

MINISTRY OF HEALTH OF THE REPUBLIC OF BELARUS
Educational Institution
BELARUSIAN STATE MEDICAL UNIVERSITY

**Контрольный
экземпляр**



APPROVED

by Vice-rector for academic work

Yu. A. Sokolov

15.11.2023

Reg. # UD-L. 685/2324 /edu.

BIOLOGICAL CHEMISTRY

**Curriculum of educational institution
in the academic discipline for the specialty:**

1-79 01 08 «Pharmacy»

Curriculum is based on the educational program «Biological Chemistry», approved 17.11.2022, registration # УД-Л.685/2223/уч.; on the educational plan in the specialty 1-79 01 08 «Pharmacy», approved 17.05.2023, registration # 7-07-0912-01/2324/mf.

COMPILERS:

A.D.Taganovich, Head of the Department of Biological Chemistry of the educational institution «Belarusian State Medical University», D.Sc., Professor;

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RECOMMENDED FOR APPROVAL:

by the Department of Biological Chemistry of the educational institution «Belarusian State Medical University»
(protocol # 1 of 31.08.2023);

by the Scientific and Methodological Council of the educational institution «Belarusian State Medical University»
(protocol # 11 of 15.11.2023)

EXPLANATORY NOTE

«Biological Chemistry» – the academic discipline of the module «Human Physiology», which contains systematized scientific knowledge about the chemical structure of vital organism, chemical processes underlying its vitality, possible causes and effects of metabolic disturbances.

The aim of the discipline «Biological Chemistry» is formation of basic professional competencies for pharmaceutical consulting.

The objectives of the discipline «Biological Chemistry» are to form students' scientific knowledge about:

chemical composition and molecular processes in human cells, tissues and full organism;

structure of major cell macromolecules;

molecular basis of bioenergetics and metabolism;

functional biochemistry of specialized tissues and organs;

mechanisms of neuroendocrine regulation of metabolism;

molecular processes being possible targets of drug action during its intake and transformation in human organism;

mechanisms of transfer and realization of genetic information in development of new drugs with genetic engineering;

mechanisms of drug biotransformation and its metabolic action in human organism;

methods of biochemical analysis and interpretation its results;

skills and abilities necessary for further studying of educational disciplines and activities of the pharmacist;

The knowledge, skills, and abilities acquired during the study of the academic discipline «Biological Chemistry» are necessary for successful mastering of the following academic disciplines: «Pathological Physiology», «Pharmaceutical Biotechnology», modules: «Pharmacology and Pharmacotherapy», «Pharmaceutical Chemistry and Pharmacognosy».

Studying the educational discipline «Biological Chemistry» should ensure the formation of students' basic professional competency:

BPC. Identify the symptoms and syndromes that require an ambulance call or immediate medical attention or that allow for the use of over-the-counter medications.

As a result of studying the discipline «Biological Chemistry» the student should

know:

the structure of major biomolecules and their relationship with function;

basic provisions of bioenergetics, mechanisms of oxidative and photosynthetic phosphorylation;

metabolic pathways; interrelations between metabolism and function of human tissues and organs;

biochemical basis of regulation of metabolism, the role of vitamins and hormones;

causes and mechanisms of «molecular diseases», principles of its diagnosis and treatment;

basic biochemical indicators in blood and urine;
metabolic pathways of drug biotransformation;

be able to:

use express methods in biochemical investigations;

master:

skills of interpreting the results of blood and urine biochemical investigations.

Total number of academic hours for the study of the discipline is 205. Classroom hours according to the types of studies: lectures - 34 hours (including supervised student independent work – 11 hours), laboratory classes - 105, student independent work (self-study) - 66 hours.

Intermediate assessment is carried out according to the syllabus of the specialty in the form of a credit (4 semester) and examination (5 semester).

Form of higher education – full-time.

ALLOCATION OF ACADEMIC TIME ACCORDING TO SEMESTERS OF STUDY

Code, name of the specialty	semester	Number of academic hours						Form of intermediate assessment
		total	in-class	including			out-of-class self-studies	
				lectures (including supervised independent work)	supervised student independent work	laboratory studies		
1-79 01 08 «Pharmacy»	4	110	82	28	9	54	28	credit
	5	95	57	6	2	51	38	exam

THEMATIC PLAN

Section (topic) name	Number of class hours	
	lectures	laboratory
1. Introduction to educational discipline «Biological chemistry». Structure and function of proteins	-	9
1.1. Introduction to biochemistry. The structure of amino acids and peptides. Determination of the protein content in biological fluids	-	3
1.2. Structural organization of proteins and basics of its functioning. Reactions of protein sedimentation	-	3
1.3. Physical and chemical properties of proteins. Methods of separation, isolation and purification of proteins	-	3
2. Enzymes	4	9
2.1. Structure and properties of enzymes. Enzyme kinetics. The mechanisms of enzyme action	2	3
2.2. Regulation of enzyme activity. Enzyme activators and inhibitors. Medical enzymology	2	6
3. Introduction to metabolism. Membranes. Biological oxidation. Central metabolic pathways	6	6
3.1. Structure and function of cell membrane. Introduction in metabolism and energy exchange. General metabolic pathways	2	3
3.2. Biological oxidation	4	3
4. Metabolism and function of carbohydrates	4	12
4.1. Carbohydrates. Glycogen metabolism. Anaerobic glucose oxidation	2	3
4.2. Aerobic glucose oxidation. Metabolism of pyruvate. Gluconeogenesis	2	3
4.3. Secondary pathways of glucose metabolism. Regulation of carbohydrate metabolism. Disorders of carbohydrate metabolism	-	6
5. Metabolism and functions of lipids	4	18
5.1. Classification and function of lipids. Lipid digestion and absorption	2	3
5.2. Lipid transport. Cholesterol metabolism. Biochemistry of atherosclerosis	2	3
5.3. Oxidation of fatty acids and glycerol. Acetyl-CoA using in lipid metabolism. Biochemistry of obesity	-	12
6. Amino acid and protein metabolism	2	6
6.1. Protein digestion. The role of proteolysis. Pathways of amino acid utilization in cells	-	3

Section (topic) name	Number of class hours	
	lectures	laboratory
6.2. Detoxification of ammonia. The fate of amino acid carbon skeletons	2	3
7. Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Protein biosynthesis. Techniques of molecular biology	4	9
7.1. Structure and metabolism of nucleoproteins	2	3
7.2. Biosynthesis of nucleic acids and proteins. Techniques of molecular biology	2	6
8. Biochemistry of vitamins	-	3
9. Regulation of metabolism. Biochemistry of hormones	4	15
9.1. Principal mechanisms of metabolism regulation. Mechanism of hormone action	2	3
9.2. Hormonal regulation of lipid, protein and carbohydrate metabolism	2	3
9.3. Hormonal regulation of water and mineral metabolism	-	3
9.4. The relationship between protein, carbohydrate and lipid metabolism. Integration of metabolism	-	6
10. Functional biochemistry	4	9
10.1. Biochemistry of the blood	2	6
10.2. Biochemistry of the liver	2	3
11. Pharmaceutical biochemistry. Drug pharmacokinetics. Xenobiotic biotransformation	2	9
Total hours	34	105

CONTENT OF THE EDUCATIONAL MATERIAL

1. Introduction to the discipline «Biological Chemistry». Structure and function of proteins

1.1. Introduction to biochemistry. Structure of amino acids and peptides. Determination of the protein content in biological fluids

The objectives of biological chemistry. Biological chemistry as a discipline about molecular basics of human's health. The development of biochemistry, major stages. Contribution of Belarusian biochemistry school. Molecular biology, genetic engineering and biotechnology in diagnosis and correction of metabolic disturbances.

