing basic biochemical reactions.
Unsatisfactory «2»	The higher education applicant does not know the material, does not take part in the discussion and solution of the situational clinical problem, has significant gaps in the knowledge of the program material, makes fundamental mistakes when explaining the laws of human metabolism, does not have the necessary practical skills.

Only those higher education applicants who have fulfilled the requirements of the training program in the discipline, have no academic debt, their average score for the current educational activity in the discipline is at least 3.00, and they have passed the test control according to the tests "KROK - 1" at least 90% (50 tasks) are admitted to the final control in the form of an exam. ». The test control of the "KROK-1" tests is conducted in the Educational and Production Complex of Innovative Technologies of Learning, Informatization and Internal Monitoring of the Quality of Education of the University at the last class before the exam.

Evaluation of the results of the higher education applicant s' training during the final control - exam.

The method of final control in the form of an exam is unified and involves the use of standardized forms. The number of questions submitted to the exam corresponds to the amount of credits assigned to the study of the academic discipline.

The examinational card form is standardized and consists of structural elements (components): theoretical questions and practical tasks (situational tasks, case-tasks, descriptions, etc.). Theoretical questions are short, simple, understandable and transparent, a complete answer to one theoretical question lasts no more than 5 minutes. Practical tasks are clearly and understandably formulated, a complete answer to one practical question lasts no more than 5 minutes. The timing of the exam is standard - no more than 30 minutes.

Each examinational card is accompanied by a check-list (answer standard), which provides full correlation with the examinational card, contains a similar number of structural elements (components), has answer standards, which are mandatory for providing complete answers to the questions.

During the exam, the higher education applicant receives an examinational card, and the examiners use a check-list for the corresponding card with standard answers and determine which mandatory components of the answer were named or not named by the higher education applicant.

The overall grade for the exam is calculated as the arithmetic average of all grades obtained for answers to theoretical questions and practical tasks on a traditional four-point scale, rounded to two decimal places.

The exam is held in the Educational and Production Complex of innovative Technologies of Learning, Informatization and Internal Monitoring of the Quality of Education of the University during the examination sessions at the end of the semester (autumn and spring) according to the schedule.

9. Distribution of points received by higher education applicant s of higher education

The obtained average score for the academic discipline for higher education applicant s who have successfully mastered the work program of the academic discipline is converted from a traditional four-point scale to points on a 200-point scale, as shown in the table:

Conversion table of traditional to multi-point scale

National score for the discipline	The sum of scores for the discipline
Excellent («5»)	185 – 200
Good («4»)	151 – 184
Satisfactory («3»)	120 – 150
Unsatisfactory («2»)	Less than 120

A multi-point scale (200-point scale) characterizes the actual success of each higher education applicant in learning the educational component. The conversion of the traditional grade (average score for the academic discipline) into a 200-point grade is performed by the information and technical department of the University.

According to the obtained points on a 200-point scale, the achievements of the higher education applicants are evaluated according to the ECTS rating scale. Further ranking according to the ECTS rating scale allows you to evaluate the achievements of higher education applicants about the educational component who are studying in the same course of the same specialty, according to the points they received.

The ECTS scale is a relative-comparative rating, which establishes the higher education applicants belonging to the group of better or worse among the reference group of fellow higher education applicants (faculty, specialty). An "A" grade on the ECTS scale cannot be equal to an "excellent" grade, a "B" grade to a "good" grade, etc. When converting from a multi-point scale, the limits of grades "A", "B", "C", "D", "E" according to the ECTS scale do not coincide with the limits of grades "5", "4", "3" according to the traditional scale. Higher education applicants who have received grades of "FX" and "F" ("2") are not included in the list of ranked higher education applicants. The grade "FX" is awarded to higher education applicants who have obtained the minimum number of points for the current learning activity, but who have not passed the final examination. A grade of "F" is assigned to higher education applicants who have attended all classes in the discipline, but have not achieved a grade point average (3.00) for the current academic activity and are not admitted to the final examination.

