**MINISTRY OF HEALTH OF UKRAINE**

**ODESA NATIONAL MEDICAL UNIVERSITY**

Department of Medical Biology and Chemistry

**CONFIRMED by**

Vice-rector for scientific and pedagogical work

_____ Eduard BURIACHKIVSKYI

September 1st, 2024

# WORKING PROGRAM IN THE DISCIPLINE «BIOLOGICAL AND BIOORGANIC CHEMISTRY»

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

**Field of knowledge:** 22 «Health care»

**Specialty:** 222 «Medicine»

**Educational and professional program**: Medicine

**2024**

The working program is compiled on the basis of the educational and professional program "Medicine" for the training of specialists of the second (master's) level of higher education in the specialty 222"Medicine" of the field of knowledge 22 "Health care", approved by the Academic Council of ONMedU (minutes No. 10 dated 27.06.2024).

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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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Approved by the subject-cycle methodological commission for Biomedical Sciences of ONMedU
Minutes No. _1_ dated 27.08 2024

Head of the subject-cycle methodological commission for Biomedical Sciences of ONMedU
_____ Leonid GODLEVSKY

Revised and approved at the meeting of the Department of _____
_____
Minutes No. __ dated __/__/20__.

Head of the department _____

Revised and approved at the meeting of the Department of _____
_____
Minutes No. __ dated __/__/20__.

Head of the department _____

Revised and approved at the meeting of the Department of _____
_____
Minutes No. __ dated __/__/20__.

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:<br><br>Credits of ECTS:8<br><br>Hours: 240<br><br>Content modules: 5 | Field of knowledge<br>22 «Health care»<br><br>Specialty<br>222«Medicine»<br><br>Level of higher education<br>second (master's degree) | *Full-time (day) education*<br>*Compulsory discipline* |
| | | *Course: 1,2* |
| | | *Semester: II-IV* |
| | | *Lectures (32 hours)* |
| | | *Seminars (0 hours)* |
| | | *Practical classes (128 hours)* |
| | | *Laboratories (0 hours)* |
| | | *Independent work (80 hours)* |
| | | *including individual tasks (0 hours)* |
| | | *Form of final control – Exam* |

## 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:**

GC1. Ability to abstract thinking, analysis and synthesis
GC 2. Ability to learn and master modern knowledge
GC 3. Ability to apply knowledge in practical situations
GC 4. Knowledge and understanding of the subject area and understanding of professional activity
GC 7. Ability to work in a team
GC 10. Ability to use information and communication technologies
GC 11. Ability to search, process and analyze information from various sources
GC 16. Ability to evaluate and ensure the quality of the work performed
GC 17. Desire to preserve the environment

- **Special competencies are:**

SC 2. Ability to determine the necessary list of laboratory and instrumental studies and evaluate their results

SC 17. Ability to assess the impact of the environment, socio-economic and biological determinants on the state of health of an individual, family, population

SC 23. Ability to develop and implement scientific and applied projects in the field of health care

SC 24. Adherence to ethical principles when working with patients and laboratory animals

SC 25. Adherence to professional and academic integrity, being responsible for the reliability of the obtained scientific results

SC 28. Ability to apply fundamental biomedical knowledge at a level sufficient to perform professional tasks in the field of health care.

**Program learning outcomes** are:

PLO 1. Having a thorough knowledge of the structure of professional activity. Being able to carry out professional activities that require updating and integration of knowledge. To be responsible for professional development, the ability for further professional training with a high level of autonomy.

PLO 2. Understanding and knowledge of basic and clinical biomedical sciences, at a level sufficient for solving professional tasks in the field of health care.

PLO 3. Specialized conceptual knowledge that includes scientific achievements in the field of health care and is the basis for conducting research, critical understanding of problems in the field of medicine and related interdisciplinary problems, including the system of early intervention.

PLO 21. Searching for the necessary information in the professional literature and databases of other sources, analysing, evaluating and application of this information.

PLO 23. Assessment of the impact of the environment on human health to assess the morbidity of the population.

PLO 24. Organization of the necessary level of individual safety (own and the persons he cares for) in case of typical dangerous situations in the individual field of activity.

**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.
### Biologically important classes of bioorganic compounds. Biopolymers and their structural components.

**Theme 1. Classification, nomenclature, isomerism of bioorganic compounds. The nature of chemical bonds. Types of chemical reactions.**

Theory of the structure of organic substances. Classification of organic compounds. Nomenclature of organic compounds: trivial, rational, IUPAC. Isomerism of organic compounds. Electronic displacements in molecules of organic compounds: inductive and mesomeric effects.

**Theme 2. Study of reactivity of alkanes, alkenes, arenes.**

Alkanes, alkenes, alkynes, arenes. Nomenclature and isomerism. Mechanism of free-radical substitution in alkanes. Chemical properties of alkenes. Electrophilic addition to alkenes. Markovnikov's rule and its modern interpretation. Benzene (electronic and spatial structure). Mechanism of electrophilic substitution in an aromatic ring.

**Theme 3. Structure and properties of hydroxo- and oxocompounds. Biologically active hydroxo- and oxocompounds.**

Classification, nomenclature and isomerism of hydroxocompounds (alcohols and phenols). Comparative characteristics of acidic properties of alcohols and phenols. Nomenclature and isomerism of aldehydes and ketones. nucleophilic addition to oxocompounds. Medical and biological significance of hydroxo- and oxocompounds.

**Theme 4. Study of the reactivity of carboxylic acids and their heterofunctional derivatives (amino alcohols, hydroxy acids, keto acids and phenolic acids). Use of carboxylic acids in medicine.**

Nomenclature and classification of carboxylic acids. Isomerism (structural and optical) of carboxylic acids. Homologous series of saturated monobasic carboxylic acids. The structure of the carboxyl group. Hydroxy acids. Oxoacids. Aromatic acids and their derivatives. Chemical properties of carboxylic acids and their derivatives

**Theme 5. Study of the properties of natural higher fatty acids. Triglycerides. Lipids.**

The main structural components of lipids. Classification of lipids and their biological functions. Features of the structure of the structural components of saponified lipids (triacylglycerols): higher fatty acids (saturated and unsaturated) and alcohols (polyatomic and monoatomic). Chemical properties of lipids. Analytical characteristics of fats.

**Theme 6 Phospholipids. Biological significance and structure of the lipid component of biomembranes.**

Classification of complex lipids. Components of complex saponified lipids. Phospholipids. Features of the structure. Chemical properties of phospholipids. Other representatives of complex lipids (glycolipids, sphingolipids, cerebrosides, sphingomyelins). Lipid composition of membranes. Biological functions of phospholipids.

**Theme 7. Carbohydrates. Structure and chemical properties of monosaccharides.**

Classification of carbohydrates. Isomerism. Tautomeric forms of monosaccharides. Mutarotation. Chemical reactions of monosaccharides involving the carbonyl group. Redox reactions as qualitative reactions for the detection of an aldehyde group.

**Theme 8. Structure and functions of di- and polysaccharides.**

Classification of disaccharides according to their capacity for redox reactions. Types of glycosidic bonds between monosaccharide residues and their influence on the reactivity of disaccharides. Structure, properties and role in structure formation of maltose and cellobiose polysaccharides, their tautomeric forms. Structure and properties of lactose and sucrose. Inversion of sucrose due to hydrolysis. Structure, biological role and application of starch, its components. Scheme of the structure of amylose and amylopectin. Confirmatory structure and secondary structure of amylose. Hydrolysis of starch and qualitative reaction of its determination. Structural and biological role of glycogen and fiber. Their role in the life processes of the body.

**Theme 9. Chemical properties of carbohydrates. Qualitative reactions for the determination of carbohydrates.**

Qualitative reactions to polyatomic alcohols. Qualitative reactions of the opening of the aldehyde group. Selivanov reaction for ketones. Qualitative reactions of disaccharides. Sucrose hydrolysis reaction. Qualitative reaction to starch.

**Theme 10. Study of the amino acid composition of proteins and peptides.**

Nomenclature and classification of amino acids. The structure of the 20 most important α-amino acids. Isomerism of amino acids. D - and L- genetic series. Physicochemical properties of amino acids. General chemical properties of amino acids (reactions of deamination, peramination, decarboxylation, specific properties of α-, β-, γ-amino acids). Polycondensation reactions of α-amino acids with the formation of peptides and proteins.

**Theme 11. Organization of protein structure. Physicochemical properties of proteins. Protein precipitation reactions. Denaturation. Qualitative reactions for the determination of amino acids and proteins**

Biological role of proteins in the body. Physicochemical properties of proteins. Levels of protein structure. Types of connections. Salting out proteins. Denaturation. Qualitative reactions to amino acids, peptides, proteins.