Position of educational discipline «Biological chemistry» in pharmaceutical education. Biological chemistry and other medical and biological disciplines. Major categories (static – bioorganic chemistry, dynamic – metabolism and functional biochemistry) and areas (depending on the living nature studied object) of the biochemistry. Biological chemistry, medicine and pharmacy (clinical biochemistry, laboratory diagnostics, metabolic therapy). Major biochemical components of the tissues. Methods of biochemical research and its clinical significance.

Proteins as a major component of the vital tissue. Protein functions. An elementary structure of proteins. Hydrolysis of proteins. Amino acids as a structural monomer of proteins. Proteinogenic and non-proteinogenic amino acids. Essential and non-essential amino acids. Amino acids as drugs.

Buffer properties of proteins, their significance. Molecular weight of the proteins and methods of its determination.

Determination of total and individual protein content. The difference in protein composition in organs. Changes of protein composition during ontogenesis and in diseases. Proteins as drugs.

1.2. Structural organization of proteins and basics of its functioning. Reactions of protein sedimentation

The levels of protein structural organization. Primary structure of proteins, its characteristic. Properties of the peptide bond. Peptides and its functions in human organism. The significance of primary structure and its impact on protein biological properties. Specificity of protein structure.

Secondary structure of protein. Spiral, layered and folded, disordered protein structures. Structure of α -helix, β -sheet, its features and differences. Chemical bonds stabilizing secondary structure. The significance of secondary structure. Supersecondary structure. Tertiary structure of protein. Weak intramolecular interactions in polypeptide chain. Disulfide bonds. Significance of tertiary structure. The role of chaperons, chaperonins in forming of native protein structure. Globular and fibrous proteins. Protein denaturation, reversibility of denaturation. Significance of protein denaturation in medicine.

Quaternary structure of proteins. Significance of quaternary structure. Cooperative changes of protomer conformation (example: myoglobin vs hemoglobin).

Simple proteins, representatives, brief characteristics. Self-association of supramolecular protein structures.

Compound proteins. General ideas about structure and nomenclature of compound proteins, structure of prosthetic groups, the types of chemical bonds between apoprotein and prosthetic group. Diversity of structural and functional different proteins.

The ability for specific interactions as a basics of biological functions of proteins. The term «complementarity». Ligands and protein functions. Reversibility of ligand binding.

1.3. Physical and chemical properties of proteins. Methods of separation, isolation and purification of proteins

Physical and chemical properties of proteins. Colloid solutions of proteins, its properties, viscosity, ability to gel forming, optical activity, ionization, amphotericity, hydration.

The scheme and methods of isolation and purification of proteins: homogenization, extraction, group separation, separation of proteins with similar physical and chemical properties according to its molecular weight (ultracentrifuging, gel-filtration), its charge (electrophoresis, isoelectric focusing, ion-exchange chromatography). Affinity chromatography. The methods of protein homogeneity analysis.

2. Enzymes

2.1. Structure and properties of enzymes. Enzyme kinetics. The mechanisms of enzyme action

Basics about enzymes. History of enzymes discovery and investigation. General ideas about catalysis. General features of catalysators: energetic barrier of the reaction, energy of activation, free energy. Essence of catalysator action. Similarities and differences of chemical and biological catalysators. Enzyme specificity, its types.

Nomenclature and classification of enzymes. Features of enzyme classes. The units of enzyme activity and quantity.

Structural and functional organization of enzymes. Simple and compound proteins-enzymes. Structure of compound enzymes: apoenzyme, co-factors: (prosthetic groups and coenzymes). Co-factors – metal ions, vitamins and non-vitaminic organic substances. Functional organization of enzymes. Active site of enzyme, its structure. Allosteric site of enzyme, its significance.

The mechanism of enzyme action. The stages of enzymatic process, its characteristics. «Lock-and-key» and «induced-fit model» theories in explanation of enzyme and substrate interactions. Molecular mechanisms of the stages of fermentative process.

Enzyme kinetics, objectives. Dependence of the enzyme catalyzed reaction velocity on the substrate concentration. General ideas about the order of reaction, Michaelis-Menten equation, the ways of graphic imaging, constant of dissociation (K_s) and Michaelis constant (K_m). Dependence of the enzyme catalyzed reaction velocity on the enzyme concentration, pH, temperature, its significance for enzyme functioning in human organism.

2.2. Regulation of enzyme activity. Enzyme activators and inhibitors. Medical enzymology

Impact of activators on enzymatic reaction, its kinds (metals, cations, anions, organic substances). Inhibitors of enzymes, its classification in accordance to mechanism of action, stability of their association with enzymes, non-specific, specific, irreversible, reversible inhibitors. The mechanism of competitive and non-competitive enzyme regulation. Antimetabolites. The examples of different kinds of inhibitors, its practical use in therapy and pharmacy. Regulation of enzyme concentration, constitutive and adaptive enzymes, antienzymes. Regulation of enzyme activity, its mechanisms: types of covalent modification; types of allosteric regulation; cooperativity effect (symmetric and consecutive model). Multi-enzyme complexes. Multiple molecular forms of enzymes, general ideas. Isoenzymes, its role (lactate dehydrogenase, creatine kinase). The characteristics and use of immobilized enzymes.

Practical significance of enzymes. The sources of enzymes. Concept of medical enzymology, enzyme diagnostics, enzyme therapy, enzyme pathology. Enzymes as analytical reagents.

3. Introduction to metabolism. Membranes. Biological oxidation. Central metabolic pathways

3.1. Structure and function of cell membrane. Introduction in metabolism and energy exchange. General metabolic pathways

Catabolism and anabolism as two sides of metabolism, their stages and interrelations. Catabolic, anabolic and amphibolic pathways in metabolism, its significance. Specific and general catabolic pathways. Concept of metabolon. The chart of metabolism. General cellular end products of metabolism: water, carbon dioxide, ammonia, urea. Other excretory products. Methods for studying metabolism, research of human organism, tissue sections. Tissue homogenates, subcellular structures. Isolation of metabolites and enzymes, determination of substrate transformation sequence. Isotopic methods.

Structural organization of biological membranes, their functions. The characteristics of membrane structural components (proteins, lipids, carbohydrates): localization, content, physical and chemical properties, ratio of components.

Catabolism of general dietary and storage substances –carbohydrates, lipids, proteins (amino acids); concept of specific catabolic pathways (pyruvate formation from carbohydrates and most of amino acids; acetyl-coenzyme A (acetyl-CoA) formation from fatty acids and some amino acids) and general catabolic pathways (pyruvate and acetyl-CoA oxidation).

Vitamins and vitamin-like substances as coenzymes in general catabolic pathways.

Oxidative decarboxylation of pyruvate: the sequence of reactions, structure of pyruvate dehydrogenase complex. Tricarboxylic acid cycle: sequence of reactions and characteristics of enzymes. Interrelations between general metabolic pathways and electron-transport chain. Mechanisms of regulation of oxidative decarboxylation and tricarboxylic acid cycle.

3.2. Biological oxidation

Low-energy and high-energy substances. High-energy phosphates and their significance in energy accumulation. Coupling of endergonic reactions with exergonic, kinds of coupling (membrane and non-membrane). Adenosine triphosphoric acid as the most important accumulator and source of energy. Adenosine triphosphoric acid synthesis during phosphorylation, its kinds. Adenosine triphosphoric acid hydrolysis, adenylate kinase. Biological oxidation as general pathway of substrate transformation in human organism. The pathways of molecular oxygen use in the reactions of biological oxidation, its localization in the cell and significance.

The ways of oxidation: by the way of dehydrogenation (dehydrogenases, peroxidases), by the way of oxygen incorporation (monooxygenases, dioxygenases) and reactive oxygen species involvement.

Dehydrogenation of substrates and hydrogen oxidation with water formation as energy source for adenosine triphosphoric acid synthesis. Structure organization of mitochondria (outer and inner membranes, intermembrane space, matrix). Structure of mitochondrial respiratory chain. The characteristics of electron and proton carriers in respiratory chain and their organization in the inner mitochondrial membrane. Mechanism of proton and electron transfer by respiratory chain carriers. Cascade free energy changes during proton and electron transfer in respiratory chain.