Applicants who study at the same course (same specialty), based on the number of points scored in the discipline, are ranked on the ECTS scale as follows:

Conversion of the traditional grade from the discipline and the sum of points on the ECTS scale

Score on the ECTS scale	Statistical indicator
A	The best 10% of higher education applicants
B	The next 25% of higher education applicants
C	The next 30% of higher education applicants
D	The next 25% of higher education applicants
E	The next 10% of higher education applicants

10. Methodological support

- Working program in the discipline
- Syllabus
- Methodological recommendations for the practical classes in the discipline
- Methodological recommendations for the individual work of higher education applicants
- Multimedia presentations
- Situational tasks
- Tests on the theme

Educational and methodical literature:

11. Questions for the final control

1. Enzymes: definition; properties of enzymes as biological catalysts.
2. Classification and nomenclature of enzymes, characteristics of individual classes of enzymes.
3. Structure and mechanisms of action of enzymes. Active and allosteric (regulatory) centers.
4. Cofactors and coenzymes. The structure and properties of coenzymes, vitamins as precursors in the biosynthesis of coenzymes. Coenzymes: The types of reactions catalyzed by particular classes of coenzymes.
5. Isoenzymes, features of structure and functioning, importance in diagnosis of diseases.
6. Mechanisms of action and kinetics of enzymatic reactions: dependence of the reaction rate on substrate concentration, pH, and temperature. Principles and methods of detecting enzymes in biological objects. Units of activity and amount of enzymes.
7. Enzyme activators and inhibitors: examples and mechanisms of action.
8. Types of enzyme inhibition: reverse (competitive, non-competitive) and irreversible inhibition.
9. Regulation of enzymatic processes. Ways and mechanisms of regulation: allosteric enzymes; covalent modification of enzymes. Cyclic nucleotides (cAMP, cGMP) as regulators of enzymatic reactions and biological functions of the cell.
10. Enzymopathies - congenital (hereditary) defects in the metabolism of carbohydrates, amino acids, porphyrins, and purines.
11. Enzyme diagnosis of pathological processes and diseases.
12. Enzymotherapy - use of enzymes, their activators and inhibitors in medicine.
13. General characteristics of energy metabolism. Metabolism: catabolism, anabolism and amphibolic pathways. General and specific pathways of catabolism. Stages of intercellular catabolism of biomolecules: proteins, carbohydrates, lipids.
14. The Citric Acid Cycle (CAC). Location in the cell. Enzymes of CAC. Importance of CAC. Bioenergetics of Citric Acid Cycle. Physiologic importance of CAC.
15. Reactions of biologic oxidation. Types of reactions: dehydrogenase, oxidase, oxygenase reactions and their biologic importance. Chemical nature of dehydrogenases. Role of coenzymes in the functions of enzymes.
16. Tissue respiration. Flavoenzymes. Chemical nature and biochemical role. Cytochromes. Cytochrome oxidase, its chemical nature, the biochemical role and mechanism of participation in the respiratory chain.
17. Oxidative phosphorylation: coupling points of electron transport and phosphorylation, coefficient of oxidative phosphorylation.
18. The chemiosmotic theory of oxidative phosphorylation. ATP synthase of mitochondria. Inhibitors of electron transport and uncouplers of oxidative phosphorylation.
19. Microsomal oxidation. Cytochrome P450 and molecular organization of the electron transport chain. Detoxification of xenobiotics and formation of biological active compounds.
20. Aerobic and anaerobic oxidation of glucose, general characteristics of the processes.
21. Anaerobic oxidation of carbohydrates. Glycolysis.
22. Oxidative-reduction steps of anaerobic glycolysis, its importance. Shuttle mechanism for the transfer of reducing equivalents of NADH.
23. Aerobic oxidation of glucose. The sequence of reactions and enzymes of glycolysis. Oxidative decarboxylation of pyruvate. Enzymes, coenzymes and the sequence of reactions in a multienzyme complex.
24. The comparison of bioenergetics of aerobic and anaerobic oxidation of glucose and glycogen. Pasteur's effect.