**Topic 12: Classification, structure and significance of biologically active five-membered heterocyclic compounds with one and two heteroatoms.**

Classification of heterocycles by cycle size, number and type of heteroatoms. Structure and properties of pyrrole, furan, thiophene. Non-benzene aromatic systems. Biological significance of tetrapyrrole compounds: porphins, porphyrins, heme. Indole and its derivatives, their formation.

Thiophene as a structural component of the biotin molecule. Pyrazole. Pyrazolone-5 and its derivatives as drugs (analgin, amidopyrine, antipyrine). Imidazole and its derivatives (histidine and histamine). Five-membered heterocycles with two different heteroatoms: thiazole, oxazole. Thiazole as a structural component of vitamin B1.

**Topic 13. Biologically important six-membered heterocycles with one and two heteroatoms. Condensed heterocycles.**

Pyridine as an aromatic system. Chemical properties. Pyridine derivatives as medicinal products. Vitamin PP as a component of redox coenzymes NAD and NADP. Pyrimidine and its derivatives (uracil, thymine, cytosine). Tautomeric forms of pyrimidine bases. Barbituric acid. Phenobarbital and veronal as hypnotics and anticonvulsants. Purine and its amino derivatives (adenine, guanine), their tautomeric forms and biological significance. Purine hydroxy derivatives (hypoxanthine, xanthine, uric acid) and their tautomeric forms.

**Theme 14. Structure and biological role of nucleosides, nucleotides and nucleic acids.**

Nucleosides and nucleotides as products of incomplete hydrolysis of nucleic acids. Nucleosides as therapeutic agents. The structure of nucleotides - components of nucleic acids (AMP, HMF, UMF, TMF, TMF). The structure and value of 3',5'-ts-AMP, its role in the action of hormones on cells. Nucleic acids are polynucleotides, biopolymers that store and transmit hereditary information and participate in protein biosynthesis. Structure and biochemical functions of DNA. Differences in the structure and functions of DNA and RNA.

## Content module 2.
## General patterns of metabolism

**Theme 15. The study of membranes.**

Biochemistry as a science. Biochemical components of the cell (biomolecules), their biochemical functions. The concept of metabolism. Structure and function of biological membranes. Separation and research technique of subcellular components structure. Safety rules in the biochemical laboratory. Introduction into the methods of differential centrifugation.

**Theme 16. 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. Demonstration-practical work: Determination of enzyme nature by the biuret reaction, and Fohl's reaction. Determination of amylase activity of saliva and urine in the presence of activator and inhibitor.

**Theme 17. Cofactors and coenzymes.**

Coenzymes, their role in catalysis. Coenzyme functions of vitamins. Demonstration-practical work: Study of the role of pyridoxal phosphate in catalytic activity of aminotransferases.

**Theme 18. Classification and nomenclature of enzymes enzymes.**

International classification and nomenclature of enzymes. Proenzymes. Activation of proenzymes, role in metabolism. Demonstration-practical work: Pepsin activity detection by the formol titration of hydrolysates.

**Theme 19. 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-practical work: Demonstration of enzymograms. Observation of the kinetics of lipase action on milk fat. Effect of bile on lipase activity.

**Theme 20. 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.

**Theme 21. Molecular mechanisms of tissue respiration.**

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. Demonstration-practical work: Detection of succinate dehydrogenase in muscles.

**Theme 22. Peroxide and microsomal oxidation.**

Peroxide and microsomal oxidation. Antioxidant system. High energy compounds. 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 3.
## Metabolism of carbohydrates, lipids and its regulation.

**Theme 23. Intracellular catabolism of glucose.**

Intracellular catabolism of glucose. Glycolysis: reactions. Comparison of glycolysis and alcoholic fermentation. Demonstration-practical work: Simulation of the "in vitro" process of glycolysis, determination of end products. Alcoholic fermentation test.

**Theme 24. Glycogenolysis. Aerobic oxidation of glucose.**

Glycogenolysis, regulation. Differences from glycolysis. Stages of aerobic oxidation of glucose: oxidative decarboxylation of pyruvate. Bioenergetics of the process. Demonstration-practical work: Determination of pyruvate content in blood serum.

**Theme 25. 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 26. 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.

**Theme 27. The role of lipids in the structure and functions of biological membranes.**

The role of lipids in the structure and functions of biological membranes. Molecular mechanisms of lipolysis regulation. Demonstration-practical work: Observation of the effect of bile on fat emulsification.

**Theme 28. Oxidation of fatty acids and glycerol.**

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 pancreatic lipase on milk fat with and without bile.

**Theme 29. 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 30. 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.

**Intermediate control for the semester.**

## Content module 4.
## Metabolism of amino acids.
## Molecular biology. Biochemistry of intercellular communications.

**Theme 31. Ways of formation and maintenance of the pool of amino acids in the body. Deamination, decarboxylation 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. Demonstration-practical work: Quantitative determination of nitrogen of ammonium salts in urine by the Model method.

**Theme 32. Transamination of amino acids.**

Transamination. Biochemical significance, mechanisms of action of aminotransferases. Diagnostic value of determination of aminotransferases in blood serum. Demonstration-practical work: Detection of alanine aminotransferase (AlAT) in normal and pathological blood serum.

**Theme 33. 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 34. 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 35. 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 36. Biosynthesis 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 37. 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 38. Protein biosynthesis in ribosomes.**

Protein biosynthesis in ribosomes. Genetic code: triplet code structure, its properties. Post-translational modification of peptide chains. Regulation of translation.

**Theme 39. Fundamentals of Molecular Genetics.**

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

**Theme 40. 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 41. 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 42. 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 43. Pancreas and adrenal medulla hormones.**

Pancreas and adrenal medulla hormones. Chemical structure and mechanism of action. Hormonal regulation of blood sugar. Diabetes mellitus. Demonstration-practical work: Determination of sugar in urine with Felling's reagent.

**Theme 44. Local hormones.**

Local hormones, their structure, biological role. Hormones of the digestive tract.

## Content module 5.
## Biochemistry of tissues and physiological functions.

**Theme 45. 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 46. 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 47. 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 48. 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 49. Biochemical characteristics and functions of blood.**

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. Demonstration-practical work: Quantitative determination of blood proteins by biuret and refractometric methods. Serum protein fractionation by the “salting out” method. Determination of erythrocytes osmotic resistance.

**Theme 50. Blood respiratory function.**

Blood respiratory function. Hemoglobin, structure, synthesis in the body. Role in the transport of oxygen and carbon dioxide. Abnormal hemoglobin. Demonstration-practical work: Determination of hemoglobin content in blood

**Theme 51. 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 52. Biochemistry of immune processes.**

Biochemistry of immune processes, humoral and cellular immunity. Immunoglobulins, cytokines.

**Theme 53. Biochemical functions of the liver. The role of the liver in the metabolism of bile pigments.**

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

**Theme 54. Detoxification function of the liver.**

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 hippuric acid and indican in urine.

**Theme 55. Urine formation mechanisms.**

Kidney role in body fluids electrolyte composition and pH regulation. Biochemical mechanisms of the urine formation in the kidneys. Demonstration-practical work: Qualitative determination of protein in urine (heating and acid precipitation). Quantitative determination of protein by the Branderg-Stolnikov method.

**Theme 56. Pathobiochemistry 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: Quantitative determination of glucose in urine using a polarimeter.

**Theme 57. Hormonal mechanisms of the water-salt balance regulation.**

Hormonal mechanisms of the water-salt balance regulation and kidney function. Antidiuretic hormone, aldosterone. Renin-angiotensin-aldosterone system. Antihypertensive drugs as inhibitors of angiotensin converting enzyme. Atrial natriuretic peptide and natriuretic peptides of other tissues.

**Theme 58. Muscle biochemistry.**

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. Demonstration-practical work: Determination of creatinine and creatine levels in blood and urine.

**Theme 59. Biochemistry of nervous tissue.**

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.

**Theme 60. Biochemistry of connective tissue.**

General characteristics of the morphology and biochemical composition of connective tissue. Biochemical structure of the intercellular substance of loose fibrous connective tissue: fibers (collagenous, reticular, elastic), the main amorphous substance. Proteins of connective tissue fibers: collagen, elastin. Collagen biosynthesis and fibrillary structures formation. Complex carbohydrates of the main amorphous matrix of connective tissue: glycosaminoglycans (mucopolysaccharides), proteoglycans. Pathochemistry of connective tissue. Biochemical mechanisms of mucopolysaccharidosis and collagenosis, their clinical and biochemical diagnosis.