Oxidative phosphorylation and its quantitative expression (P/O ratio). Energy formation in respiratory chain during proton and electron transfer from substrate to

oxygen. Coupling between respiration and phosphorylation. Localization of phosphorylation points in mitochondrial respiratory chains. Oxidative phosphorylation hypotheses: chemical coupling, mechanical and chemical, chemiosmotic. Postulates of Mitchell chemiosmotic theory. Selective permeability of mitochondrial membrane. Transmembrane electrochemical potential as intermediate form of energy accumulation in oxidative phosphorylation. Structure and functions of proton adenosine triphosphate synthase. Respiratory control.

Uncoupling and inhibition of oxidative phosphorylation. Thermoregulatory function of tissue respiration. Drugs uncoupling and inhibiting oxidative phosphorylation.

Photosynthetic phosphorylation.

Microsomal oxidation. Biological role of mitochondrial monooxygenase systems. Role of dioxygenase system in aromatic substances detoxification.

4. Metabolism and function of carbohydrates

4.1. Carbohydrates. Glycogen metabolism. Anaerobic glucose oxidation.

General dietary carbohydrates. Carbohydrate content in human tissues. Biological role of carbohydrates. Carbohydrate digestion and absorption of the products of carbohydrate digestion. Glucose as the most important component of carbohydrate metabolism. General scheme of glucose sources and ways of its utilization in organism. Central role of glucose-6-phosphate in carbohydrate metabolism. Glycogen as a reserve polysaccharide in animals, its properties.

Chemistry of glycogen synthesis (glycogenesis). Characteristics of glycogen synthase. Regulation of glycogen synthesis.

Glycogen mobilization (glycogenolysis), hydrolytic and phosphorolytic pathways. Phosphorolysis as general pathway of glycogen mobilization. Characteristics of phosphorylase. Regulation of glycogen mobilization. Interrelations between enzymes of glycogen synthesis and breakdown. The role of protein kinases and cyclic 3',5'-adenosine monophosphate in synchronization of synthesis and breakdown of glycogen.

Glucose catabolism. Anaerobic and aerobic pathways of glucose oxidation, its general characteristics and interrelations. Glucose oxidation to pyruvate as a specific pathway of glucose catabolism, its localization.

Anaerobic glycolysis, glycolytic oxidoreduction, pyruvate as hydrogen acceptor in glycolysis. Substrate phosphorylation. Energetic balance of anaerobic degradation of glucose. Allocation and physiologic significance of anaerobic degradation of glucose. Alcoholic fermentation. Alcohol metabolism in organism, concept of endogenic ethanol.

4.2. Aerobic glucose oxidation. Metabolism of pyruvate. Gluconeogenesis

Aerobic oxidation as the predominant pathway of glucose catabolism in humans and other aerobic organisms to pyruvate in cytosol with further oxidative decarboxylation of pyruvate and oxidation of acetyl-CoA in mitochondria to water and carbon dioxide. Energetic yield of glucose aerobic oxidation. Switching of anaerobic pathway of glucose oxidation to aerobic. Shuttle mechanisms of reducing equivalent transfer across mitochondria membranes and oxidation of glycolytic

reduced nicotinamide dinucleotide (NADH+H⁺) in mitochondria. Allosteric regulation of aerobic glucose oxidation pathway (Paster's effect).

Pyruvate as a central metabolite. Gluconeogenesis. Bypass reverse pathways for irreversible steps of glycolysis. Key enzymes of gluconeogenesis, biological role of gluconeogenesis. Interrelations between glycolysis in muscle tissue and gluconeogenesis in liver (Cory's cycle (glucose-lactate cycle)).

4.3. Secondary pathways of glucose metabolism. Regulation of carbohydrate metabolism. Disorders of carbohydrate metabolism

Pentose phosphate pathway of glucose metabolism, chemistry of its oxidative stage (ribulose-5-phosphate formation) and non-oxidative stages. Products of pentose phosphate pathway: formation of reduced nicotinamide dinucleotide phosphate (NADPH+H⁺) and pentose phosphates. Allocation and biological role of pentose phosphate pathway of glucose metabolism. Interrelations between pentose phosphate pathway of glucose metabolism and glycolysis.

Carbohydrate synthesis in Calvin's cycle.

Glucuronic acid pathway. Major reactions. Biological role. Connection with pentose phosphate pathway and glycolysis.

The role of different pathways of carbohydrate metabolism in blood glucose level regulation. Hormonal regulation of blood glucose level. The role of insulin, epinephrine, glucagon, glucocorticoids.

Disorders in carbohydrate metabolism. Hereditary disorders of mono- and disaccharide metabolism.

Carbohydrates as drugs. Drugs impacting on intracellular energy exchange.

Quantitative determination of glucose in blood.

5. Metabolism and functions of lipids

5.1. Classification and function of lipids. Lipid digestion and absorption

Functions of lipids in vital organisms. Major lipids of human tissues. Storage and membrane lipids. Lipid digestion. Essential conditions for lipid digestion. Bile acids: structure, role in lipid digestion and absorption of products of lipid digestion. Pancreatic lipase, its activators. Hydrolysis of phospholipids by phospholipases A₁, A₂, C, D and cholesterol esters by cholesterol esterase. End products of lipid hydrolysis, their absorption.

Re-synthesis of lipids in enterocytes. Transport forms of lipids in blood, chylomicron as a transport form of exogenous lipids.

5.2. Lipid transport. Cholesterol metabolism. Biochemistry of atherosclerosis

Exogenous and endogenous lipid transport in organism. Structure and content of transfer lipoprotein complexes, location of its formation. Lipoprotein lipase, its functions.

Synthesis of neutral fats and phospholipids, its functions, general stages.

Synthesis of cholesterol. β -hydroxy- β -methylglutaryl-coenzyme A as an intermediate product in ketone body and cholesterol synthesis. Ketone body formation and its role in human organism. Hydroxymethylglutaryl-CoA reductase, regulation of its activity. Hydroxymethylglutaryl-CoA reductase inhibitors are drugs suppressing cholesterol biosynthesis.

Direct and reverse cholesterol transport. Cholesterol as precursor of other steroids (bile acids, hormones, vitamin D₃). Excretion of cholesterol and bile acids out of the human body.

Hypercholesterolemia and its causes. Cholelithiasis. Biochemistry of atherosclerosis, risk factors. Biochemical basics of atherosclerosis treatment and prevention.

5.3. Oxidation of fatty acids and glycerol. Acetyl-CoA using in lipid metabolism. Biochemistry of obesity

Mechanism of fatty acid activation. Fatty acid transport in mitochondria, the role of carnitine. β -Oxidation of fatty acids is a specific catabolic pathway of fatty acids. β -Oxidation enzymes. Oxidation of fatty acids with odd carbon count. Connection of β -oxidation with tissue respiration enzymes, energy yield of fatty acid β -oxidation.

Synthesis of higher fatty acids on polyenzyme complex – fatty acid synthase. Chemical structure of polyenzyme complex. The role of malonyl-CoA in fatty acid synthesis, its formation. The role of NADPH+H⁺ in fatty acid synthesis, its sources. Synthesis of fatty acids with longer carbon chain. Highly unsaturated fatty acids.

Storage and mobilization of fats in adipose tissue, its regulation. Obesity. Lipotropic factors as drugs.

Synthesis of neutral fats and phospholipids, their functions and general stages.

6. Amino acid and protein metabolism

6.1. Protein digestion. The role of proteolysis. Pathways of amino acid utilization in cells

Nitrogen balance, its conditions. The concept of wear rate, physiological protein minimum in the diet. Protein standards in human nutrition, biological value of proteins.