25. Pentose phosphate pathway of carbohydrates metabolism. Regulation of glycogen phosphorylase activity.
26. Biosynthesis and catabolism of glycogen in the liver. Regulation of glycogen synthase activity.
27. Mechanism of reciprocal regulation of glycogenolysis and gluconeogenesis by cAMP dependent cascade phosphorylation of enzymes. The role of adrenaline, glucagon and insulin in hormonal regulation of glycogen metabolism in muscles and liver.
28. Genetic disorders of glycogen metabolism (glycogenosis, aglycogenosis).
29. Gluconeogenesis. Mechanism in the different tissues and organs. Corey's cycle and the glucose alanine cycle.
30. Blood glucose (glucosemia): normoglycemia, hypo- and hyperglycemia, glucosuria. Diabetes mellitus is a pathology of glucose metabolism. Hormonal regulation of blood glucose concentration and metabolism.
31. Pentose phosphate pathway of glucose oxidation: scheme of the process and biological significance. Metabolic ways of conversion of fructose and galactose; hereditary enzymopathies of their metabolism.
32. Catabolism of triacylglycerols in adipocytes of adipose tissue: sequence of reactions, mechanisms of regulation of triglyceride lipase activity. Neurohumoral regulation of lipolysis with the participation of adrenaline, norepinephrine, glucagon and insulin).
33. Fatty acid oxidation reactions (β -oxidation); the role of carnitine in the transport of fatty acids in mitochondria. Energy value of in-oxidation of fatty acids in cells.
34. Glycerol oxidation: enzymatic reactions, bioenergetics.
35. Ketone bodies. Reactions of biosynthesis and disposal of ketone bodies, physiological significance. Violation of the metabolism of ketone bodies under pathological conditions (diabetes mellitus, starvation).
36. Biosynthesis of higher fatty acids: reactions of biosynthesis of saturated fatty acids (palmitate) and regulation of the process. Biosynthesis of mono- and polyunsaturated fatty acids in the human body.
37. Biosynthesis of triacylglycerols and phosphoglycerides. Metabolism of sphingolipids. Genetic abnormalities of sphingolipid metabolism - sphingolipidosis.
38. Cholesterol biosynthesis: scheme of reactions, regulation of cholesterol synthesis. Ways of biotransformation of cholesterol: esterification; formation of bile acids, steroid hormones, vitamin D3.
39. Pathologies of lipid metabolism: atherosclerosis, obesity, diabetes.
40. Circulatory transport and deposition of lipids in adipose tissue. Endothelial lipoprotein lipase. Blood plasma lipoproteins: lipid and protein (apoprotein) composition. Hyperlipoproteinemia.
41. The pool of the amino acids in the body. Routes for transport and utilization of amino acids in tissues. Glucogenic and ketogenic amino acids.
42. Direct and indirect deamination of free L-amino acids in tissues.
43. Transamination of amino acids: reactions and their biochemical significance, mechanisms of action of aminotransferases.
44. Decarboxylation of L-amino acids in the human body. Physiological value of the products formed. Oxidation of biogenic amines.
45. Ways of formation and neutralization of ammonia in the body. Urea biosynthesis: the sequence of enzymatic reactions of biosynthesis, genetic anomalies of urea cycle enzymes.
46. Biosynthesis and biological role of creatine and creatine phosphate. Glutathione: structure, biosynthesis and biological functions of glutathione.
47. Specialized ways of metabolism of cyclic amino acids - phenylalanine and tyrosine. Hereditary enzymopathies of the exchange of cyclic amino acids - phenylalanine and tyrosine. Metabolism of the cyclic amino acid tryptophan and its hereditary enzymopathies.