**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. Biologically important classes of bioorganic compounds. Biopolymers and their structural components.** | | | | | | |
| Theme 1. Classification, nomenclature, isomerism of bioorganic compounds. The nature of chemical bonds. Types of chemical reactions. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 2. Study of reactivity of alkanes, alkenes, arenes. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 3. Structure and properties of hydroxo- and oxocompounds. Biologically active hydroxo- and oxocompounds. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 4. Study of the reactivity of carboxylic acids and their heterofunctional derivatives (amino alcohols, hydroxy acids, keto acids and phenolic acids). Use of carboxylic acids in medicine. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 5. Study of the properties of | 4 | 1 | 0 | 2 | 0 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| natural higher fatty acids. Triglycerides. Lipids. | | | | | | |
| Theme 6. Phospholipids. Biological significance and structure of the lipid component of biomembranes. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 7. Carbohydrates. Structure and chemical properties of monosaccharides. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 8. Structure and functions of di- and polysaccharides. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 9. Chemical properties of carbohydrates. Qualitative reactions for the determination of carbohydrates. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 10. Study of the amino acid composition of proteins and peptides. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 11. Organization of protein structure. Physicochemical properties of proteins. Protein precipitation reactions. Denaturation. Qualitative reactions for the determination of amino acids and proteins | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 12. Classification, structure and significance of biologically active five-membered heterocyclic compounds with one and two heteroatoms. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 13. | 4 | 1 | 0 | 2 | 0 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Biologically important six-membered heterocycles with one and two heteroatoms. Condensed heterocycles. | | | | | | |
| Theme 14. Structure and biological role of nucleosides, nucleotides and nucleic acids. | 3 | 0 | 0 | 2 | 0 | 1 |
| *Total by content module 1* | 50 | 8 | 0 | 28 | 0 | 14 |
| **Content module 2. General patterns of metabolism** | | | | | | |
| Theme 15. The study of membranes. | 2 | 0 | 0 | 2 | 0 | 0 |
| Theme 16. General characteristics, properties of enzymes. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 17. Cofactors and coenzymes. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 18. Classification and nomenclature of enzymes enzymes. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 19. Mechanism of action of enzymes. Kinetics of catalysis. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 20. Citric acid cycle. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 21. Molecular mechanisms of tissue respiration. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 22. Peroxide and microsomal oxidation. | 3 | 0 | 0 | 2 | 0 | 1 |
| *Total by content module 2* | 27 | 4 | 0 | 16 | 0 | 7 |
| **Content module 3. Metabolism of carbohydrates, lipids and its regulation** | | | | | | |
| Theme 23. Intracellular catabolism of glucose. | 5 | 1 | 0 | 2 | 0 | 2 |
| Theme 24. | 5 | 1 | 0 | 2 | 0 | 2 |

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|---|---|---|---|---|---|---|
| Glycogenolysis. Aerobic oxidation of glucose. | | | | | | |
| Theme 25. Alternative pathways of monosaccharide metabolism. | 4 | 0 | 0 | 2 | 0 | 2 |
| Theme 26. Gluconeogenesis. Glycogen biosynthesis. Regulation of carbohydrate metabolism. | 4 | 0 | 0 | 2 | 0 | 2 |
| Theme 27. The role of lipids in the structure and functions of biological membranes. | 5 | 1 | 0 | 2 | 0 | 2 |
| Theme 28. Oxidation of fatty acids and glycerol. | 4 | 0 | 0 | 2 | 0 | 2 |
| Theme 29. Biosynthesis of glycerol, fatty acids, glycerides and phospholipids. | 5 | 1 | 0 | 2 | 0 | 2 |
| Theme 30. Cholesterol metabolism. Metabolism of acetoacetic acid. | 4 | 0 | 0 | 2 | 0 | 2 |
| Intermediate control for the semester. | 7 | 0 | 0 | 4 | 0 | 3 |
| *Total by content module 3* | 43 | 4 | 0 | 20 | 0 | 19 |
| **Content module 4. Metabolism of amino acids. Molecular biology. Biochemistry of intercellular communications** | | | | | | |
| Theme 31. Ways of formation and maintenance of the pool of amino acids in the body. Deamination, decarboxylation of amino acids. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 32. Transamination of amino acids. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 33. Ammonia | 3 | 0 | 0 | 2 | 0 | 1 |

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| metabolism in the human body. | | | | | | |
| Theme 34. Amino acids nitrogen-free skeleton metabolism in the body. Hereditary enzymopathies of amino acid metabolism. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 35. Catabolism of purine and pyrimidine nucleotides. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 36. Biosynthesis of purine and pyrimidine nucleotides. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 37. Biosynthesis of nucleic acids. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 38. Protein biosynthesis in ribosomes. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 39. Fundamentals of Molecular Genetics. | 4 | 0 | 0 | 2 | 0 | 2 |
| Theme 40. Hormones general concept. Hypothalamus and pituitary gland hormones. | 5 | 1 | 0 | 2 | 0 | 2 |
| Theme 41. Thyroid and parathyroid glands hormones. Regulation of phosphorus-calcium metabolism. | 5 | 1 | 0 | 2 | 0 | 2 |
| Theme 42. Steroid hormones. | 5 | 1 | 0 | 2 | 0 | 2 |
| Theme 43. Pancreas and adrenal medulla hormones. | 5 | 1 | 0 | 2 | 0 | 2 |
| Theme 44. Local hormones. | 4 | 0 | 0 | 2 | 0 | 2 |
| *Total by content module 4* | 56 | 8 | 0 | 28 | 0 | 20 |
| **Content module 5. Biochemistry of tissues and physiological functions** | | | | | | |
| Theme 45. Digestion | 4 | 1 | 0 | 2 | 0 | 1 |

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|---|---|---|---|---|---|---|
| of carbohydrates, lipids, proteins, nucleoproteins in the gastrointestinal tract. | | | | | | |
| Theme 46. Water-soluble vitamins B1, B2, B6, PP. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 47. Water-soluble vitamins C, biotin, folic acid, B12, pantothenic acid. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 48. Fat-soluble vitamins. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 49. Biochemical characteristics and functions of blood. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 50. Blood respiratory function. | 4 | 1 | 0 | 2 | 0 | 1 |
| Theme 51. Biochemistry of coagulation, anticoagulation and fibrinolytic blood systems. | 5 | 2 | 0 | 2 | 0 | 1 |
| Theme 52. Biochemistry of immune processes. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 53. Biochemical functions of the liver. The role of the liver in the metabolism of bile pigments. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 54. Detoxification function of the liver. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 55. Urine formation mechanisms. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 56. Pathobiochemistry of the kidneys. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 57. Hormonal mechanisms of the water-salt balance regulation. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 58. Muscle biochemistry. | 3 | 0 | 0 | 2 | 0 | 1 |

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| Theme 59. Biochemistry of nervous tissue. | 3 | 0 | 0 | 2 | 0 | 1 |
| Theme 60. Biochemistry of connective tissue. | 3 | 0 | 0 | 2 | 0 | 1 |
| Intermediate control for the semester. | 8 | 0 | 0 | 4 | 0 | 4 |
| *Total by content module 5* | 64 | 8 | 0 | 36 | 0 | 20 |
| *Individual task* | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total hours** | 240 | 32 | 0 | 128 | 0 | 80 |

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

### 5.1. Themes of lectures

| No | Theme | Hours |
|---|---|---|
| 1. | Lipids, phospholipids, steroids: properties and biological role. Characteristics of phospholipids as functional components of biomembranes. | 2 |
| 2. | Structure and chemical properties of carbohydrates. | 2 |
| 3. | Proteinogenic amino acids, peptides, proteins: structure, properties, biological role. | 2 |
| 4. | Heterocyclic compounds as structural components of nucleic acids. The structure of nucleic acids. | 2 |
| 5. | 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 |
| 6. | Bioenergetics: general pathways of catabolism of carbohydrates, lipids, amino acids. Citric acid cycle. Biological oxidation and oxidative phosphorylation. Electron transport chain in mitochondria. | 2 |
| 7. | Carbohydrate metabolism: glycolysis, glycogenolysis, oxidative decarboxylation of pyruvate, interconversion of monosaccharides, metabolism of fructose, galactose. Carbohydrate metabolism: Glycogen biosynthesis, pentose phosphate pathway, gluconeogenesis. Enzymopathies of carbohydrate metabolism (glycogen storage diseases). Diabetes mellitus. | 2 |
| 8. | Lipid metabolism. Catabolism of triacylglycerols: oxidation of fatty acids and glycerol; ketogenesis. Lipid metabolism. Lipogenesis. Cholesterol metabolism. Regulation and pathology of lipid metabolism: obesity, atherosclerosis. | 2 |
| 9. | 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 |
| 10. | Biosynthesis and catabolism of purine and pyrimidine nucleotides. Biosynthesis of nucleic acids: DNA replication; RNA transcription. Protein synthesis in ribosomes. Regulation of protein biosynthesis. | 2 |
| 11. | Biochemical and molecular biological mechanisms of hormone action; hierarchy of hormones. Hormones of protein-peptide nature. | 2 |

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| 12. | Hormones and bioregulators - derivatives of amino acids; hormones and physiologically active compounds of lipid nature. Local hormones. | 2 |
| 13. | Biochemistry of human nutrition. Vitamins and micro elements as components of human nutrition. Water-soluble vitamins. | 2 |
| 14. | Fat-soluble vitamins, bioantioxidants. Exogenous and endogenous hypo- and avitaminosis, hypervitaminosis | 2 |
| 15. | 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 |
| 16. | Biochemistry of coagulation, anticoagulation and fibrinolytic systems. Violation of coagulation homeostasis | 2 |
| | **Total** | 32 |

**5.2. Themes of seminars**

Seminars are not provided.

