

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

**Контрольный  
экземпляр**

**APPROVED**

by Rector of the Educational  
Institution **«Belarusian State  
Medical University»**

S.P. Rubnikovich

26.06.2024

Reg. # UD-091-074/2425/edu.

**BIOLOGICAL CHEMISTRY**

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

**7-07-0911-01 «General Medicine»**

Curriculum is based on the educational program «Biological Chemistry», approved 26.06.2024, registration # УД-091-074/2425/уч.; on the educational plan in the specialty 7-07-0911-01 «General Medicine», approved 17.05.2022, registration # 7-07-0911-01/2425/mf.

**COMPILERS:**

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**RECOMMENDED FOR APPROVAL:**

by the Department of Biological Chemistry of the educational institution «Belarusian State Medical University»  
(protocol # 12 of 24.05.2024);

by the Scientific and Methodological Council of the educational institution «Belarusian State Medical University»  
(protocol # 18 of 26.06.2024)

## EXPLANATORY NOTE

«Biological chemistry» – the educational discipline of the module «Biomedical Module #1», which contains systematized scientific knowledge and techniques in the field of medical biochemistry, studying the molecular basis of normal life processes in human and the possible causes and effects of metabolic disturbances.

The aim of the discipline «Biological Chemistry» is the formation of basic professional competencies about the molecular basis of normal physiological functions in human in terms of ontogenesis; molecular basis of the pathological processes, their prevention and treatment; biochemical methods of diagnosing and monitoring of human health status.

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

basic principles of the molecular organization of the cell, tissue, organism;

basic laws of metabolic processes, metabolic regulation and its interaction with the functional activity in a living system;

pathogenetic mechanisms of pathological processes, subject to the main types of heritable metabolic defects;

biochemical research techniques;

basic principles of clinical, laboratory and knowledge-based sanitary and hygienic technologies;

skills and abilities necessary for:

using the results of biochemical analyses for the health assessment;

interpretation of the results of laboratory and instrumental methods of analysis; diagnosing.

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: «Pharmacology», «Endocrinology».

Studying the educational discipline «Biological Chemistry» should ensure the formation of students' basic professional: use knowledge about the molecular basis of the vital activity processes in the human body in normal and pathological conditions, apply the basic methods of biochemical investigation for disease diagnosis.

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

**know:**

the molecular composition of living systems; structure, physical and chemical properties of the main classes of compounds: proteins, nucleic acids, carbohydrates, lipids; metabolism of these compounds, mechanisms of metabolism regulation;

structure of enzymes; mechanisms of the enzyme-catalyzed reactions (in terms of protein, nucleic acid, carbohydrate and lipid conversions); molecular mechanisms regulating the action of enzymes (types of regulation); hierarchy of the regulation; types of catalysis in enzymatic reactions;

mechanisms of oxidative phosphorylation, molecular mechanisms of the energy coupling;

mechanisms of protein synthesis, the sequence of the reactions and their mechanisms, regulation and energy supply of the process; mechanisms of the protein spatial structure formation;

the role of free radicals and chain reactions of oxidation in biological systems under physiological and pathological conditions;

biochemical basis of a healthy diet and the effects of malnutrition on physical condition;

the rules of medical ethics and deontology;

**be able to:**

carry out the chemical testing according specified scheme using laboratory equipment;

analyze and document the obtained results of biochemical research;

**master:**

operating skills to work with instruments and equipment used in biochemical laboratories (spectrophotometer, photoelectric colorimeter, centrifuge, automatic pipettes, automatic analysators);

methods of qualitative and quantitative analysis of nucleic acids, proteins, lipids, carbohydrates, vitamins and hormones in biological material.

**Total number** of hours for the study of the discipline is 228 academic hours, of which 153 classroom hours and 75 hours of student independent work. Classroom hours according to the types of studies: lectures – 48 hours (including 15 hours of supervised student independent work (SSIW)), laboratory classes – 105 hours.