48. Nitrogen bases, nucleosides and nucleotides as the composite components of the nucleic acids. Minor nitrogen bases and nucleotides. Free nucleotides: ATP, NAD⁺, NADP⁺, FAD, FMN, CTP, UTP, 3',5'-cAMP, 3',5'-cGMP, their biochemical functions.
49. Nucleic acids. General characteristics of DNA and RNA, their biological importance in the storage and the transfer of genetic information. Features of DNA and RNA primary structure. Chemical bonds, which are responsible for the formation of nucleic acids primary structure.
50. Secondary structure of DNA, role of hydrogen bonds in its formation (Chargaff's rules, Watson-Crick model), anti-parallelity of strands. Tertiary structure of DNA. Physical and chemical properties of DNA, interaction with cation ligands, formation of nucleosomes.
51. Molecular organization of nuclear chromatin of eukaryotes; nucleosome organization, histone and non-histone proteins. Nucleoproteins: structure, biological functions.
52. Structure, properties and biological functions of RNA. Types of RNA: m-RNA, t-RNA, r-RNA. Features of the different type of RNA structural organization.
53. Biosynthesis of purine nucleotides; scheme of IMP synthesis reactions. Formation of AMP and GMP from IMP, mechanisms of regulation.
54. Biosynthesis of pyrimidine nucleotides; scheme of reactions, regulation of synthesis. Biosynthesis of deoxyribonucleotides. Formation of the thymidine nucleotides. Inhibitors of TMP synthesis as anti-cancer medicines. Catabolism of purine nucleotides, hereditary disturbances of the uric acid metabolism.
55. Replication of DNA, its biological importance, and semiconservative mechanism of replication.
56. RNA transcription: prokaryotes and eukaryotes RNA-polymerases, signals of transcription: promoter, initiator and terminator fragments of genome. Processing and post-translational modification of synthesized RNA.
57. Genetic (biologic) code, triplet structure and properties. Transport RNA and transportation of amino acids. Amino acyl-tRNA-synthetases. Steps and mechanism of translation (protein synthesis) in ribosomes: initiation, elongation and termination.
58. Post-translational modification of peptide chains. Regulation of translation. Inhibitors of transcription and translation in prokaryotes and eukaryotes. Antibiotics and interferons, they use in medicine. Diphtheria toxin.
59. Regulation of prokaryote gene expression: regulatory and structural fragments of lactose, Lac-operon, gene regulator, promoter, operator.
60. Gene engineering: construction of recombinant DNA, gene cloning. Genetic engineering of enzymes, hormones, interferons, etc.
61. Mutations: genome, chromosome, gene. Mechanisms of mutagen activity; role of the induced mutations in the origin of the enzymopathy and hereditary human diseases. Biological importance and mechanisms of DNA reparations. Reparation of UV-induced gene mutations: xeroderma pigmentosum.
62. Hormones and their general characteristics. Role of hormones and other bioregulators in the system of the intracellular integration of the human organism functions.
63. Classification of hormones and bioregulators in correspondence of structure and mechanisms of hormone activity.
64. Reaction of the target cells on the hormone action. Membrane (ionotropic, metabotropic) and cytosol receptors. Biochemical systems of the hormonal signals intracellular transfer: G-proteins, and secondary messengers cAMP, Ca²⁺-calmodulin, inositol-3-phosphate, and diacylglycerol. Molecular cell mechanisms of the steroid and thyroid hormone activity.
65. Neuropeptides of hypothalamus. Liberins and statins, their mechanisms of activity and biologic role.
66. Hormones of pituitary gland: melanotropin, thyrotropin, corticotropin, lutropin, somatotropin (growth hormone), prolactin. Their mechanisms of activity and biological role. Pathological processes related to the disturbances of hormone functions. Hormones of

- posterior lobe of pituitary gland. Vasopressin and oxytocin: structure, biological functions. Pathological processes related to the disturbances of hormone functions.
67. Insulin: structure, biosynthesis and secretion. Mechanism of insulin activity on the carbohydrate metabolism. Mechanism of insulin activity on the lipid metabolism. Mechanism of insulin activity on the protein and nucleotide metabolism. Glucagon and its mechanisms of activity on the carbohydrate and lipid metabolism.
 68. Thyroid hormones, their structures, biological effects of T3 and T4. Disturbances of metabolic processes due to hypo- and hyperthyreosis.
 69. Epinephrine, norepinephrine, dopamine, their structure, biosynthesis, physiological effects, biochemical mechanisms of activity. Pathological processes related to the disturbances of hormone functions.
 70. Steroid hormones of the suprarenal glands (C₂₁-steroids), glucocorticoids and mineralocorticoids, their structures and properties. Mechanisms of glucocorticoids activity on the carbohydrate and lipid metabolism. Mechanisms of glucocorticoids activity on the protein and nucleotide metabolism.
 71. Female sex hormones estrogens, progesterone. Physiological and biochemical effects, related to the ovulation cycle phases. Male sex hormones (C₁₉-steroids). Physiological and biochemical effects of androgens, regulation of synthesis and secretion.
 72. Eicosanoids: structure, biological and pharmacological properties. Aspirin and other nonsteroidal anti-inflammatory drugs as inhibitors of prostaglandin synthesis.
 73. Biochemistry of human nutrition, the food components and nutrients, biological value of certain nutrients.
 74. Mechanisms of conversion of nutrients, proteins, carbohydrates, and lipids, in the digestive tract. The saliva, stomach and intestine enzymes. Digestion disorders of certain nutrients in the stomach and intestines, and hereditary enzymopathies of digestive processes.
 75. Microelements in human nutrition. Biological functions of certain microelements, and microelement deficiency manifestations.
 76. Vitamins in human nutrition. Water-soluble and fat-soluble vitamins; exogenous and endogenous causes of vitamin deficiency.
 77. Vitamin B₁ (thiamin): structure, biological properties, mechanism of action, the sources, daily need. Vitamin B₂ (riboflavin): structure, biological properties, mechanism of action, the sources, daily need. Vitamin PP (nicotinic acid, nicotinamide): structure, biological properties, mechanism of action, manifestations of deficiency, sources, the daily need.
 78. Vitamin B₆ (pyridoxine): structure, biological properties, mechanism of action, the sources, the daily need. Vitamin B₁₂ (cobalamin): biological properties, mechanism of action, manifestations of deficiency, sources, the daily need. Vitamin B_c (Folic Acid): biological properties, mechanism of action, the sources, the daily need.
 79. Vitamin H (biotin): biological properties, mechanism of action, the sources, the daily need. Vitamin B₃ (pantothenic acid): biological properties, mechanism of action, the sources, and the daily need. Vitamin C (ascorbic acid): structure, biological properties, mechanism of action, manifestations of deficiency, sources, the daily need. Vitamin P (flavonoids): structure, biological properties, mechanism of action, manifestations of deficiency, sources, the daily need.
 80. Vitamin A (retinol, retinal, retinoic acid): biological properties, mechanism of action, manifestations of deficiency, sources, the daily need. Vitamin D₃ (cholecalciferol): biological properties, mechanism of action, manifestations of deficiency, sources, the daily need.
 81. Vitamin K (phylloquinone, farnohinon): biological properties, mechanism of action, manifestations of deficiency, sources, the daily need. Vitamin E (α -tocopherol): biological properties, mechanism of action, manifestations of deficiency, sources, the daily need.