Protein digestion. Gastric juice, its characteristic. The role of hydrochloric acid in protein digestion. Gastric juice enzymes (pepsin, gastricsin, rennin). Mechanism of pepsinogen activation. Features of gastricsin and rennin action. Proteolytic enzymes of pancreatic juice (trypsin, chymotrypsin, carboxypeptidase, elastase), mechanism of their activation. Proteolytic enzymes of intestine juice: aminopeptidase, dipeptidases, tripeptidases, prolinases and prolidases. Intestine juice proteolytic enzymes specificity. Amino acid absorption. Major transport systems for amino acid absorption. Regulation of protein digestion. The major biochemical processes in colon. Putrefaction of proteins, detoxification of putrefaction products. Protein degradation in tissues. Cathepsins. Partial proteolysis. Inhibitors of proteolysis. The pathways of amino acid utilization in liver and tissues. Amino acid transfer across the cellular membranes. General diagram of amino acid sources and ways of their utilization. The dynamic condition of proteins in human organism.

Amino acid amino group metabolism. Transamination of amino acids. Structure and characteristics of aminotransferases. Coenzyme function of vitamin B₆, chemistry of amino acid transamination. Biological role of amino acid transamination. The significance of determination of aminotransferase activity in blood serum. Types of amino acid deamination. Oxidative deamination. Structure and characteristics of L- and D-amino acid oxidases, glutamate dehydrogenase,

chemistry of oxidative deamination. Direct and indirect amino acid deamination. Biological role of amino acid deamination.

Decarboxylation of amino acids. Characteristics of decarboxylases. Biogenic amines, its structure and biological role (tryptamine, serotonin, dopamine, histamine, γ -aminobutyric acid, putrescin, cadaverine). Amino oxidases: monoamine oxidases and diamine oxidases. Detoxification of biogenic amines. Polyamines (spermidine, spermine), its role. Drugs as monoamine oxidase inhibitors. Antihistamine drugs.

Methylation and transmethylation as pathways of amino acid residue metabolism. Methionine and S-adenosylmethionine. Creatine, epinephrine, phosphatidylcholine synthesis, xenobiotic methylation. Methylation of homocysteine. Using of single carbon fragments of tetrahydrofolic acid derivatives. Phenylalanine and tyrosine metabolism. Catecholamine synthesis. Hereditary disorders of amino acid metabolism (phenylketonuria, albinism, alkaptonuria).

6.2. Detoxification of ammonia. The fate of amino acid carbon skeletons

Ammonia as a final product of nitrogen-containing substances, sources of its formation. Ammonia detoxification in vital organism (local and general), its mechanisms. The role of glutamine in ammonia detoxification and transport. Glutamine as nitrogen donor in organic substance synthesis. Glucose-alanine cycle. General detoxification of ammonia by urea and ammonium salts synthesis, its chemistry. Urea and ammonium salts as end products of nitrogen metabolism. Connection of the ornithine cycle with the tricarboxylic acid cycle, energy balance. The source of nitrogen atoms in urea. The role of renal glutaminase in ammonium salts synthesis, its activation in acidosis.

The ways of amino acid carbon skeletons metabolism. Glycogenic and ketogenic acids. Biosynthesis of non-essential amino acids.

Amino acids as precursors of biologically active substances.

7. Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Protein biosynthesis. Techniques of molecular biology

7.1. Structure and metabolism of nucleoproteins

Nucleoproteins, structure and functions. Characteristics of histones and protamines as protein components of nucleoproteins. Nucleic acids. The features of primary structure of nucleic acids. Chemical bonds between nucleotides. Secondary structure of nucleic acids: features of DNA and RNA secondary structure, types of bonds stabilizing secondary structure. Tertiary structure, role of proteins in organization of nucleic acid spatial structure. Structure of ribosomes. Polyribosomes. Informosome and messenger RNA, transfer RNA, structure and functions. Chromosome structure.

Nucleic acid denaturation. DNA-DNA, DNA-RNA hybridization. Methods of nucleic acid structure investigation.

Nucleic acid degradation. Gastrointestinal tract nucleases. Tissue nucleases. Degradation of purine nucleotides, formation of uric acid. Purine nucleotide synthesis. Substrates of synthesis, key enzymes and regulation of purine nucleotide synthesis. Degradation of pyrimidine nucleotides, end products. Pyrimidine nucleotides synthesis: substrates and enzymes

Re-use of nucleosides and nitric bases for nucleotide synthesis. Disorders of nucleotide metabolism.

7.2. Biosynthesis of nucleic acids and proteins. Techniques of molecular biology

Replication: substrates, enzymes and biological significance. Stages of replication. DNA-polymerases, their function. DNA injuries and repair.

RNA biosynthesis (transcription), its mechanism and significance. RNA-polymerase. Structural and functional characteristics of transcription (operon). Reversibility of transcription.

Protein biosynthesis (translation), the essential components of translation. The role of mRNA as a matrix for protein synthesis. Genetic code, its properties. Stages of translation. Amino acid activation, characteristics and role of aminoacyl-tRNA synthetase in protein biosynthesis, their specificity. The role of tRNA in protein biosynthesis, functional sites in its molecule. Stages of translation, regulation.

Processing of nucleic acids and proteins. Changes in structure of nucleic acids and proteins after their primary synthesis.

Epigenetics. Concept of epigenome. Epigenetic mechanisms of gene regulation (DNA methylation, histone acetylation, genome imprinting, the role of regulatory RNA and prions). Factors impacting on epigenome. Epigenetics in medicine.

Activators and inhibitors of nucleic acid and protein synthesis, their use in medicine (levels of inhibition).

Modern techniques of molecular biology. Polymerase chain reaction (PCR). Genome dactyloscopy. DNA and RNA blot-analysis. DNA sequencing. Cloning.

8. Biochemistry of vitamins

History of development of vitamins doctrine. Classification, nomenclature, distinctive features of vitamins as essential components of nutrition. Vitamin functions. Disorders in vitamin balance, their causes. Sources of vitamins. Vitamins as intracellular metabolic regulators. Vitamins and intestinal microflora.

Fat-soluble vitamins. Vitamin A (antixerophthalmic, retinol), manifestations of deficiency and hypervitaminosis. Retinol, retinal, retinoic acid, provitamins and possibility of forming a vitamin from them. The role of β -carotin, sources, requirement, biological role, vitamin A participation in the photochemical act of seeing, vitamin A and β -carotin as drugs. Vitamins D (calciferols, antirachitic), manifestations of deficiency and hypervitaminosis, chemical structure, provitamins and possibility of forming a vitamin from them, sources, requirement, biological role, synthesis of biologically active form, mechanism of calcitriol action. Vitamin E (tocopherols, antisterilic), manifestations of deficiency, chemical structure, sources, requirement, biological role. Antioxidant complexes of vitamins. Vitamin K (phylloquinone, antihemorrhagic), manifestations of deficiency, chemical structure, sources, requirement, biological role, vitamin K-dependent carboxylase and carboxylation of amino acid residues of glutamate, vitamin K and dicumarol anticoagulants.

Water-soluble vitamins. Vitamin C (ascorbic acid, antiscorbutic), manifestations of deficiency, chemical structure, properties, sources, requirement, biological functions. Connection of biological functioning of vitamin C with

vitamin P. Vitamin B₁ (thiamine, antineuritic), manifestations of deficiency, chemical structure, properties, sources, requirement, coenzyme form, biological role. Vitamin B₂ (riboflavin), manifestations of deficiency, chemical structure, properties, sources, requirement, coenzyme forms, biological role. Vitamin PP (nicotinic acid, nicotinamide, niacin, antipellagric), manifestations of deficiency, chemical structure, properties, sources, requirement, coenzyme forms, biological role. Vitamin B₆ (pyridoxine, antidermatitic), manifestations of deficiency, chemical structure, properties, sources, requirement, coenzyme forms, biological role. Pantothenic acid, manifestations of deficiency, chemical structure, properties, sources, requirement, coenzyme forms, biological functions. Vitamin H (biotin, antiseborrheic), experimental deficiency, chemical structure, properties, sources, requirement, coenzyme form, biological role, the examples of carboxylation reactions. Folic acid (vitamin B₉), manifestations of deficiency, chemical structure, participation of para-aminobenzoic acid in folic acid formation, sources, requirement, coenzyme forms, biological role. Sulfanilamide drugs. Vitamin B₁₂ (cobalamin, antianemic), manifestations of deficiency, chemical structure, sources, requirement, causes of deficiency, storage, coenzyme forms. Interrelations between vitamin B₁₂ and folic acid functions in single carbon radicals transfer and synthesis of major biological substances.