Intermediate assessment is carried out according to the syllabus of the specialty in the form of a credit (3 semester) and examination (4 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	supervised student independent work	laboratory practicals		
<b>1-79 01 01</b> «General Medicine»	3	114	78	18	6	54	36	credit
	4	114	75	15	9	51	39	examination

## THEMATIC PLAN

Section (topic) name	Number of class hours	
	lectures (incl. SSIW)	laboratory
<b>1. Introduction to the discipline «Biological Chemistry». The structure and functions of proteins</b>	<b>3</b>	<b>9</b>
1.1. The subject and significance of biochemistry. Proteins: properties and functions	1,5	3
1.2. Structure of protein molecule	-	3
1.3. Methods of protein isolation and purification	1,5	3
<b>2. Enzymes</b>	<b>3</b>	<b>9</b>
2.1. Enzymes: properties and mechanism of action	1,5	3
2.2. Regulation of enzyme action	1,5	6
<b>3. Introduction to metabolism. Biological oxidation. Central metabolic pathways</b>	<b>3</b>	<b>6</b>
3.1. Introduction to metabolism and energy exchange. Central pathways of metabolism	1,5	3
3.2. Biological oxidation	1,5	3
<b>4. Carbohydrate metabolism and functions</b>	<b>4,5</b>	<b>12</b>
4.1. Carbohydrates. Anaerobic pathways of glucose utilization in the cell. Glycogen metabolism	1,5	3
4.2. Aerobic glucose degradation. Pathways of pyruvate metabolism. Gluconeogenesis	1,5	3
4.3. Secondary pathways of glucose metabolism. Fructose and galactose metabolism. Hereditary disorders of carbohydrate metabolism. Hormones influence on blood glucose level	1,5	6
<b>5. Lipid metabolism and functions</b>	<b>6</b>	<b>18</b>
5.1. Classification of lipids. Lipid digestion and absorption. Transport forms of lipids in the blood	1,5	3
5.2. Cholesterol metabolism. Lipid synthesis in the liver.	1,5	3
5.3. Intracellular metabolism of fatty acids. Ketone bodies. Regulation of lipid metabolism. Disorders of lipid metabolism	3	12
<b>6. Simple protein and amino acid metabolism</b>	<b>4,5</b>	<b>6</b>
6.1. Protein digestion. Pathways of amino acid utilization in the cell	1,5	3
6.2. Ammonia detoxification. The fate of the amino acids carbon skeletons. Characteristics of nitrogen metabolism	3	3
<b>7. Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Protein biosynthesis. Techniques of</b>	<b>6</b>	<b>9</b>

Section (topic) name	Number of class hours	
	lectures (incl. SSIW)	laboratory
<b>molecular biology</b>		
7.1. Structure and metabolism of nucleoproteins	3	3
7.2. Biosynthesis of nucleic acids and proteins. Modern techniques of molecular biology and their medical application	3	6
<b>8. Regulation of metabolism. Biochemistry of hormones</b>	<b>4,5</b>	<b>6</b>
8.1. Principal mechanisms of metabolism regulation. Mechanism of hormone action	1,5	3
8.2. Influence of major hormones on metabolism	3	3
<b>9. Biochemistry of organs and tissues</b>	<b>7,5</b>	<b>15</b>
9.1. Biochemistry of the blood	3	6
9.2. Biochemistry of the liver	1,5	3
9.3. Biochemistry of the connective tissue	1,5	-
9.4. Biochemistry of kidneys and urine	-	6
9.5. Biochemistry of the muscle and nervous tissues	1,5	-
<b>10. Biochemistry of nutrition</b>	<b>4,5</b>	<b>9</b>
10.1. Essential nutritive factors. Vitamins. Causes and biochemical characteristics of malnutrition	3	3
10.2. Water and mineral salts. Calcium and phosphorus metabolism. Microelements	1,5	6
<b>11. Integration of metabolism</b>	<b>1,5</b>	<b>6</b>
<b>Total hours</b>	<b>48</b>	<b>105</b>

## CONTENT OF THE EDUCATIONAL MATERIAL

### 1. Introduction to the discipline «Biological Chemistry». The structure and functions of proteins

#### 1.1. The subject and significance of biochemistry. Proteins: properties and functions

The development of biochemistry, major stages. Position of biochemistry in medical education. Major categories and areas in biochemistry. Objects in biochemical research. Medical biochemistry. Role of biochemistry in understanding of human and environment interrelations. The rules of medical ethics and deontology.

Discovery of amino acids, peptide theory of structure. Protein classification according to their functions, molecular shape, constitution complexity.

Physical and chemical properties of proteins and protein solutions. Quantitative determination of protein in the blood.

## **1.2. Structure of protein molecule**

Primary protein structure, types of bonds, properties of the peptide bond. Methods of primary structure analysis. Amino acid composition of proteins in different organs and tissues, importance of this fact in biochemistry of nutrition. Protein composition of tissues, its changes in ontogenesis and pathology.