**5.3. Themes of practical classes**

| No | Theme | Hours |
|---|---|---|
| 1. | Practical class 1. Classification, nomenclature, isomerism of bioorganic compounds. The nature of chemical bonds. Types of chemical reactions. | 2 |
| 2. | Practical class 2. Study of reactivity of alkanes, alkenes, arenes. | 2 |
| 3. | Practical class 3. Structure and properties of hydroxo- and oxocompounds. Biologically active hydroxo- and oxocompounds. | 2 |
| 4. | Practical class 4. Study of the reactivity of carboxylic acids and their heterofunctional derivatives (amino alcohols, hydroxy acids, keto acids and phenolic acids).Use of carboxylic acids in medicine | 2 |
| 5. | Practical class 5. Studying the properties of natural higher fatty acids. Triglycerides. Lipids. | 2 |
| 6. | Practical class 6. Phospholipids. Biological significance and structure of the lipid component of biomembranes. | 2 |
| 7. | Practical class 7. Carbohydrates. Structure and chemical properties of monosaccharides. | 2 |
| 8. | Practical class 8. Structure and functions of di- and polysaccharides. | 2 |
| 9. | Practical class 9. Chemical properties of carbohydrates.<br>Demonstration-practical work: Qualitative reactions for determination of carbohydrates | 2 |
| 10. | Practical class 10. Study of the amino acid composition of proteins and peptides. | 2 |
| 11. | Practical class 11. Organization of the structure of proteins. Physicochemical properties of proteins. Protein precipitation reactions. Denaturation.<br>Demonstration-practical work: Qualitative reactions for the determination of amino acids and proteins | 2 |
| 12. | Practical class 12. Classification, structure and significance of biologically active five-membered heterocyclic compounds with one and two heteroatoms. | 2 |
| 13. | Practical class 13. Biologically important six-membered heterocycles with one and two heteroatoms. Condensed heterocycles. | 2 |
| 14. | Practical class 14. Structure and biological role of nucleosides, nucleotides and nucleic acids. | 2 |
| 15. | Practical class 15. Biochemistry as a science. Biochemical components of the cell (biomolecules), their biochemical functions. The concept of metabolism. | 2 |

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| | Structure and function of biological membranes. Separation and research technique of subcellular components structure. Safety rules in the biochemical laboratory. Introduction into the methods of differential centrifugation. | |
| 16. | Practical class 16. General characteristics, properties of enzymes. The protein nature of enzymes. Active, allosteric enzyme centers. Regulation of enzyme activity. Enzyme activators and inhibitors. Demonstration-practical work: Determination of enzyme nature by the biuret reaction, and Fohl's reaction. Determination of amylase activity of saliva and urine in the presence of activator and inhibitor. | 2 |
| 17. | Practical class 17. Coenzymes, their role in catalysis. Coenzyme functions of vitamins. Demonstration-practical work: Study of the role of pyridoxal phosphate in catalytic activity of aminotransferases. | 2 |
| 18. | Practical class 18. International classification and nomenclature of enzymes. Proenzymes. Activation of proenzymes, role in metabolism. Demonstration-practical work: Pepsin activity detection by the formol titration of hydrolysates. | 2 |
| 19. | Practical class 19. 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-practical work: Demonstration of enzymograms. Observation of the kinetics of lipase action on milk fat. Effect of bile on lipase activity. | 2 |
| 20. | Practical class 20. 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. | 2 |
| 21. | Practical class 21. 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. Demonstration-practical work: Detection of succinate dehydrogenase in muscles. | 2 |
| 22. | Practical class 22. Peroxide and microsomal oxidation. Antioxidant system. High energy compounds. 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. | 2 |
| 23. | Practical class 23. Intracellular catabolism of glucose. Glycolysis: reactions. Comparison of glycolysis and alcoholic fermentation. Demonstration-practical work: Simulation of the "in vitro" process of glycolysis, determination of end products. Alcoholic fermentation test. | 2 |
| 24. | Practical class 24. Glycogenolysis, regulation. Differences from glycolysis. Stages of aerobic oxidation of glucose: oxidative decarboxylation of pyruvate. Bioenergetics of the process. Demonstration-practical work: Determination of pyruvate content in blood serum. | 2 |
| 25. | Practical class 25. 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. | 2 |

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| 26. | Practical class 26. 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. | 2 |
| 27. | Practical class 27. The role of lipids in the structure and functions of biological membranes. Molecular mechanisms of lipolysis regulation. Demonstration-practical work: Observation of the effect of bile on fat emulsification. | 2 |
| 28. | Practical class 28. 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 pancreatic lipase on milk fat with and without bile. | 2 |
| 29. | Practical class 29. 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. | 2 |
| 30. | Practical class 30. 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. | 2 |
| 31. | Practical class 31. Intermediate control for the semester (part 1) | 2 |
| 32. | Practical class 32. Intermediate control for the semester (part 2) | 2 |
| 33. | Practical class 33. 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. Demonstration-practical work: Quantitative determination of nitrogen of ammonium salts in urine by the Model method. | 2 |
| 34. | Practical class 34. Transamination. Biochemical significance, mechanisms of action of aminotransferases. Diagnostic value of determination of aminotransferases in blood serum. Demonstration-practical work: Detection of alanine aminotransferase (AlAT) in normal and pathological blood serum. | 2 |
| 35. | Practical class 35. 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. | 2 |
| 36. | Practical class 36. 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) | 2 |
| 37. | Practical class 37. Nucleotides' metabolism in tissues: purine and pyrimidine nucleotides catabolism. Disorders of purine metabolism (gout). Demonstration-practical work: Quantitative determination of uric acid in | 2 |

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|---|---|---|
| | urine. | |
| 38. | Practical class 38. Purine and pyrimidine nucleotides biosynthesis. Regulation of nucleotide biosynthesis. Deoxyribonucleotide biosynthesis. Formation of thymidine nucleotides: dTMP biosynthesis inhibitors as antitumor agents. | 2 |
| 39. | Practical class 39. 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 |
| 40. | Practical class 40. Protein biosynthesis in ribosomes. Genetic code: triplet code structure, its properties. Post-translational modification of peptide chains. Regulation of translation. | 2 |
| 41. | Practical class 41. Regulation of gene expression. Mechanisms of DNA mutations and repairs. Obtaining recombinant DNA, transgenic proteins. | 2 |
| 42. | Practical class 42. 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 |
| 43. | Practical class 43. 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 |
| 44. | Practical class 44. 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 |
| 45. | Practical class 45. Pancreas and adrenal medulla hormones. Chemical structure and mechanism of action. Hormonal regulation of blood sugar. Diabetes mellitus. Demonstration-practical work: Determination of sugar in urine with Felling's reagent. | 2 |
| 46. | Practical class 46. Local hormones, their structure, biological role. Hormones of the digestive tract. | 2 |
| 47. | Practical class 47. 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. | 2 |
| 48. | Practical class 48. 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 | 2 |
| 49. | Practical class 49. 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 |
| 50. | Practical class 50. 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 |
| 51. | Practical class 51. Biochemical characteristics and functions of blood. Biochemical composition of blood plasma. Characteristics of protein fractions | 2 |