82. Biochemical and physiological functions of blood in the human body. Respiratory function of erythrocytes. Hemoglobin: mechanisms of its' participation in the transport of oxygen and carbon dioxide. Types and pathological forms of human hemoglobin. The decomposition of hemoglobin. Differential diagnosis of jaundice.
83. Buffer systems of blood. Acid-base balance disturbances in the body, metabolic and respiratory acidosis, and alkalosis. Mechanisms of compensation. Biochemical composition of human blood. Plasma proteins and their clinical and biochemical characteristics.
84. Enzymes of plasma; its' importance in enzyme diagnostics of diseases. Kallikrein-kinin system of blood and tissues. Medicines, which are antagonists of kinin formation.
85. Non-protein organic compounds of plasma. Inorganic plasma components.
86. Biochemical and functional characteristics of the hemostasis system.
87. Coagulation and characterization of certain factors of coagulation, mechanism of function of the cascade blood clotting system. The role of vitamin K in the reactions of coagulation, therapeutic agents, which are agonists and antagonists of vitamin K.
88. Anticoagulation blood system and characteristics of anticoagulants. Hereditary disorders of blood coagulation. Fibrinolytic system of blood. Medicines that affect the processes of fibrinolysis.
89. Immunoglobulins and biochemical characteristics of individual classes of human immunoglobulins. Mediators and hormones of the immune system: interleukins, interferons, protein-peptide factors regulating growth and cell proliferation. Complement system, biochemical components of human complement, and the classical and alternative ways of activation. Biochemical mechanisms of immunodeficiency states: primary (hereditary) and secondary immunodeficiencies.
90. Biochemical functions of liver: carbohydrate and protein synthetic, urine formation, cholepoietic, regulation of lipid composition of blood.
91. Detoxicative function of liver. Types of biotransformation reactions of xenobiotics and endogenous toxins.
92. Microsomal oxidation reactions. Cytochrome P450 and related electron-transport chain in the membranes of the endoplasmic reticulum of hepatocytes.
93. Metholism of porphyrins: structure of heme. Scheme of protoporphyrin IX and heme biosynthesis. Hereditary disorders of the porphyrins biosynthesis, types of porphyrias.
94. Catabolism of hemoglobin and heme (scheme); formation and structure of bile pigments. Pathobiology and types of jaundice; biochemical diagnosis of jaundice. The role of the liver in the metabolism of bile pigments. Pathobiology of jaundice. Types of hereditary (enzyme) jaundice.
95. Water-salt metabolism in the body. Intracellular and non-cellular water; metabolism of water, sodium, potassium. The role of the kidneys in regulating the volume, electrolyte composition and pH of the body fluids. Biochemical mechanisms of urine-forming function of the kidneys.
96. Renin-angiotensin system of the kidneys. Hypotensive drugs - angiotensin converting enzyme inhibitors.
97. Biochemical composition of muscles. Myocyte proteins: myosin, actin, tropomyosin, troponin. Molecular mechanisms of muscle contraction. The role of Ca^{2+} ions in the regulation of muscle contraction and relaxation. Bioenergy of muscle tissue. ATP sources. The role of creatine phosphate in providing energy for muscle contraction.
98. Biochemistry of the nervous system: features of the biochemical composition and metabolism of the brain. Energy metabolism in the human brain. The value of aerobic oxidation of glucose; changes in conditions of physiological sleep and anesthesia.
99. Biochemistry of neurotransmitters; receptors of neurotransmitters and physiologically active compounds. Peptidergic system of the cerebrum: opioid peptides, receptors of opioid peptides.