Conformation of the polypeptide chain. Secondary protein structure, types; role of hydrogen bonds in its stabilization. Supersecondary structure, its types. Protein tertiary structure. Role of weak intramolecular interactions in stabilization of protein 3-D structure and conformational changes. Dependence of protein biological activity on conformational changes. Protein denaturation, its reversibility.

Quaternary protein structure. Functional features of proteins with quaternary structure.

Conjugated proteins. General notion of conjugated proteins composition, structure of prosthetic groups, types of bonds between apoprotein and prosthetic group.

Capability to specific interactions as the base of protein biological functions. The concept of complementarity. Ligands and protein function. Reversibility of ligand binding.

## **1.3. Methods of protein isolation and purification**

Separation and purification methods for proteins: ultracentrifuging, ultrafiltration, electrophoresis, isoelectrofocusing, chromatography. Dialysis and its medical application. Techniques of protein preparation production. Methods of protein identification, Western-blot.

Quantitative determination of total and individual proteins based on their biological properties.

## **2. Enzymes**

### **2.1. Enzymes: properties and mechanism of action**

History of enzymes discovery and investigation. Enzyme classification and nomenclature. Properties of enzymes. Dependence of the velocity of enzyme-catalyzed reactions on temperature, pH, substrate and enzyme concentrations. Single- and two-component enzymes. Coenzymes, classification. Coenzyme function of water-soluble vitamins.

Units of enzyme activity.

### **2.2. Regulation of enzyme action**

Mechanisms of enzyme activity regulation: competitive inhibition, allosteric enzymes, regulation of enzyme structure by covalent modification. Role of enzyme cooperative conformational changes in mechanisms of reaction catalysis. Natural and artificial inhibitors of enzyme activity. Medical application of enzyme inhibitors.

Cellular organization of enzymes. Enzyme composition in different cells, organs and tissues. Organ specific enzymes. Determination of enzyme activity in blood for diagnosis; plasma enzymes origin. Determination of amylase activity in the urine. Isoenzymes. Enzymes as medical preparations. Enzymes as analytical reagents in laboratory research, immobilized enzymes.

### **3. Introduction to metabolism. Biological oxidation. Central metabolic pathways**

#### **3.1. Introduction to metabolism and energy exchange. Central pathways of metabolism**

The concept of metabolism, metabolic pathways. Forms of metabolic pathways. Methods of metabolism study at the level of the whole organism, organs, tissue sections, cell cultures. Tissue homogenates, fractionation of homogenates, subcellular structures. Isolation of metabolites and enzymes, determination of substrate transformation sequence. Isotopic methods. Methods of modelling and synthesis.

The diagram of the main substances (carbohydrates, lipids, proteins) catabolism. The concept of specific and central metabolic pathways. The concept of metabolon. Interrelations between anabolism and catabolism.

Oxidative decarboxylation of pyruvate, sequence of reactions, characteristics of enzymes and coenzymes. The concept of multienzyme complex. Connection of the process with the electron transport chain. Mechanisms of regulation.

Citric acid cycle: sequence of reactions, characteristics of enzymes. Connection of the process with the electron transport chain. Mechanisms of regulation. Functions of the citric acid cycle.

#### **3.2. Biological oxidation**

Endergonic and exergonic reactions in the living cell. The concept of high-energy compound. Oxidation as the main energy producing pathway in the living cell. Mechanisms of oxidation – electron transfer, addition of oxygen to substrate, dehydrogenation. Dehydrogenases, structure and role of coenzymes. Oxidative reaction chains.

Mitochondria structure, structural organization of electron and proton transport chain. Mitochondrial multienzyme complexes, their composition.

Mechanisms of adenosine triphosphate (ATP) production in the cell. Substrate-level phosphorylation, oxidative phosphorylation. Mechanism of oxidative phosphorylation. Inhibitors of tissue respiration and oxidative phosphorylation. Uncoupling of oxidative phosphorylation, properties of uncouplers.

The role of oxygen in oxidation processes of a cell. Oxidases and oxygenases. Reactive oxygen species and their role in life processes. Brief characteristic of enzyme (catalase, superoxide dismutase, peroxidase) and non-enzyme components of antioxidant system. The role of external factors in activation of free-radical mechanism of intracellular structures injury.

### **4. Carbohydrate metabolism and functions**

#### **4.1. Carbohydrates. Anaerobic pathways of glucose utilization in the cell. Glycogen metabolism**

Major carbohydrates in animals, their biological role. Dietary carbohydrates, daily requirement.