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| | 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. Demonstration-practical work: Quantitative determination of blood proteins by biuret and refractometric methods. Serum protein fractionation by the "salting out" method. Determination of erythrocytes osmotic resistance. | |
| 52. | Practical class 52. Blood respiratory function. Hemoglobin, structure, synthesis in the body. Role in the transport of oxygen and carbon dioxide. Abnormal hemoglobin. Demonstration-practical work: Determination of hemoglobin content in blood | 2 |
| 53. | Practical class 53. 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 |
| 54. | Practical class 54. Biochemistry of immune processes, humoral and cellular immunity. Immunoglobulins, cytokines. | 2 |
| 55. | Practical class 55. 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. Demonstration-practical work: Determination of total, direct and indirect bilirubin in blood serum. | 2 |
| 56. | Practical class 56. 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 hippuric acid and indican in urine. | 2 |
| 57. | Practical class 57. Kidney role in body fluids electrolyte composition and pH regulation. Biochemical mechanisms of the urine formation in the kidneys. Demonstration-practical work: Qualitative determination of protein in urine (heating and acid precipitation). Quantitative determination of protein by the Branderg-Stolnikov method. | 2 |
| 58. | Practical class 58. 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: Quantitative determination of glucose in urine using a polarimeter. | 2 |
| 59. | Practical class 59. Hormonal mechanisms of the water-salt balance regulation and kidney function. Antidiuretic hormone, aldosterone. Renin-angiotensin-aldosterone system. Antihypertensive drugs as inhibitors of angiotensin converting enzyme. Atrial natriuretic peptide and natriuretic peptides of other tissues. | 2 |
| 60. | Practical class 60. Muscle biochemistry. Features of the chemical composition | 2 |

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| | and metabolism in muscles. Molecular mechanisms of muscle contraction. Bioenergetics of muscle tissue: sources of ATP in muscles. Demonstration-practical work: Determination of creatinine and creatine levels in blood and urine. | |
| 61. | Practical class 61. 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. | 2 |
| 62. | Practical class 62. General characteristics of the morphology and biochemical composition of connective tissue. Biochemical structure of the intercellular substance of loose fibrous connective tissue: fibers (collagenous, reticular, elastic), the main amorphous substance. Proteins of connective tissue fibers: collagen, elastin. Collagen biosynthesis and fibrillary structures formation. Complex carbohydrates of the main amorphous matrix of connective tissue: glycosaminoglycans (mucopolysaccharides), proteoglycans. Pathochemistry of connective tissue. Biochemical mechanisms of mucopolysaccharidosis and collagenosis, their clinical and biochemical diagnosis. | 2 |
| 63. | Practical class 63. Intermediate control for the semester (part 1) | 2 |
| 64. | Practical class 64. Intermediate control for the semester (part 2) | 2 |
| | **Total** | 128 |

**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 | 1 |
| 2. | Theme 2. Preparation for practical class 2 | 1 |
| 3. | Theme 3. Preparation for practical class 3 | 1 |
| 4. | Theme 4. Preparation for practical class 4 | 1 |
| 5. | Theme 5. Preparation for practical class 5 | 1 |
| 6. | Theme 6. Preparation for practical class 6 | 1 |
| 7. | Theme 7. Preparation for practical class 7 | 1 |
| 8. | Theme 8. Preparation for practical class 8 | 1 |
| 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 | 0 |
| 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. | Theme 19. Preparation for practical class 19 | 1 |
| 20. | Theme 20. Preparation for practical class 20 | 1 |
| 21. | Theme 21. Preparation for practical class 21 | 1 |
| 22. | Theme 22. Preparation for practical class 22 | 1 |

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| 23. | Theme 23. Preparation for practical class 23 | 1 |
| 24. | Theme 24. Preparation for practical class 24 | 2 |
| 25. | Theme 25. Preparation for practical class 25 | 2 |
| 26. | Theme 26. Preparation for practical class 26 | 2 |
| 27. | Theme 27. Preparation for practical class 27 | 2 |
| 28. | Theme 28. Preparation for practical class 28 | 2 |
| 29. | Theme 29. Preparation for practical class 29 | 2 |
| 30. | Theme 30. Preparation for practical class 30 | 2 |
| 31. | Preparation for practical class 31 | 2 |
| 32. | Preparation for practical class 32 | 2 |
| 33. | Theme 31. Preparation for practical class 33 | 1 |
| 34. | Theme 32. Preparation for practical class 34 | 1 |
| 35. | Theme 33. Preparation for practical class 35 | 1 |
| 36. | Theme 34. Preparation for practical class 36 | 1 |
| 37. | Theme 35. Preparation for practical class 37 | 1 |
| 38. | Theme 36. Preparation for practical class 38 | 1 |
| 39. | Theme 37. Preparation for practical class 39 | 1 |
| 40. | Theme 38. Preparation for practical class 40 | 1 |
| 41. | Theme 39. Preparation for practical class 41 | 2 |
| 42. | Theme 40. Preparation for practical class 42 | 2 |
| 43. | Theme 41. Preparation for practical class 43 | 2 |
| 44. | Theme 42. Preparation for practical class 44 | 2 |
| 45. | Theme 43. Preparation for practical class 45 | 2 |
| 46. | Theme 44. Preparation for practical class 46 | 2 |
| 47. | Theme 45. Preparation for practical class 47 | 2 |
| 48. | Theme 46. Preparation for practical class 48 | 1 |
| 49. | Theme 47. Preparation for practical class 49 | 1 |
| 50. | Theme 48. Preparation for practical class 50 | 1 |
| 51. | Theme 49. Preparation for practical class 51 | 1 |
| 52. | Theme 50. Preparation for practical class 52 | 1 |
| 53. | Theme 51. Preparation for practical class 53 | 1 |
| 54. | Theme 52. Preparation for practical class 54 | 1 |
| 55. | Theme 53. Preparation for practical class 55 | 1 |
| 56. | Theme 54. Preparation for practical class 56 | 1 |
| 57. | Theme 55. Preparation for practical class 57 | 1 |
| 58. | Theme 56. Preparation for practical class 58 | 1 |
| 59. | Theme 57. Preparation for practical class 59 | 1 |
| 60. | Theme 58. Preparation for practical class 60 | 1 |
| 61. | Theme 59. Preparation for practical class 61 | 1 |
| 62. | Theme 60. Preparation for practical class 62 | 1 |
| 63. | Preparation for practical class 63 | 1 |
| 64. | Preparation for practical class 64 | 2 |
| | **Total** | **80** |

## 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 understanably 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 applicant s 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 applicant s 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 applicant 's 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 applicant s who have received grades of "FX" and "F" ("2") are not included in the list of ranked higher education applicant s. 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:


- Burdina Y.F., Kuzmina A.V., Grekova A.V. Lipids. Saponified lipids. Triglycerides. Complex lipids. Phospholipids / Educational and methodological manual / Odesa: Astroprint, 2017. – 32 p.
- 2.Burdina Y.F., Kuzmina A.V., Grekova A.V. Carbohydrates - monoses, bioses, polyoses. Their chemical properties / Educational and methodological manual / Odesa: Astroprint, 2017. – 44.
- 3.Grekova A.V., Burdyna Y.F., Kuzmina A.V. Peptides, proteins - composition, structure and properties. / Educational and methodological manual. - Odesa, 2018. - 48 p.
- 4.Grekova A. V., Burdina Y. F., Stepanov G. F. Nomenclature, structure and classification of organic compounds. Types and mechanisms of reactions in organic chemistry: teaching method. manual – Odesa: Astroprint, 2021 – 48 p.
- 5.Burdina Y. F., Grekova A. V., Stepanov G. F. Oxygen-containing organic compounds. Classification, nomenclature, chemical properties: educational method. manual – Odesa: Astroprint, 2021 – 40 p.
- 6.Grekova A. V., Burdina Y. F., Stepanov G. F. Heterocyclic compounds as structural components of drugs and nucleic acids: teaching method. guide – Odesa: Astroprint, 2021 – 52 p.
- 7. Grekova A. V., Burdina Y. F., Stepanov G. F. Biological role and chemical properties of amino acids and proteins: teaching method. manual – Odesa: Astroprint, 2021 – 44 p.
- 8. Burdina Y.F., Grekova A.V., Stepanov G.F. Biological role and chemical properties of carbohydrates: educational method. manual – Odesa: Astroprint, 2021 – 40 p.
- 9. Grekova A. V., Burdina Y. F., Stepanov G. F. Biologically active heterocyclic compounds

as components of nucleic acids and drugs: educational method. guide – Odesa: Astroprint, 2022 – 52 p.

## 11. Questions for the final control

CONTENT MODULE 1. BIOLOGICALLY IMPORTANT CLASSES OF BIOORGANIC COMPOUNDS. BIOPOLYMERS AND THEIR STRUCTURAL COMPONENTS.