100. Violations of the metabolism of mediators and modulators of the brain in mental disorders. Neurochemical mechanisms of psychotropic drugs action.

12. Recommended literature

Basic:

1. Gubsky Yu.I., I.V. Nizhenkovska, Korda M.M. Biological and Bioorganic Chemistry: in 2 books. Book 2. Biological Chemistry: textbook. 2021. 544 p.
2. Satyanarayana U. Biochemistry. 5th edition. India 2020. 777 p.
3. Lehninger. Principles of Biochemistry. 7th edition. NY, United States. 2017.
4. Jeremy M. Berg, John L. Tymoczko, Gregory J. Gatto. Biochemistry. 8th Revised edition. 2015.
5. Lippincott Illustrated Reviews: Biochemistry. Philadelphia :Wolters Kluwer, 2017. 560 p.
6. Baynes J., Dominiczak M. Medical Biochemistry. 5th Edition. Elsevier, 2018. 712 p.
7. Donald Voet, Judith G. Voet, Charlott W. Pratt. Fundamentals of Biochemistry: Life at the Molecular Level. ISBN: 978-1-118-91840-1 February 2016, 1184 p.

Additional:

1. William Marshall, Marta Lapsley, Andrew Day, Kate Shipman. Clinical Chemistry. Elsevier, 2020. 432 p.
2. Harper's Illustrated Biochemistry / V.W. Rodwell, D.A. Bender, K.M. Botham et al. – Mc Graw Hill Education, 2015. – 817 p.
3. Storchylo O. V. Membrane digestion and absorption of some nutrients in vitro and in vivo: Revision and analysis of own Data. *Journal of Gastrointestinal & Digestive System*. 2018. Vol. 8. DOI: 10.4172/2161-069X-C1-064 (12th Global Gastroenterologists Meeting and 3rd International Conference on Metabolic and Bariatric Surgery, Barcelona, Spain, 15-16 March 2018).
4. Storchylo O. V. (2019) Mechanisms of radioprotective and radiocorrective effects of dietary phytoadditive of milk thistle fruits. *Environment&Health*. 2019. №1 (90). P. 33-37.
<https://doi.org/10.32402/dovkil2019.01.033>.
5. Storchylo Olha V. (2019) Mechanisms of the implementation of damage to the functions of the small intestine in two generations of posterity of irradiated rats. *Seventh International Conference on Radiation in Various Fields of Research (RAD 2019)*. June 10-14, 2019|Hunguest Sun Resort|Herceg Novy|Montenegro| www.rad-conference.org. P.452.
https://www.rad-conference.org/Book_of_Abstracts-RAD_2019.pdf.

13. Electronic information resources

1. <http://info.odmu.edu.ua/chair/biology/>- materials of the Department of Medical Biology and Chemistry
2. <http://libblog.odmu.edu.ua/> - ONMedU library
3. <https://moodle.odmu.edu.ua/login/index.php> - system of electronic testing and electronic journal of ONMedU
4. <http://moz.gov.ua> – Ministry of Health of Ukraine
5. www.who.int – World Health Organization
6. www.dec.gov.ua/mtd/home/ - State Expert Center of the Ministry of Health of Ukraine
7. <http://bma.org.uk> – British Medical Association
8. www.gmc-uk.org - General Medical Council (GMC)
9. www.bundesaerztekammer.de – German Medical Association