Central reaction of carbohydrate metabolism. Anaerobic glucose degradation (anaerobic dichotomy, glycolysis). Glycolytic oxidoreduction; pyruvate as hydrogen acceptor. Substrate-level phosphorylation. Other hydrogen acceptors under anaerobic conditions, alcoholic and lactic fermentation, their biological role. Cellular



localization of glycolysis, regulation of anaerobic dichotomy. Energy yield of anaerobic glucose oxidation.

Glycogen properties and its distribution as a reserve polysaccharide. Glycogen biosynthesis and mobilization. Glycogenoses and aglycogenoses.

#### **4.2. Aerobic glucose degradation. Pathways of pyruvate metabolism. Gluconeogenesis**

Aerobic glucose degradation: common reactions with glycolysis. Oxidative decarboxylation of pyruvate and tricarboxylic acid cycle as stages of aerobic glucose degradation. Energy yield of glucose oxidation under aerobic conditions.

Pyruvate as a central metabolite. Its quantitative determination in the urine. Gluconeogenesis, major substrates for glucose biosynthesis in the cell. Key enzymes of gluconeogenesis. Regulation of gluconeogenesis.

#### **4.3. Secondary pathways of glucose metabolism. Fructose and galactose metabolism. Hereditary disorders of carbohydrate metabolism. Hormones influence on blood glucose level**

Pentose phosphate pathway of glucose oxidation (apotomy). Enzymes of oxidative phase. Role of the oxidative phase. Non-oxidative phase of pentose phosphate pathway, major enzymes. Connection with glycolysis. Cellular distribution and biological role. Regulation of the pathway.

Uronic acid pathway. The main reactions. Biological role of the pathway. Connection with pentose phosphate pathway and glycolysis.

Sucrose, lactose and maltose metabolism. Fructose and galactose metabolism. Hereditary disorders of monosaccharide and disaccharide metabolism: galactosemia, fructosuria, fructose and disaccharide intolerance.

Hormonal regulation of blood glucose level. Role of insulin, epinephrine, glucagon, glucocorticosteroids.

Quantitative methods of blood glucose determination.

### **5. Lipid metabolism and functions**

#### **5.1. Classification of lipids. Lipid digestion and absorption. Transport forms of lipids in the blood**

The concept of lipids. Saponifiable and unsaponifiable lipids. Simple and complex lipids. Dietary lipids. Requirements for lipid composition of food products. Lipid digestion: emulsification, enzymatic hydrolysis, micelle formation. Role of bile acids. Disorders of digestion and absorption.

Lipid re-synthesis in enterocytes. Lipid transport forms in the blood, chylomicron as a transport form of exogenous lipids.

#### **5.2. Cholesterol metabolism. Lipid synthesis in the liver**

Lipid synthesis in the liver, formation of very-low density lipoproteins (VLDL). Lipoprotein lipase and its role in blood lipoprotein metabolism.

Synthesis of hydroxy-methylglutaryl-CoA, its role. The reduction of hydroxy-methylglutaryl-CoA to mevalonic acid. Cholesterol biosynthesis. Regulation of cholesterol biosynthesis. Cholesterol transport in the blood, role of VLDL, low density lipoproteins (LDL), high density lipoproteins (HDL) in the mechanisms of cholesterol transport in the body. Cholesterol conversion into the bile acids. Cholesterol excretion from the body. Quantitative determination of cholesterol and

LDL in the blood.

### **5.3. Intracellular metabolism of fatty acids. Ketone bodies. Regulation of lipid metabolism. Disorders of lipid metabolism**

Mechanisms of fatty acid activation. Fatty acid transport to mitochondria. Role of carnitine.  $\beta$ -Oxidation of fatty acids – specific fatty acid catabolic pathway. Enzymes of  $\beta$ -oxidation. Oxidation of «odd-chain» fatty acids. Connection of  $\beta$ -oxidation with tissue respiration enzymes, energy yield of fatty acid oxidation.

Other pathways of fatty acid oxidation, their significance. Ways of active acetic acid utilization.

Fatty acid biosynthesis. Structure of fatty acid synthase complex. Role of glucose metabolic pathways in fatty acid synthesis. Polyunsaturated fatty acids.

Lipid storage and mobilization in the adipose tissue; hormonal regulation of the processes. Fatty acid transport in the blood. Role of lipid storage and mobilization, their disturbances in obesity.

Mechanisms of ketone bodies synthesis and their biological role.

Hypercholesterolemia and its causes. Gallstones. Biochemistry of atherosclerosis, risk factors. Biochemical basis for treatment and prevention of hypercholesterolemia and atherosclerosis.