Vitamin F. The role of essential fatty acids. Vitamin-like substances and their role in human organism. The donors of methyl radicals.

Vitamins and coenzyme forms as drugs.

Antivitamins, its characteristics, major representatives, their structure, impact on metabolism, use in medicine.

9. Regulation of metabolism. Biochemistry of hormones

9.1. Principal mechanisms of metabolism regulation. Mechanism of hormone action

Hormones and hormone-like substances, its characteristics. Hormones as distant regulators of cellular metabolism. Transpituitary and parapituitary ways of metabolism regulation. Classification of hormones based on its chemical structure: amino acid derivatives, proteins and peptides, steroid hormones. Target cells and cellular hormone receptors. General mechanisms of hormone regulating impact on metabolism: changing in enzyme activity (activating and inhibition), changing in enzyme concentration in the cell (induction or repression of protein biosynthesis, changing in velocity of enzyme degradation); changing in cellular membrane properties. The mechanisms of direct and reverse connection in regulation of hormone biosynthesis and hormone action. Hormones that cannot diffuse across the membrane of target cell (proteins and peptides, catecholamines). Messengers in their action in the cell: cyclic nucleotides, calcium ions, the products of phosphatidylinositol metabolism, tyrosine kinase activity. Adenylate cyclase and guanylate cyclase as the signal systems of cellular membrane. The mechanism of hormone signal transfer in the cell, its stages. Removal of hormonal signal. Impact of drugs on cyclic nucleotide concentration.

The mechanism of action of hormones diffusing across the cellular membrane. Hormone receptors localization. Hormone response DNA elements.

Structure of steroid and thyroid hormone receptors. Steroid hormones as regulators of gene expression. Practical use of hormones.

9.2. Hormonal regulation of lipid, protein and carbohydrate metabolism

Protein and peptide hormones: hypothalamic (liberins and statins), pituitary hormones. Tropic pituitary hormones and their significance in peripheral glands regulation (somatotropin, corticotropin, thyrotropin, gonadotropins, lipotropins), chemical structure, biological functions. Melanotropin and its functions in organism. Neurohormones (oxytocin and vasopressin), its biological action.

Pancreatic hormones: insulin and glucagon. Insulin biosynthesis. Insulin sensitive and insulin resistant tissues. Biological action of insulin and glucagon. Diabetes mellitus, characteristics of metabolic disorders in diabetes. Complications of diabetes. Insulin drugs and its use.

Adrenal medulla hormones (catecholamines), structure and biosynthesis, impact on metabolism.

Steroid hormones. General diagram of steroid biosynthesis. Corticosteroids – glucocorticoids and mineralocorticoids. Glucocorticoids: structure, regulation of secretion, impact on carbohydrate, lipid and protein metabolism. Anti-inflammatory and anti-allergic action of glucocorticoids.

The manifestations of adrenal cortex hormone hypoproduction (Addison disease), adrenal cortex hormone hyperproduction.

Thyroid hormones. Iodothyronines, structure, biosynthesis. connection with thyrotropic hormone. Biological function and mechanism of action of iodothyronines. General manifestation of thyroid gland function disorders, endemic goiter.

Sex hormones. Male sex hormones, structure, biological role. Female sex hormones: structure, connection with menstrual cycle. Sex hormone impact on reproductive and non-reproductive tissues. Metabolic action of sex hormones. Anabolic steroids as drugs. Female sex hormones as components of oral contraceptive drugs.

9.3. Hormonal regulation of water and mineral metabolism.

Mineral substances of human tissues. Water, its functions, content in vital organism. Water compartmentalization by its location in the organism (intracellular, extracellular, intravascular and interstitial), by its ability to move in the organism (free, immobilized). Age, organ, sex differences in water content. Daily requirement and loss of water. Non-organic ions functions. Content of mineral substances. Macro- and microelements.

Sodium and potassium in human organism, its intake, content, daily requirement, biological role. Regulation of the electrolyte consistency and extracellular fluid volume by vasopressin, aldosterone, atrial natriuretic factor. Renin-angiotensin system. The role of angiotensin II. Angiotensin converting enzyme inhibitors as drugs. Mineralocorticoids, structure, impact on electrolyte metabolism.

Calcium and phosphorous, its intake, content, daily requirement, biological functions in human organism. Metabolism and functions of iron, copper.

Parathyroid hormones (parathyrin): structure, the role in phosphorous and calcium metabolism regulation. Thyroid gland hormone (calcitonin): structure, biological role, connection with parathyrin in phosphorous and calcium metabolism regulation.

9.4. The relationship between protein, carbohydrate and lipid metabolism. Integration of metabolism

Intracellular localization of general metabolic pathways. Metabolic specialization of main organs.

Convention of metabolism division to several kinds of metabolism. Manifestations of interrelations in protein, carbohydrate and lipid metabolism. Main integrating metabolites, their biological role. The ability of mutual transformation of glucose, fatty acids and amino acids. Common mechanisms of regulation of carbohydrate, lipid and protein metabolism. Mechanisms of interorgan integration in metabolism regulation: blood and lymph circulation (communicational role), hormonal factors, neuroendocrine regulation.

10. Functional biochemistry

10.1. Biochemistry of the blood

Features of blood cell metabolism. Plasma components. Plasma proteins and enzymes. Plasma albumins and globulins, its characteristics and functions. Hemoglobin, structure, derivatives, types. Hemoglobinopathies. Heme and hemoglobin biosynthesis, regulation. Hemoglobin degradation. Biochemical indicators in blood, their use. Blood as the source of drugs.

Hemostasis: blood clotting and anti-clotting systems.

Plasminogen activators and proteolytical enzymes as thrombolytic drugs.

10.2. Biochemistry of the liver

Liver functions in human organism. Liver role in carbohydrate, lipid, protein and amino acid, vitamin, mineral metabolism. Detoxifying function of the liver. The role of microsomal oxidation in xenobiotics detoxification. Cytochrome P450-hydroxylase cycle. Bilirubin metabolism. Types of jaundices.

Synthesis and secretion of the bile as a way of end metabolic products excretion. Enterohepatic recirculation of bile acids in lipid digestion and absorption. Biochemical mechanisms of hepatocellular failure development, its laboratory diagnostics.

11. Pharmaceutical biochemistry. Drug pharmacokinetics. Xenobiotic biotransformation

Pharmaceutical biochemistry. Pharmaceutical biochemistry. Biochemistry and pharmacy. Biogenic and synthetic drugs. Use of biochemical methods in standardization and quality control of drugs. Use of enzymes in drug synthesis and analysis.

Drug transfer across the cellular membranes in various ways of their administration in human organism.

Blood transport of drugs. Specific and non-specific transport systems in blood. Drug interactions with cellular receptors in tissues.

Biochemical basics of individual variability of drug metabolism.

Xenobiotic and drug biotransformation, stages of metabolism. Changing of drug activity and toxicity during metabolism: emerging of toxicity, gain of toxicity,

emerging of activity, gain of activity, changing of activity and full inactivity. Localization and kinds of enzyme xenobiotic transformation: reactions of first stage of biotransformation: oxidation by microsomal enzymes (aromatic and acyclic oxidation, O-dealkylation, N-dealkylation, deamination, sulfoxidation), reduction, hydrolysis; non-microsomal enzyme reactions of xenobiotic metabolism. Reactions of the second stage of biotransformation: conjugation (with glucuronic acid, sulfuric acid, with amino acids, glutathione), thiosulfate reaction, methylation, conjugation, acetylation.