***Theoretical basis of the future and reaction properties of bioorganic compounds*.**

1. Bioorganic chemistry as a science: significance, subject and knowledge, sections, research methods. Significance in the system of high medical coverage.
2. Classification of organic compounds based on the carbon radical and the nature of the functional groups.
3. The most important classes of bioorganic compounds based on the nature of functional groups: alcohols, phenols, thiols, aldehydes, ketones, carboxylic acids, folded ethers, amides, nitrogen compounds, etc.
4. Nomenclature of organic ideas: trivial, rational, international. The principles of establishing the names of organic structures according to the IUPAC nomenclature: mixed, radical-functional.
5. The nature of the chemical binder in organic compounds: hybridization of orbit, electronic structure of semi-carbon.
6. Expanse of bioorganic properties: stereochemical formulas; configuration and conformation. Stereoisomers: geometric, optical, rotational (conformers).
7. Optical isomerism; chirality of organic molecules. D/L- and R/S-stereochemical nomenclatures. Enantiomers and diastereoisomers of bioorganic compounds. The connection between spacious living and physiological activity.
8. Types of reactions in bioorganic chemistry: classification based on the result (directness) and the reaction mechanism. Apply it.
9. Carbonyl compounds in bioorganic chemistry. Chemical power and biomedical significance of aldehydes and ketones.
10. Carboxylic acids in bioorganic chemistry: natural and chemical power; functional derivatives of carboxylic acids (anhydrides, amides, folding esters). Decarboxylation reactions.
11. Structure and the power of dicarboxylic acids: oxalic, malonic, succinic, glutaric, fumaric.
12. Lipids: identification, classification. Fatty acids: palmitic, stearic, oleic, linoleic, linolenic, arachidonic. Sorry lipids. Triacylglycerols (neutral fats): structure, physiological significance, hydrolysis.
13. Folding lipids. Phospholipids: phosphatidic acid, phosphatidylethanolamine, phosphatidylcholine, phosphatidylserine. Sphingolipids. Glycolipids. The role of folding lipids in everyday biomembranes.
14. Amen: nomenklatura, authorities. Biomedical significance of biogenic amines (adrenaline, norepinephrine, dopamine, tryptamine, serotonin, histamine) and polyamines (putrescine, cadaverine).
15. Amino alcohols: structure, power. Biomedically important are ethanol amine (cola mine), choline, acetylcholine.
16. Hydroxy acids in bioorganic chemistry: the presence and power of monocarboxylic (lactic and hydroxybutyric), dicarboxylic (malic, tartaric) hydroxy acids.

***α-Amino acids, peptides, proteins.***

17. Amino acids: amino acids, stereoisomerism, chemical power. Biomedical significance of L-a-amino acids. Reactions of biochemical transformations of amino acids:

deamination, transamination, decarboxylation.

18. Amino acid storage of proteins and peptides; classification of natural L-a-amino acids. Chemical and physical-chemical power of proteinogenic amino acids. Ninhydrin reaction, its significance in the analysis of amino acids.

19. Proteins and peptides: identification, classification, biological functions. Types of bonds between amino acid residues in protein molecules. Peptide link: composition, structure; Biuret reaction.

20. Levels of structural organization of proteins: primary, secondary, tertiary and quaternary structures. Oligomeric proteins.

21. Physico-chemical properties of proteins; Ex molecular weight. Denaturation of proteins.

***Structure and function of carbohydrates.***

22. Carbohydrates: identification, classification. Monosaccharides (aldoses and ketoses; trioses, tetrosities, pentoses, hexoses, heptoses), biomedical significance of several representatives.

23. Monosaccharides: pentose (ribose, 2-deoxyribose, xylose), hexose (glucose, galactose, manose, fructose) - Structure, properties. Clear reactions to glucose.

24. The power of similar monosaccharides. Amino derivatives: glucosamine, galactosamine. Uronic acids. L-Ascorbic acid (vitamin C). Monosaccharide renewal products: sorbitol, mannitol.

25. Oligosaccharides: power, power. Disaccharides (sucrose, lactose, maltose), their biomedical value.

26. Polysaccharides. Homopolysaccharides: starch, glycogen, cellulose, dextrin-structure, hydrolysis, biomedical value. A clear reaction to starch.

27. Heteropolysaccharides: meaning, structure. The potential and biomedical significance of glycosaminoglycans (mucopolysaccharides) – hyaluronic acid, chondroitin sulfates, heparin**.**

***Biologically active heterocyclic compounds. Nucleosides, nucleotides, nucleic acids.***

28. Five-membered heterocycles with one heteroatom (pyrole, furan, thiophene). Biomedical significance of tetrapyrolic compounds: porphins, porphyrins, heme.

29. Indol and its derivatives: tryptophan and reactions of tryptamine and serotonin; Indoxyl, skatole, skatol are important in the processes of protein rotting into the intestines.

30. Five-membered heterocycles with two nitrogen heteroatoms. Pyrazol, pirazolone; Similar treatments for pirazolon-5 as medicinal agents (antipyrine, amidopirine, analgin). Imidazole and its derivatives: histidine, histamine.

31. Five-membered heterocycles with two different heteroatoms: thiazole, oxazole. Thiazole is a structural component of the thiamine molecule (vitamin B1).

32. Six-membered heterocycles with a nitrogen atom: pyridine. Nicotinamide (vitamin PP.) is a storage component of oxidatively derived pyridine coenzymes. Pyridoxine and molecular forms of vitamin B6.

33. Six-membered heterocycles with two nitrogen atoms. Diazines: pyrimidine, pirazine, pyridazine. Nitrogen bases - similar pyrimidines (uracil, cytosine, thymine).

34. Related substances as medicinal uses: 5-fluorouracil, potassium orotate. Barbituric acid; barbiturates as an anesthetic and against epileptic symptoms (phenobarbital, veronal).

35. Purin and it’s derivates. Amino-like purines (adenine, guanine), their tautomeric forms; biochemical significance in the concentration of nucleotides and coenzymes.

36. Hydroxy-based purines: hypoxanthine, xanthine, uric acid. Methylated xanthine compounds (caffeine, theophylline, theobromine) are physiologically active and act on the central nervous and cardiovascular system.

37. Nucleosides, nucleotides. Nitrogens are the basis of the purine and pyrimidine series, which are part of the stock of natural nucleotides. Minor nitrogenous bases.

38. Nucleosides. Nucleotides as phosphorylated derivatives of nucleosides (nucleoside

mono-, di- and triphosphates). Nomenclature of nucleosides and nucleotides as components of RNA and DNA.

39. What are the biochemical functions of strong nucleotides: coenzyme nucleotides; cyclic nucleotides 3',5'-cAMP and 3',5'-cGMP.

40. Nucleic acids (deoxyribonucleic acids, ribonucleic acids) as polynucleotides. Polarity of polynucleotide lances of DNA and RNA.

41. Structure and the power of DNA; nucleotide storage, complementarity of nitrogenous bases. The primary, secondary and tertiary structure of DNA. RNA: Structure, types of RNA and their role in protein biosynthesis.

42. Vitamins: halal characteristics; understanding about the coenzyme action of vitamins. Structure and the power of vitamins B1, B2, B6, PP.

CONTENT MODULE 2. General patterns of metabolism.

***Introduction into biochemistry. Biochemical components of cells.'***

43. Biological chemistry (biochemistry) as a science. The place of biochemistry among other medical and biological disciplines. History of biochemistry; development of biochemical research in Ukraine.

44. Objects of education and training in biochemistry. The role of biochemistry in the established molecular mechanisms of the pathogenesis of human illness is evident.

45. Relationship between biochemistry and other biomedical sciences. Medical biochemistry. Clinical biochemistry. Biochemical laboratory diagnostics.

46. Biochemical components of cellulose, their biochemical functions. Class of biomolecules. Hierarchy of biomolecules, their relationships.

***Enzymes and coenzymes. Regulation of metabolism.***

47. Enzymes: value; the power of enzymes as biological catalysts.

48. Classification and nomenclature of enzymes, characteristics of certain classes of enzymes.

49. What are the mechanisms of enzymes. Active and allosteric (regulatory) center.

50. Cofactors and coenzyme. Due to the power of coenzymes, vitamins are precursors in the biosynthesis of coenzymes. Coenzymes: types of reactions that catalyze other classes of coenzymes.

51. Isoenzymes, features of their functioning, significance in the diagnosis of illness.

52. Mechanisms of action and kinetics of enzymatic reactions: duration of liquid reaction, substrate concentration, pH and temperature. Principles and methods for identifying enzymes in biological objects. One type of activity and number of enzymes.

53. Activators and inhibitors of enzymes: applications and mechanisms of action.

54. Types of enzyme inhibition: turnaround (competitive, non-competitive) and non-turnover inhibition.

55. Regulation of enzymatic processes. Paths and mechanisms of regulation: allosteric enzymes; covalent modification of enzymes. Cyclic nucleotides (cAMP, cGMP) as regulators of enzymatic reactions and biological functions of cells.