Phospholipids and glycolipids. General concept of mechanisms of their synthesis and degradation. Phospholipases. Phospholipids and glycolipids – functions, congenital disorders of metabolism.

## **6. Simple protein and amino acid metabolism**

### **6.1. Protein digestion. Pathways of amino acid utilization in the cell**

Food proteins as a source of amino acids. Requirements for protein nutrition. Protein digestion. The role of gastric juice in protein digestion. Mechanism of hydrochloric acid formation in the stomach. Determination of gastric juice acidity. Endo- and exopeptidases of the gastrointestinal tract. Amino acid absorption. Protein putrefaction in the gut. Nitrogen balance: positive, negative nitrogen balance, nitrogen equilibrium.

Amino acid pool of the cell: sources and ways of utilization of amino acid pool. Mechanisms of amino acid catabolism. Transamination, aminotransferases. Tissue and intracellular specificity of aminotransferases, their significance. Determination of alanine aminotransferase activity in blood serum. Direct and indirect amino acid deamination. Biological role of deamination. Central role of glutamic acid in amino acid metabolism. Decarboxylation of amino acids. Biogenic amines, formation, functions. Oxidation of biogenic amines. Aminooxidases.

Role of individual amino acids. Methionine and S-adenosylmethionine, synthesis of creatine, epinephrine, phosphatides, DNA methylation, source of single-carbon groups. Lipotropic factors. Metabolism of tyrosine and phenylalanine, its disorders: phenylketonuria, alkaptonuria, albinism. Synthesis of hormones - tyrosine derivatives.

### **6.2. Ammonia detoxification. The fate of the amino acids carbon skeletons. Characteristics of nitrogen metabolism**

Ammonia major sources in the body. The ways of ammonia utilization and detoxification: reductive amination, synthesis of dicarboxylic acid amides, formation

of carbamoyl phosphate. Kidney and liver glutaminase. Ammonia salts production and excretion. Activation of kidney glutaminase in acidosis. Urea synthesis, sources of urea nitrogen. Abnormalities of urea synthesis and excretion. Quantitative determination of urea in urine. Other non-protein nitrogen-containing plasma components, significance of their determination in medical practice.

The ways of amino acid carbon skeletons utilization: synthesis of new amino acids, glucose production (glucogenic amino acids), ketone bodies production (ketogenic amino acids), direct oxidation, conversion into lipids in the abnormal protein nutrition.

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

### **7.1. Structure and metabolism of nucleoproteins**

History of nucleoprotein discovery. Nucleic acids.

Nucleic acid degradation. Nucleases in gastrointestinal tract. Degradation of purine nucleotides, uric acid formation. Synthesis of purine nucleotides. Substrates, key enzymes and regulation of purine nucleotide synthesis.

Degradation of pyrimidine nucleotides, end products. The concept of pyrimidine synthesis: substrates and enzymes.

Cellular proteins and nucleic acids degradation. Proteins and nucleic acids biological half-life. Enzymes catalyzing the processes of protein and nucleic acid degradation. Reutilization of nucleosides and nitrogen bases for nucleotide synthesis. Disorders of nucleotide metabolism.

Quantitative determination of uric acid in urine.

### **7.2. Biosynthesis of nucleic acids and proteins. Modern techniques of molecular biology and their medical application**

Synthesis of DNA, substrates, enzymes, conditions of synthesis. Replication as a way of the information transfer from matrix to the reaction product. Reverse transcription, its biological role.

Biosynthesis of RNA (transcription): substrates, enzymes, conditions of transcription. Transcription as a way of the information transfer from DNA to RNA. Biosynthesis of ribosomal, transfer and messenger RNA. Mechanisms of transcription regulation.

Protein biosynthesis. Genetic (amino acid, nucleotide) code and its properties. Adaptor role of transfer RNA. Recognition. Biosynthesis of aminoacyl-tRNA: substrate specificity of aminoacyl-tRNA-synthetases. Mechanisms and stages of translation. Regulation of translation. Universality of genetic code and protein biosynthesis mechanism. Antibiotics – inhibitors of protein and nucleic acid synthesis.

Processing of nucleic acids and proteins. Pattern of changes in nucleic acid and protein structure after the initial synthesis.

Polymerase chain reaction, steps and application. Blot-analysis of DNA and RNA. Genomic fingerprinting.

DNA nucleotide sequence determination by Sanger.

Cloning, genetic engineering.