Excretion of xenobiotics from human organism. Factors impacting on drug metabolism, kinds and ways of excretion from human organism. Factors impacting on drug metabolism: genetic, physiological and environmental. Impact of alcohol and nicotine on drug metabolism.

ACADEMIC DISCIPLINE CURRICULAR CHART OF EDUCATIONAL DISCIPLINE «BIOLOGICAL CHEMISTRY» OF MEDICAL AND BIOLOGICAL MODULE 1

Section, topic #	Section (topic) name	Number of hours			Student independent work	Form of control
		lectures	supervised student work	laboratory		
3 semester						
1.	Introduction to discipline «Biological chemistry». Structure and functions of proteins	-	-	9	4	
1.1.	Introduction to biochemistry. The structure of amino acids and peptides. Lab. work Determination of the protein content in biological fluids	-	-	3	1	interviews, written accounts of laboratory work, electronic testing
1.2.	Structural organization of proteins and basics of its functioning. Lab. work Reactions of protein sedimentation	-	-	3	1	interviews, written accounts of laboratory work, electronic testing
1.3.	Physical and chemical properties of proteins. Methods of separation, isolation and purification of proteins. Lab. work Gel-filtration	-	-	3	2	interviews, written accounts of laboratory work, electronic testing
2.	Enzymes	2,66	1,32	9	4	
2.1.	<i>Structure and properties of enzymes. Enzyme kinetics. The mechanisms of enzyme action.</i>	1,33	0,66	3	2	
	introduction to enzymology. Classification and general properties of enzymes	1,33	0,66	-	-	
	Enzymes: classification, structure, properties. Enzyme kinetics. Lab. work. Impact of various factors on enzyme activity. Enzyme specificity.	-	-	3	2	interviews, written accounts of laboratory work, electronic testing
2.2.	<i>Regulation of enzyme activity. Enzyme activators and inhibitors. Medical enzymology</i>	1,33	0,66	6	2	
	Regulation of enzyme activity. Medical enzymology.	1,33	0,66	-	-	
	Enzyme regulation. Lab. work Determining of enzyme activity.	-	-	3	1	interviews, written accounts of laboratory work, electronic testing

	Colloquium «Introduction to discipline «Biological chemistry». «Structure and functions of proteins», «Enzymes»	-	-	3	1	colloquium, control questioning
3.	Introduction to metabolism. Membranes. Biological oxidation. Central metabolic pathways	3,99	1,98	6	4	
3.1.	<i>Structure and functions of cell membrane. Introduction in metabolism and energy exchange. General metabolic pathways</i>	1,33	0,66	3	2	
	Introduction in metabolism and energy exchange. General metabolic pathways	1,33	0,66	-	-	interviews, written accounts of laboratory work, electronic testing
	Introduction in metabolism. Biological oxidation. Central metabolic pathways (oxidative decarboxylation of pyruvate, citric acid Crebs cycle)	-	-	3	2	
	Lab. work Crebs cycle functioning studying					
3.2.	<i>Biological oxidation</i>	2,66	1,32	3	2	
	Tissue respiration. Oxidative phosphorylation	1,33	0,66	-	-	
	Photosynthesis. Photosynthetic phosphorylation	1,33	0,66	-	-	
	Energy exchange. Tissue respiration. Photosynthesis (light stage).	-	-	3	2	interviews, written accounts of laboratory work, electronic testing
	Lab. work Studying of reactions of oxidative phosphorylation					
4.	Metabolism and function of carbohydrates	2,66	1,32	12	8	
4.1.	<i>Carbohydrates. Glycogen metabolism. Anaerobic pathway of glucose oxidation</i>	1,33	0,66	3	2	
	Carbohydrates metabolism. Glycogen metabolism. Glucose oxidation under anaerobic conditions.	1,33	0,66	-	-	
	Carbohydrates. Carbohydrate digestion. Glycogen metabolism. Lab. work Alcoholic fermentation.	-	-	3	2	interviews, written accounts of laboratory work, electronic testing
4.2.	<i>Aerobic glucose oxidation. Metabolism of pyruvate. Gluconeogenesis</i>			3	1	
4.3.	<i>Secondary pathways of glucose metabolism. Disorders in carbohydrate metabolism. Regulation of carbohydrate metabolism</i>	1,33	0,66	6	5	
	Carbohydrate metabolism. Glucose oxidation under aerobic conditions. Gluconeogenesis.	1,33	0,66	-	-	
	Anaerobic and aerobic pathways of glucose oxidation. Pyruvate metabolism. Gluconeogenesis. Exogenous ethanol metabolism. Lab. work Quantitative determination of pyruvate in urine	-	-	3	1	interviews, written accounts of laboratory work, electronic testing
	Pentose phosphate and glucuronic pathways of glucose	-	-	3	1	interviews, written accounts of

	metabolism. Photosynthesis (dark stage). Regulation of glucose level in blood. Lab. work Determination of glucose concentration in the serum. Colloquium «Introduction to metabolism. Membranes. Biological oxidation. Central metabolic pathways», «Carbohydrate metabolism and function»	-	-	3	3	laboratory work, electronic testing colloquium, control questioning
5.	Metabolism and functions of lipids	2,66	1,32	18	8	
5.1.	<i>Classification and function of lipids. Lipid digestion and absorption</i>	1,33	0,66	3	2	
	Lipid metabolism. Lipid digestion and absorption. Transport of exogenous lipids	1,33	0,66	-	-	interviews, written accounts of laboratory work, electronic testing
	Lipid metabolism. Digestion, absorption and resynthesis of lipids. Transport of exogenous lipids. Lab. work Determination of lipase activity.	-	-	3	2	
5.2.	<i>Lipid transport. Cholesterol metabolism. Biochemistry of atherosclerosis.</i>	1,33	0,66	3	2	
	Lipid metabolism. Cholesterol metabolism. Transport of endogenous lipids.	1,33	0,66	-	-	interviews, written accounts of laboratory work, electronic testing
	Lipid storage and mobilization. Cholesterol metabolism. Lipid transport in the blood. Lab. work Quantitative determination of β -lipoproteins in blood serum.	-	-	3	2	
5.3.	<i>Oxidation of fatty acids and glycerol. Using acetyl-coA in lipid metabolism. Biochemistry of obesity.</i>	-	-	12	4	
	Intracellular metabolism of fatty acids. Ketone bodies. Lab. work Quantitative determination of cholesterol in blood serum.	-	-	3	1	interviews, written accounts of laboratory work, electronic testing
	Colloquium «Metabolism and function of lipids»	-	-	3	1	colloquium, control questioning
	Control of practical skills of biochemical analysis	-	-	3	1	written accounts of laboratory work, their oral defense
6.	Amino acid and protein metabolism	1,33	0,66	-	-	
	Protein metabolism. Ways of amino acid utilization in the cell. Ammonia detoxification	1,33	0,66	-	-	interview
7.	Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Protein biosynthesis. Techniques of molecular biology	2,66	1,32	-	-	