56. Enzymopathies - problems (surges) in the metabolism of carbohydrates, amino acids, porphyrins, purines.

57. Enzymodiagnosis of pathological processes and illness.

58. Enzymotherapy - stagnation of enzymes, their activators and inhibitors in medicine.

***Metabolism fundamentals. Citric acid cycle.***

59. Metabolism (metabolism) - the underlying patterns of catabolic and anabolic processes.

60. Complex stages of internal cellular catabolism of biomolecules: proteins, carbohydrates, lipids.

61. Tricarboxylic acid cycle. Localization, sequence of enzymatic reactions, significance

in the metabolism of speech. Energy balance of the tricarboxylic acid cycle. Physiological significance of the TCA reaction.

***Molecular basis of bioenergetics.***

62. Reactions of biological oxidation; types of reactions (dehydrogenase, oxidase, oxygenase) and their biological significance. Respiratory chain.

63. Enzymes of biological oxidation in mitochondria: pyridine-, flavin-dehydrogenases, cytochromes. Sequence of components of the mitochondrial membrane. Molecular complexes of the inner membranes of mitochondria.

64. Oxide phosphorylation: points of conjugation of electron transport and phosphorylation, coefficient of oxide phosphorylation

65. Chemiosmotic theory of oxide phosphorylation, mitochondrial ATP synthetase.

66. Inhibitors of electron transport and inhibitors of oxide phosphorylation.

67. Microsomal oxidation: cytochrome P-450; molecular organization of electron transfer chain.

## CONTENT MODULE 3. METABOLISM OF CARBOHYDRATES, LIPIDS AND IT'S REGULATION.

***Metabolism of carbohydrates and its regulation.***

68. Aerobic and anaerobic oxidation of glucose, natural characteristics of processes.

69. Anaerobic oxidation of glucose. Sequence of reaction of enzymes to glycolysis.

70. Aerobic oxidation of glucose. Stages of transformation of glucose to CO2 and H2O. Oxidation decarboxylation of pyruvate. Enzymes, coenzymes and sequence of reactions in a multienzyme complex.

71. Glycolytic oxidoreduction: substrate phosphorylation and nutrient mechanisms of glycolytic NADH oxidation.

72. The bioenergetics of aerobic and anaerobic glucose oxidation, the Pasteur effect, are consistent.

73. Phosphorolytic pathway for the breakdown of glycogen in liver and meat. Regulation of glycogen phosphorylase activity.

74. Glycogen biosynthesis: enzymatic reactions, physiological significance. Regulation of glycogen synthase activity.

75. Mechanisms of reciprocal regulation of glycogenolysis and glycogenesis through cascade cAMP-dependent phosphorylation of enzyme proteins. The role of adrenaline, glucagon and insulin in the hormonal regulation of glycogen exchange in meat and liver.

76. Genetic disorders of glycogen metabolism (glycogenosis, aglycogenosis).

77. Gluconeogenesis: substrates, enzymes and physiological significance of the process. Glucose-lactate (Coria cycle) and glucose-alanine cycles.

78. Blood glucose (glucosemia): normoglycemia, hypoglycemia, glucosuria. Blood diabetes is a pathology of glucose metabolism. Hormonal regulation of blood glucose concentration and exchange.

79. Pentose phosphate pathway of glucose oxidation: scheme of the process and biological significance.

80. Metabolic pathways for the transformation of fructose and galactose; hereditary disorders of metabolism.

***Lipid metabolism and its regulation.***

81. 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).

82. Reactions of oxidation of fatty acids (b-oxidation); the role of carnitine in the transport of fatty acids in mitochondria. Energetic activity of the oxidation of fatty acids in cells.

83. Oxidation of glycerol: enzymatic reactions, bioenergetics.

84. Ketone bodies. The reactions of biosynthesis and utilization of ketone bodies are of physiological significance. Disruption of the exchange of ketone bodies due to pathology (diabetes of the blood, fasting).

85. Biosynthesis of saturated fatty acids: reactions to the biosynthesis of saturated fatty acids (palmite) and regulation of the process. Biosynthesis of unsaturated fatty acids in the human body.

86. Biosynthesis of triacylglycerols and phosphoglycerides. Metabolism of sphingolipids. Genetic abnormalities in the metabolism of sphingolipides - sphingolipidoses.

87. Biosynthesis of cholesterol: reaction scheme, regulation of cholesterol synthesis. Ways of biotransformation of cholesterol: esterification; the release of urinary acids, steroid hormones, vitamin D3.

88. Circulatory transport and deposition of lipids in adipose tissue. Lipoprotein lipase in endothelium. Blood plasma lipoproteins: lipid and protein (apoprotein) storage. Hyper-lipoproteinemia.

89. Pathologies of lipid metabolism: atherosclerosis, obesity, blood diabetes.

## CONTENT MODULE 4. METABOLISM OF AMINO ACIDS. MOLECULAR BIOLOGY. BIOCHEMISTRY OF INTERCENTAL COMMUNICATIONS.

***Metabolism of amino acids. Enzymopathies of amino acid metabolism.***

90. Pool of free amino acids in the body: the supply and vigor of free amino acids in tissues.

91. Transamination of amino acids: reactions and their biochemical significance, mechanisms of aminotransferases.

92. Direct and indirect deamination of high-grade L-amino acids in tissues.

93. Decarboxylation of L-amino acids in the human body. Physiological significance of the creation of products. Oxidation of biogenic amines.

94. Ways of creation and release of ammonia in the body. Biosynthesis of meat: sequence of enzyme reactions in biosynthesis, genetic abnormalities of enzymes in the fruit cycle.

95. Pathways to the metabolism of carbon skeletons of amino acids in the human body. Glucogenic and ketogenic amino acids.

96. Biosynthesis and biological role of creatine and creatine phosphate.

97. Glutathione: potential, biosynthesis and biological functions of glutathione

98. Specialized routes to the metabolism of cyclic amino acids - phenylalanine and tyrosine. Decreased enzyme metabolism of cyclic amino acids - phenylalanine and tyrosine.

99. Exchange of cyclic amino acid tryptophan and cyclic enzyme.

Fundamentals of molecular biology.

100. Nitrogen bases, nucleosides and nucleotides are storage components of nucleic acid molecules. Minor nitrogenous bases and nucleotides. Free nucleotides (ATP, NAD, NADP, FAD, FMN, CTP, UTP; 3',5'-AMP, 3',5'-GMP) and their biochemical functions.

101. Nucleic acids. The essential characteristics of DNA and RNA, their biological significance in the preservation and transmission of genetic information. Features of the primary structure of DNA and RNA. Ligaments that stabilize the primary structure of nucleic acids.

102. Secondary structure of DNA, the role of water links in its creation (Chargaff rules, Watson-Crick model), anti-parallelism of chains. Tertiary structure of DNA. Physico-chemical powers of DNA: interaction of DNA with cationic ligands, creation of nucleosomes.

103. Molecular organization of nuclear chromatin in eukaryotes: nucleosomal organization; histones and non-histone proteins. Nucleoproteins: natural, biological functions

104. Structure, the power of biological functions of RNA. Types of RNA: mRNA, tRNA, rRNA. Features of the structural organization of different types of RNA.

105. Biochemical warehouse, the future functions of biological membranes.

Compartmentalization of biochemical processes in cells.

106. The role of lipids in biological membranes. Ride-mosaic model of biomembranes.

107. Biosynthesis of purine nucleotides: reaction scheme for the synthesis of IMP; concentration of AMP and GMF; regulation mechanisms.

108. Biosynthesis of pyrimidine nucleotides: reaction scheme; regulation of synthesis. Biosynthesis of deoxyribonucleotides. Solution of thymidyl nucleotides; Inhibitors of dTMP biosynthesis as antitumor agents.

109. Catabolism of purine nucleotides; decreased metabolism of uric acid.

110. Scheme of catabolism of pyrimidine nucleotides.

111. DNA replication: biological significance; non-conservative mechanism of replication. Sequence of stages and enzymes of DNA replication in prokaryotes and eukaryotes.

112. RNA transcription: RNA polymerases of prokaryotes and eukaryotes, transcription signals (promoter, initiator and terminator parts of the genome). Processing is a post-transcriptional modification of newly synthesized mRNA.

113. Genetic (biological) code; triplet structure of the code, properties. Transport - tRNA and activation of amino acids. Aminoacyl-tRNA synthetases. Stages and mechanisms of translation (protein biosynthesis) in ribosomes: initiation, elongation and termination.