## **8. Regulation of metabolism. Biochemistry of hormones**

### **8.1. Principal mechanisms of metabolism regulation. Mechanism of hormone action**

Regulation of metabolic processes by changing of enzymes' activity (activation, inhibition), changing enzymes' amount (induction and repression of synthesis, enzyme degradation rate), changing plasma membrane permeability.

Hormonal regulation as a way of intercellular and inter-organ coordination of metabolism.

Hormones classification by the chemical structure, place of synthesis, mechanism of action. Target cells and cellular hormonal receptors.

Action of hormones binding to plasma membrane receptors, special features. Messengers of hormonal action on a cell: cyclic purine nucleotides, calcium ions, products of phosphatidylinositol hydrolysis. Protein kinases, role in mechanisms of enzyme activity modulation.

Mechanism of action of hormones binding to intracellular receptors. Influence on protein biosynthesis.

### **8.2. Influence of major hormones on metabolism**

Structure, mechanism of action and influence on metabolism of hypothalamic, pituitary, thyroid, pancreatic and adrenal hormones. Procedure and diagnostic value of glucose tolerance test. Hormonal regulation of calcium and phosphorus metabolism.

Abnormalities of endocrine glands function: hyper- and hypoproduction of hormones. General approaches to treatment of such states.

Eicosanoids (prostaglandins, thromboxanes, leucotriens) and their role in metabolism and physiological functions regulation.

## **9. Biochemistry of organs and tissues**

### **9.1. Biochemistry of the blood**

Blood cells. Peculiarities of red blood cells chemical composition and structure. Reactions of heme biosynthesis, substrates and enzymes. Kinds and derivatives of hemoglobin. Oxygen and carbon dioxide transport in blood. Peculiarities of hemoglobin saturation with oxygen and carbon monoxide. Hemoglobinopathies. White blood cells, peculiarities of chemical composition and structure. Role of white blood cells.

Blood plasma and serum. Plasma proteins. Classification of blood proteins according to their functions: transfer proteins, proteins of complement system, kinin system, blood clotting, system of fibrinolysis, immunoglobulins, protein inhibitors of proteolysis. Plasma proteins as a source of amino acids in starvation. Methods of plasma proteins separation.

Biochemical blood analysis, its significance in description of human health state.

Blood clotting. Primary and secondary hemostasis (coagulation). Role of platelets in hemostasis. Intrinsic and extrinsic systems of coagulation. Cascade mechanism of activation of enzymes involved in blood clotting. Role of vitamin K and calcium ions in blood clotting. Anticoagulative systems (anticoagulant, fibrinolytic). Concept of haemophilias and thromboses.

## **9.2. Biochemistry of the liver**

Role of the liver in carbohydrate, lipid, amino acid metabolism. Synthesis of plasma proteins in the liver.

Reactions of substances detoxification in the liver. Role of microsomal oxidation in detoxification processes. Active glucuronic and sulfuric acids in detoxification processes.

Role of the liver in pigment metabolism. Reactions of heme degradation, direct and indirect bilirubin. Disorders of bilirubin metabolism. Jaundices: hemolytic, obstructive, parenchymatous. Jaundice of newborns. Bile pigments in blood, intestine, urine. Quantitative determination of blood bilirubin.

Biochemical mechanisms of hepatocellular failure and hepatic coma development. Biochemical tests for diagnosis of liver function disturbances.

## **9.3. Biochemistry of the connective tissues**

Cells of the connective tissue, characteristics of metabolism. Chemical composition of intercellular substance. Collagen, peculiarities of synthesis and degradation. Elastin, peculiarities of metabolism.

Protein-carbohydrate complexes. Classification. Proteoglycans, glycosaminoglycans, glycoproteins. Peculiarities of synthesis and degradation. Role in the body. Connective tissue changes in ageing. Role of nutrition in the connective tissue metabolism.

## **9.4. Biochemistry of kidneys and urine**

The main parameters of urinalysis under physiological conditions – volume, density, color, transparency, pH, mineral and organic urine components (urea, uric acid, creatinine, amino acids, nitrogen-free organic components, hormones and their metabolites).

Diagnostic value of pathological urine components determination: proteinuria, glucosuria, hematuria, ketonuria, bile pigments, enzymes.

Characteristics of metabolism in the renal tissue. Role of kidneys in maintenance of the acid-base balance. Production of the biologically active substances in kidneys.

Qualitative pathological urine components determination: ketone bodies, glucose, protein, blood pigments.

Quantitative pathological urine components determination: glucose, protein.