	Nucleic acid metabolism	1,33	0,66	-	-	interview
	Matrix biosynthesis. Modern techniques of molecular biology	1,33	0,66	-	-	interview
9.	Regulation of metabolism. Biochemistry of hormones	2,66	1,32	-	-	
	Biochemistry of hormones	1,33	0,66	-	-	interview
	Biochemistry of hormones (continuation)	1,33	0,66	-	-	interview
5.3	Final class «Introduction to educational discipline «Biological chemistry». Structure and functions of proteins». «Introduction to metabolism Membranes. Biological oxidation. Central metabolic pathways». «Carbohydrate metabolism». «Metabolism and function of lipids»	-	-	3	1	Credit, electronic testing
4 semester						
6.	Amino acid and protein metabolism			6	4	
6.1.	<i>Protein digestion. The role of proteolysis. Pathways of amino acid utilization in cells</i>	-	-	3	2	
	Nitrogen balance. Protein digestion and absorption. Lab. work Analysis of gastric juice.	-	-	3	2	interviews, written accounts of laboratory work, electronic testing
6.2.	<i>Detoxification of ammonia. The fate of amino acid carbon skeletons.</i>	-	-	3	2	
	Intracellular amino acid metabolism. Ways of ammonia detoxification. Lab. work Quantitative determination of nonprotein nitrogen nonprotein nitrogen in the blood and urea in urine.	-	-	3	2	interviews, written accounts of laboratory work, electronic testing
7.	Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Protein biosynthesis. Techniques of molecular biology			9	6	
7.1.	<i>Structure and metabolism of nucleoproteins.</i>	-	-	3	3	
	Chemistry and nucleoprotein metabolism. Lab. work Determination of uric acid and general nitrogen in urine.	-	-	3	3	interviews, written accounts of laboratory work, electronic testing
7.2.	<i>Biosynthesis of nucleic acids and proteins. Techniques of molecular biology.</i>			6	3	
	Matrix biosynthesis (synthesis of DNA, RNA, proteins). Techniques of molecular biology. Lab. work Analysis of hydrolysis products of yeast nucleoproteins	-	-	3	1	interviews, written accounts of laboratory work, electronic testing

	Colloquium «Simple protein and amino acid metabolism», «Nucleoprotein metabolism. Structure and synthesis of nucleic acid. Protein synthesis. Techniques of molecular biology»	-	-	3	2	colloquium, control questioning
9.	Regulation of metabolism. Biochemistry of hormones	-	-	6	6	
9.1.	<i>Principal mechanisms of metabolism regulation. Mechanism of hormone action</i>	-	-	3	3	interviews, written accounts of laboratory work, electronic testing
9.2.	<i>Hormonal regulation of lipid, protein and carbohydrate metabolism</i>	-	-	3	3	interviews, written accounts of laboratory work, electronic testing
10.	Functional biochemistry	1,33	0,66	3	2	
10.2	<i>Biochemistry of the liver</i>	1,33	0,66	3	2	
	Biochemistry of the liver	1,33	0,66	-	-	interviews, written accounts of laboratory work, electronic testing
	Biochemistry of the liver	-	-	3	2	
9.	Regulation of metabolism. Biochemistry of hormones	-	-	6	6	
9.4	<i>The relationship between protein, carbohydrate and lipid metabolism. Integration of metabolism</i>	-	-	6	6	
	Integration of metabolism.	-	-	3	3	interviews, written accounts of laboratory work, electronic testing
	Lab. work Studying of hormone impact on glucose content in the blood	-	-	3	3	colloquium, control questioning
	Colloquium «Regulation of metabolism. Biochemistry of hormones». «Biochemistry of the liver».	-	-	3	3	
10.	Functional biochemistry	1,33	0,66	6	4	
10.1	<i>Biochemistry of the blood</i>	1,33	0,66	6	4	
	Biochemistry of the blood. Hemostasis synthesis	1,33	0,66	-	-	interviews, written accounts of laboratory work, electronic testing
	Biochemistry of the blood. Physical and chemical properties. Plasma proteins.	-	-	3	2	
	Lab. work Blood plasma proteins electrophoresis.	-	-	3	2	interviews, written accounts of laboratory work, electronic testing
	Hemostasis systems.	-	-	3	2	
	Lab. work Quantitative determination of calcium in blood	-	-	3	2	interviews, written accounts of laboratory work, electronic testing

serum.									
8. Biochemistry of vitamins									
8.1	<i>Basics of vitaminology. Fat-soluble of vitamins. Water-soluble of vitamins. Vitamin-like substances</i>							3	2
	Biochemistry of nutrition. The role of proteins, fats, carbohydrates and vitamins. Lab. work Qualitative determination of vitamin C.	-	-	-	-	-	-	3	2
9. Regulation of metabolism. Biochemistry of hormones									
9.3	<i>Hormonal regulation of water and mineral metabolism.</i>								
	Biochemistry of nutrition. Macro- and microelements. Regulation of water and salt balance. Lab. work Quantitative determination of sodium and potassium in blood serum	-	-	-	-	-	-	3	2
11. Pharmaceutical biochemistry. Drug pharmacokinetics. Xenobiotics biotransformation									
11.1	<i>Basics of pharmaceutical biochemistry. Xenobiotic biotransformation.</i>	1,33	0,66	9	6				
	Pharmaceutical biochemistry	1,33	0,66	-	-				
	Pharmaceutical biochemistry. Biotransformation of the substances and their excretion. Lab. work Quantitative determination of paracetamol, salicylic acid and their metabolites in the urine	-	-	-	-	-	-	3	1
	Colloquium «Biochemistry of the blood», «Biochemistry of vitamins», «Hormonal regulation of water, salt and mineral balance», «Pharmaceutical biochemistry. Pharmacokinetics of drugs. Xenobiotic biotransformation»	-	-	-	-	-	-	3	2
	Colloquium «Simple protein and amino acid metabolism», «Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Protein biosynthesis. Techniques of molecular biology», «Regulation of metabolism. Hormone biochemistry», «Functional biochemistry», «Vitamin biochemistry», «Pharmaceutical biochemistry. Drug pharmacokinetics. Xenobiotic biotransformation»								
Total hours		23	11	105	66				66

interviews, written accounts of laboratory work, electronic testing

interviews, written accounts of laboratory work, electronic testing

interviews, written accounts of laboratory work, electronic testing

colloquium, control questioning

control questioning, electronic exam

INFORMATION AND INSTRUCTIONAL UNIT

LITERATURE

General:

1. Биологическая химия. Вспомогательный материал к лекциям = Biological chemistry. Lecture notes: учеб.-метод. пособие/ А.Д. Таганович и др.- Минск: БГМУ, 2017 - 163 с.
2. Gubsky, Yu. Biological chemistry : textbook / Vinnytsia : Nova Knyha, 2018. – 2nd edition. – 488p.

Additional:

3. Biological chemistry. Lecture notes / A. D. Tahanovich [et al.] – Minsk : BSMU, 2017. – 162 p.

METHODOLOGICAL RECOMMENDATIONS FOR THE ORGANIZATION AND PERFORMANCE OF STUDENT INDEPENDENT WORK IN THE ACADEMIC DISCIPLINE

Main forms of supervised student independent work:
 preparation for lectures and laboratory classes;
 preparation for colloquia, tests and exam in the academic discipline;
 research practice and creative tasks;
 preparation of thematic reports, abstracts, presentations;
 taking notes of original sources;
 the study of topics that are not included in lectures and laboratory classes:
 «Basics of clinical biochemistry», «Biochemistry of kidneys and urea».

METHODOLOGICAL RECOMMENDATIONS FOR THE ORGANIZATION AND PERFORMANCE OF SUPERVISED STUDENT INDEPENDENT WORK IN THE ACADEMIC DISCIPLINE

Main forms of supervised student independent work:

the study of topics that are not included in the lectures.

Forms of supervised student independent work control:

colloquium;
 testing;
 interview.

LIST OF AVAILABLE DIAGNOSTIC TOOLS

The following forms are used for competences assessment:

1. Oral form:

colloquiums
 interviews;
 examination.

2. Written form:

colloquiums;

- control questioning;
written accounts of laboratory work.
3. Oral-written form:
accounts of laboratory work with oral defense;
credit.
4. Technical form:
electronic tests

LIST OF AVAILABLE TEACHING METHODS

- Traditional method (lecture, laboratory practicals);
Active (interactive) methods:
Problem-Based Learning (PBL);
Case-Based Learning (CBL).

LIST OF PRACTICAL SKILLS

1. Quantitative determination of protein, glucose, cholesterol, bilirubin, calcium, sodium and potassium ions in blood serum.
2. Analysis of gastric juice.
3. Qualitative determination of pathological components in urine: ketone bodies, glucose, protein, blood pigments.
4. Quantitative determination of calcium, potassium, sodium in blood.
5. Quantitative determination of pathological components in blood and urine: glucose, cholesterol, lipoproteins, urea, bilirubin, vitamin C.