***Fundamentals of molecular genetics.***

114. Post-translational modification of peptide lances. Regulation of broadcasting. Transcription and translation inhibitors in prokaryotes and eukaryotes: antibiotics and interferons - their use in medicine; diphtheria toxin.

115. Regulation of gene expression in prokaryotes: regulatory and structural parts of the lactose (Lac-) operon (regulatory gene, promoter, operator).

116. Mutations: genomic, chromosomal, gene; mechanisms of mutagens; the role of inducing mutations in human culprit enzyme diseases and disease diseases. The mechanisms of DNA repair are of biological significance. Reparation of UV-induced gene mutations: xeroderma pigmentosum.

117. Genetic engineering: design of recombinant DNA; cloning of genes; genetic engineering synthesis of enzymes, hormones, interferons, etc.

***Molecular mechanisms of hormone action on target cells.***

118. Hormones: general characteristic; the role of hormones and other bioregulators in the system of intercellular integration of functions in the human body.

119. Classification of hormones and bioregulators: type of structure and mechanisms of action of hormones.

120. Response of target cells to hormones. Membrane (ionotropic, metabotropic) and cytosolic receptors. Biochemical systems of intracellular transmission of hormonal signals: G-proteins, second messengers (cAMP, Ca2+/calmodulin, IP3, DAG). Molecular-clinical mechanisms of steroid and thyroid hormones.

***Biochemistry of hormonal regulation of metabolism.***

121. Hormones of the hypothalamus - liberin and statin.

122. Hormones of the anterior pituitary gland: somatotropin (STH), prolactin. pathological processes associated with impaired functions of these hormones.

123. Hormones of the posterior part of the pituitary gland. Vasopressin and oxytocin: biological, biological functions.

124. Insulin: structure, biosynthesis and secretion; influx on the exchange of carbohydrates, lipids, amino acids and proteins. Rest-stimulating effects of insulin. Glucagon: regulation of carbohydrate and lipid metabolism.

125. Thyroid hormones: structure, biological effects of T4 and T3. Disruption of metabolic processes in hypo- hyperthyroidism. Hormonal regulation of calcium homeostasis in the body. Parathyroid hormone, calcitonin, calcitriol.

126. Catecholamines (adrenaline, norepinephrine, dopamine): biological, biosynthesis, physiological effects, biochemical mechanisms of action.

127. Steroid hormones of measles (C21-steroids) - glucocorticoids and mineralocorticoids; Structure, power.

128. Women's state hormones: estrogens, progesterone. Physiological and biochemical effects; sound of the phases of the ovulation cycle. Human state hormones (C19-steroids). Physiological and biochemical effects of androgens; regulation of synthesis and secretion.

129. Eicosanoids: biological, biological and pharmacological influences. Aspirin and other non-steroidal anti-inflammatory agents as inhibitors of prostaglandin synthesis.

## CONTENT MODULE 5. BIOCHEMISTRY OF TISSUE AND PHYSIOLOGICAL FUNCTIONS

***Biochemistry of human food. Vitamins as components of food.***

130. Biochemistry of human food: components and vital parts of normal food; biological value of other nutrients. Mechanisms of transformation of living substances (proteins, carbohydrates, lipids) in the grass tract. Enzymes of the pouch and intestines.

131. Disruption of digestion of certain nutrients in the stomach and intestines; hereditary enzymopathies of digestive processes. Microelements in human nutrition. Biological functions of individual trace elements; manifestations of trace element deficiency..

132. Vitamins in people's food. Water- and fat-rich vitamins; Exogenous and endogenous causes of vitamin deficiency.

133. Vitamin B1 (thiamine): biological, biological power, mechanism of action, sources, dietary needs. Vitamin B2 (riboflavin): biological, biological power, mechanism of action, food, dietary needs. Vitamin PP (nicotinic acid, nicotinamide): biological, biological power, mechanism of action, show deficiencies, sources, basic needs.

134. Vitamin B6 (pyridoxine): biological power, mechanism of action, product, dietary needs. Vitamin B12 (cobalamin): biological influences, mechanism of action, manifestations of deficiencies, food intake. Vitamin B (folic acid): biological influences, mechanism of action, product, dietary requirements.

135. Vitamin N (biotin): biological influences, mechanism of action, product, dietary needs. Vitamin B3 (pantothenic acid): biological properties, mechanism of action, food consumption.

136. Vitamin C (ascorbic acid): biological, biological influences, mechanism of action, show deficiencies, food, dietary needs. Vitamin P (flavonoids): biological, biological power, mechanism of action, show deficiencies, food, supplementary needs.

137. Vitamin A (retinol, retinal, retinoic acid): biological influences, mechanism of action, show deficiencies, sources, basic needs. Vitamin D3 (cholecalciferol): biological influences, mechanism of action, manifestations of deficiencies, dietary requirements.

138. Vitamin K (phyloquinone, farnoquinone): biological influences, mechanism of action, show deficiencies, sources, dietary needs. Vitamin E (a-tocopherol): biological influences, mechanism of action, manifest deficiencies, food intake.

***Biochemistry and pathobiochemistry of blood.***

139. Biochemical and physiological functions of blood in the human body. Dihal function of erythrocytes. Hemoglobin: mechanisms of participation in the transport of acid and carbon dioxide. Variants and pathological forms of hemoglobins in humans.

140. Buffers of the blood system. Disturbance of the acid-base balance in the body (metabolic and respiratory acidosis, alkalosis). Biochemical storage of human blood. Blood plasma proteins and their clinical and biochemical characteristics.

141. Blood plasma enzymes; significance in enzymodiagnostics of diseases of organs and tissues. Kalikrein-kinin system of blood and tissues. Medicines - antagonists of kinin production.

142. Non-protein organic compounds of blood plasma. Inorganic components of plasma.

143. Biochemical and functional characteristics of the hemostatic system.

144. Laryngeal blood system; characteristics of other factors; mechanisms of functioning

of the cascade system of laryngeal blood. The role of vitamin K in coagulation reactions; medicinal properties - agonists and antagonists of vitamin K.

145. Anticoagulant blood system; characteristics of anticoagulants. Recession of the process of laryngeal blood. Fibrinolytic blood system. Medicines that influence the process of fibrinolysis.

146. Immunoglobulins; biochemical characteristics of several classes of immunoglobulin in humans. Mediators and hormones of the immune system: interleukins; interferons; protein-peptide factors regulating the growth and proliferation of cells.

147. Complement system; biochemical components of the human complement system; classic and alternative ways of activation. Biochemical mechanisms of immunodeficiency states: primary (slump) and secondary immunodeficiency.

***Functional and clinical biochemistry of organs and tissues.***

148. Biochemical functions of the liver: carbohydrate-producing, protein-synthesizing, nut-creating, fermentative-creating, regulation of lipid composition in the blood.

149. Detoxifying function of the liver; types of biotransformation reactions of xenobiotics and endogenous toxins. Conjugation reactions in hepatocytes: biochemical mechanisms, functional significance.

150. Reactions of microsomal oxidation. Cytochrome P-450; electron transport lancets in the membranes of the endoplasmic reticulum of hepatocytes.

151. Metabolism of porphyrins: heme; Scheme of the biosynthesis reaction of protoporphyrin IX and heme. Decrease in the biosynthesis of porphyrins, such as porphyria.

152. The role of the liver in the exchange of chewing pigments. Pathobiochemistry and types of diseases; biochemical diagnostics of diarrhea; slump (enzymatic) jaundices. Catabolism of hemoglobin and heme (scheme); creation and development of precious pigments.

153. Water-salt metabolism in the body. Internal and post-clinical water; exchange of water, sodium, potassium.

154. The role of kidneys in the regulation of volume, electrolyte storage and pH in the body. Biochemical mechanisms of the sebaceous function of kidneys. The biochemical composition of humans urine is normal and responsible for the development of pathological processes. Clinical and diagnostic significance of stock analysis.

155. Renin-angiotensin system. Hypotensive drugs are inhibitors of angiotensin-converting enzyme.

156. Biochemical composition of muscle. Myofibril proteins: myosin, actin, tropomyosin, troponin. Molecular mechanisms of muscle shortening. Bioenergetics of muscle tissue.

157. Biochemistry of the nervous system. Energy exchange in the human brain. Significance of aerobic oxidation of glucose; change the minds of physiological sleep and anesthesia.

158. Biochemistry of neurotransmitters; receptors of neurotransmitters and physiologically active reactions.

159. Peptidergic system of the brain: opioid peptides, opioid peptide receptors.

160. Disruption of the exchange of neurotransmitters and modulators in the brain during mental disorders. Neurochemical mechanisms of psychotropic disorders.

## 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. https://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