## **9.5. Biochemistry of the muscle and nervous tissues**

Chemical composition of muscles. Myofibril proteins, peculiarities of amino acid composition. Myofibril molecular structure. Sarcoplasmic proteins, individual representatives, their structure and functions. Non-protein muscle compounds.

Biochemical mechanisms of muscle contraction and relaxation. Role of ions in regulation of muscle contraction. Special features of energy exchange in muscles. Creatine phosphokinase and its isoenzymes.

Chemical composition of the nervous tissue. Myelin membranes: features of composition and structure.

Features of energy exchange in the nervous tissue, the role of aerobic glucose oxidation.

Molecular mechanisms of synaptic transfer. Neurotransmitters, mechanisms of

synthesis and breakdown. The role of biogenic amines. Active brain peptides.

## **10. Biochemistry of nutrition**

### **10.1. Essential nutritive factors. Vitamins. Causes and biochemical characteristics of malnutrition**

Vitamins, history of discovery and study. Classification of vitamins. Causes of vitamin deficiency: exogenous and endogenous hypo- and avitaminoses. Hypervitaminoses and their causes.

Water-soluble vitamins (B<sub>1</sub>, B<sub>2</sub>, PP, B<sub>6</sub>, B<sub>9</sub>, B<sub>12</sub>, biotin, pantothenic acid, C, rutin). Chemical structure, active forms, role of water-soluble vitamins in metabolism, mechanisms of absorption and excretion from the body.

Fat-soluble vitamins. Vitamins A, E, K, D, special features of structure and mechanism of action. Influence on metabolism and organism development. Antioxidant function of fat-soluble vitamins. Use as medicinal preparations.

Vitamin daily requirements. Vitamin content in foods. Gut microflora – important source of vitamins in human. Antivitamins. Evaluation of body saturation with vitamins.

Other essential nutritive factors and their role (polyunsaturated fatty acids, amino acids). Vitamin-like substances.

Nutrition disturbances. Clinical forms of protein-energy malnutrition – kwashiorkor and marasmus. Causes of development, principal biochemical disorders.

Evaluation of body saturation with vitamins (quantitative determination of vitamin C in urine).

### **10.2. Water and mineral salts. Calcium and phosphorus metabolism. Microelements**

Minerals as essential nutritional factors. Classification. Body entering routes for minerals, mechanisms of absorption. Functions of minerals.

Electrolyte composition of biological fluids. Mechanisms of regulation of body fluids volume, electrolyte composition and pH. Role of kidneys, gastro-intestinal tract, skin, lungs in regulation of water and mineral metabolism. Conditions and development mechanisms of acidosis, alkalosis, exsiccation and edema.

Sodium and potassium metabolism. Peculiarities of distribution in the body. Regulation of metabolism.

Calcium and phosphorus requirement. Mechanisms of absorption. Distribution in the body. Regulation of their metabolism.

Microelements (trace elements). Biological role of iron, copper, cobalt, iodine, zinc, manganese, fluorine, selenium. Microelement exchange in the body. Iron metabolism. Transferrin, ferritin. Iron-deficient anemias, diagnosis.

## **11. Integration of metabolism**

Intracellular localization of the major metabolic pathways. Metabolic specialization of the organs.

Inter-organ metabolism in the well-fed state, between meals and in starvation. The major energy sources. Role of hormones.

Examples of metabolic disorders. Diabetes mellitus: causative agents, major biochemical derangements. Diabetic and hypoglycemic coma. Mechanism of development of diabetes mellitus complications (angiopathies, neuropathies, cataract).

### ACADEMIC DISCIPLINE CURRICULAR CHART

Section, topic #	Section (topic) name	number of hours			Practical skill	Forms of control	
		lectures	<i>laboratory</i>	supervised student independent work		Practical skills	Current/intermediate assessment
<b>3 semester</b>							
	<b>Lectures</b>	<b>18</b>	-	<b>6</b>			
1.	Introduction to the discipline «Biological Chemistry». The structure and functions of proteins and peptides	-	-	1,5			Online tests
2.	Methods of protein and peptide study	1,5	-	-			
3.	Introduction to enzymology. Classification and general properties of enzymes. Mechanisms of enzyme action	1,5	-	-			
4.	Regulation of enzyme action	1,5	-	-			
5.	Introduction to metabolism and energy exchange. Central pathways of metabolism: oxidative decarboxylation of pyruvate	1,5	-	-			
6.	Central metabolic pathways: citric acid cycle. Tissue respiration. Oxidative phosphorylation	1,5	-	-			
7.	Carbohydrate metabolism. Digestion and absorption. Glycogen metabolism	1,5	-	-			
8.	Carbohydrate metabolism. Aerobic and anaerobic pathways of glucose oxidation. Gluconeogenesis	1,5	-	-			
9.	Secondary pathways of glucose metabolism. Fructose and galactose metabolism	-	-	1,5			Online tests
10.	Lipid metabolism. Digestion and absorption. Transport of exogenous lipids	1,5	-	-			