LIST OF EQUIPMENT USED

Centrifuge, thermostat, photoelectric colorimeter, fume hood, laboratory ware, automatic pipettes, pipette-holders.

LIST OF LECTURES

4 semester

1. Introduction to enzymology. Classification and general properties of enzymes.
2. Regulation of enzyme activity. Medical enzymology.
3. Tissue respiration. Oxidative phosphorylation.
4. Carbohydrates. Glycogen metabolism. Anaerobic pathway of glucose oxidation. Gluconeogenesis.
5. Lipid metabolism. Digestion, absorption and resynthesis of lipids. Transport of exogenous lipids.
6. Lipid metabolism. Cholesterol metabolism. Transport of endogenous lipids.
7. Protein metabolism. Ways of amino acid utilization in the cell. Ammonia detoxification.
8. Nucleic acid metabolism.
9. Matrix biosynthesis. Modern techniques of molecular biology.
10. Hormone biochemistry.

11. Biochemistry of hormones (continuation).

5 semester

1. Biochemistry of the liver
2. Biochemistry of the blood. Hemostasis.
3. Pharmaceutical biochemistry.

LIST OF LABORATORY STUDIES**4 semester**

Lesson 1. Introduction to biochemistry. Structure of amino acids and peptides.

Lab. work Determination of the protein content in biological fluids.

Lesson 2. Structure organization of proteins and basics of its functioning.

Lab. work Reactions of protein sedimentation.

Lesson 3. Physical and chemical properties of proteins. Methods of separation, isolation and purification of proteins.

Lab. work Gel-filtration

Lesson 4. Enzymes: classification, structure, properties. Enzyme kinetics.

Lab. work Impact of various factors on enzyme activity. Enzyme specificity.

Lesson 5. Regulation of enzyme activity.

Determining of enzyme activity.

Lesson 6. Colloquium «Introduction to discipline «Biological chemistry». «Structure and functions of proteins», «Enzymes»

Lesson 7. Introduction in metabolism. Biological oxidation. Central metabolic pathways (oxidative decarboxylation of pyruvate, citric acid Crebs cycle)

Lab. work Crebs cycle functioning studying

Lesson 8 Energy exchange. Tissue respiration. Photosynthesis (light stage).

Lab. work Studying of reactions of oxidative phosphorylation

Lesson 9. Carbohydrates. Carbohydrate digestion. Glycogen metabolism.

Lab. work Alcoholic fermentation.

Lesson 10. Anaerobic and aerobic pathways of glucose degradation. Pyruvate metabolism. Gluconeogenesis. Exogenous ethanol metabolism.

Lab. work Quantitative determination of pyruvate in urine

Lesson 11. Pentose phosphate and glucuronic pathways of glucose metabolism. Photosynthesis (dark stage). Regulation of glucose level in blood.

Lab. work Determination of glucose concentration in the serum.

Lesson 12. Colloquium «Introduction to metabolism. Membranes. Biological oxidation. Central metabolic pathways», «Carbohydrate metabolism and function»

Lesson 13. Lipid metabolism. Digestion, absorption and resynthesis of lipids. Transport of exogenous lipids.

Lab. work Determination of lipase activity.

Lesson 14. Lipid storage and mobilization. Cholesterol metabolism. Lipid transport in the blood.

Lab. work Quantitative determination of β -lipoproteins in blood serum.

Lesson 15. Intracellular metabolism of fatty acids. Ketone bodies.

Lab. work Quantitative determination of cholesterol in blood serum.

Lesson 16. Colloquium «Metabolism and function of lipids».

Lesson 17. Control of practical skills of biochemical analysis.

Lesson 18. Final class «Introduction to educational discipline «Biological chemistry».

Structure and functions of proteins». «Introduction to metabolism. Membranes.

Biological oxidation. Central metabolic pathways». «Carbohydrate metabolism».

«Metabolism and function of lipids».

5 semester

Lesson 1. Nitrogen balance. Protein digestion and absorption.

Lab. work Analysis of gastric juice.

Lesson 2. Intracellular amino acid metabolism. Ways of ammonia detoxification.

Lab. work Quantitative determination of nonprotein nitrogen in the blood and urea in urine.

Lesson 3. Chemistry and nucleoprotein metabolism.

Lab. work Determination of uric acid and general nitrogen in urine.

Lesson 4. Matrix biosynthesis (synthesis of DNA, RNA, proteins). Techniques of molecular biology.

Lab. work Analysis of hydrolysis products of yeast nucleoproteins.

Lesson 5. Colloquium «Simple protein and amino acid metabolism», «Nucleoprotein metabolism. Structure and synthesis of nucleic acid. Protein synthesis. Techniques of molecular biology».

Lesson 6. Hormones. General characteristic, classification, mechanisms of action.

Lab. work Qualitative reactions for hormones.

Lesson 7. Hormone regulation of metabolism.

Lab. work. Glucose tolerance test.

Lesson 8. Biochemistry of the liver.

Lab. work Quantitative determination of total bilirubin in blood serum.

Lesson 9. Integration of metabolism.

Lab. work Studying of hormone impact on glucose content in the blood.

Lesson 10. Colloquium «Regulation of metabolism. Biochemistry of hormones». «Biochemistry of the liver».

Lesson 11. Biochemistry of the blood. Physical and chemical properties. Plasma proteins.

Lab. work Blood plasma proteins electrophoresis.

Lesson 12. Hemostasis.

Lab. work Quantitative determination of calcium in blood serum.

Lesson 13. Biochemistry of nutrition. The role of proteins, fats, carbohydrates and vitamins.

Lab. work Qualitative determination of vitamin C.

Lesson 14. Biochemistry of nutrition. Macro- and microelements. Regulation of water and mineral balance.

Lab. work Quantitative determination of sodium and potassium in blood serum.

Lesson 15. Pharmaceutical biochemistry. Biotransformation of the substances and their excretion.

Lab. work Quantitative determination of paracetamol, salicylic acid and their metabolites in the urine.

Lesson 16 Colloquium «Biochemistry of the blood», «Biochemistry of vitamins», «Hormonal regulation of water, salt and mineral balance», «Pharmaceutical biochemistry. Pharmacokinetics of drugs. Xenobiotic biotransformation».

Lesson 17. Colloquium «Simple protein and amino acid metabolism», «Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Protein biosynthesis. Techniques of molecular biology», «Regulation of metabolism. Hormone biochemistry», «Functional biochemistry», «Vitamin biochemistry», «Pharmaceutical biochemistry. Drug pharmacokinetics. Xenobiotic biotransformation».

**PROTOCOL OF THE CURRICULUM APPROVAL
BY OTHER DEPARTMENTS**

Title of the discipline requiring approval	Department	Amendments to the curriculum in the academic discipline	Decision of the department, which designed the curriculum (date, protocol #)
1. Pathological physiology	Department of pathological physiology	No proposals and remarks	protocol #1 of 31.08.2022
2. Pharmaceutical biotechnology	Department of pharmaceutical chemistry	No proposals and remarks	protocol #1 of 31.08.2022
3. Module «Pharmacology and pharmacotherapy»	Department of pharmacology Department of clinical pharmacology	No proposals and remarks	protocol #1 of 31.08.2022
4. Module «Pharmaceutical chemistry and pharmacognosy»	Department of pharmaceutical chemistry	No proposals and remarks	protocol #1 of 31.08.2022

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Curriculum content, composition and the accompanying documents comply with the established requirements

Dean of the Medical Faculty for International Students of the educational institution «Belarusian State Medical University»

13. 11. 2023

O.S.Ishutin

Methodologist of the educational institution «Belarusian State Medical University»

13. 11. 2023

S.V.Zaturanova