11.	Lipid metabolism. Cholesterol and triacylglycerol biosynthesis in the liver. Transport of endogenous lipids in the blood. Atherosclerosis	1,5	-	-			
12.	Lipid metabolism. Oxidation and biosynthesis of fatty acids	1,5	-	-			
13.	Synthesis and mobilization of lipids in adipose tissue. Synthesis of unsaturated fatty acids. Eucosanoids formation and biological role	-	-	1,5			Online tests
14.	Protein metabolism. Intracellular amino acid metabolism	1,5	-				
15.	Protein metabolism. Ammonia detoxification	1,5	-				
16.	Disturbances in amino acid metabolism	-	-	1,5			Online tests
<b>Laboratory classes</b>		-	<b>54</b>	-			
<b>1.</b>	<b>Introduction to the discipline «Biological Chemistry». The structure and functions of proteins</b>	-	<b>9</b>	-			
1.1	The subject and significance of biochemistry. Proteins: properties and functions Introduction to practical work. Introduction to biochemistry. The structure of amino acids and peptides. ; Lab. work: Quantitative determination of the protein content in biological fluids	-	3	-	Quantitative determination of the protein content in blood serum	written account of laboratory work	interviews, surveys, case tasks solving, online tests
1.2	Structure of protein molecule Levels of organization of a protein molecule. Physical and chemical properties of proteins Lab. work: Reactions of protein sedimentation	-	3	-			interviews, surveys, case tasks solving, online tests
1.3	Methods of protein isolation and purification Methods of separation, isolation and purification of proteins Lab. work: Gel-filtration	-	3	-			interviews, surveys, case tasks solving, online tests
<b>2.</b>	<b>Enzymes</b>	-	<b>9</b>	-			
2.1.	Enzymes: properties and mechanism of action Enzymes. Classification, structure, properties. Lab. work: Effect of various factors on enzyme activity	-	3	-			interviews, surveys, case tasks solving, online tests



2.2.	Regulation of enzyme action	-	6	-			
	Regulation of enzyme action Lab. work: Quantitative determination of enzyme activity	-	3	-	Determination of amylase activity in urine	written account of laboratory work	interviews, surveys, case tasks solving, online tests
	Colloquium «The chemistry of proteins, enzymes»	-	3	-			Colloquium*
<b>3.</b>	<b>Introduction to metabolism. Biological oxidation. Central metabolic pathways</b>	-	<b>6</b>	-			
3.1.	Introduction to metabolism and energy exchange. Central pathways of metabolism Introduction to metabolism. Central metabolic pathways (oxidative decarboxylation of pyruvate, citric acid cycle). Lab. work: Evaluation of TCA cycle functioning	-	3	-			interviews, surveys, case tasks solving, online tests
3.2.	Biological oxidation Biological oxidation. Oxidative phosphorylation. Pathways of oxygen utilization by cells. Lab. work: Studying of oxidative phosphorylation	-	3	-			interviews, surveys, case tasks solving, online tests
<b>4.</b>	<b>Carbohydrate metabolism and functions</b>	-	<b>12</b>	-			
4.1.	Carbohydrates. Anaerobic pathways of glucose utilization in the cell. Glycogen metabolism Digestion of carbohydrates. Glycogenesis and glycogenolysis. Glycolysis and alcoholic fermentation. Lab. work: Detection of alcoholic fermentation products	-	3	-			interviews, surveys, case tasks solving, online tests
4.2.	Aerobic glucose degradation. Pyruvate metabolism pathways. Gluconeogenesis Metabolic pathways of pyruvate. Gluconeogenesis. Aerobic oxidation of glucose (CO <sub>2</sub> and H <sub>2</sub> O). Lab. work: Determination of pyruvate in the urine	-	3	-	Quantitative determination of pyruvate in the urine	written account of laboratory work	interviews, surveys, case tasks solving, online tests
4.3.	Secondary pathways of glucose metabolism. Fructose and galactose metabolism. Hereditary disorders of carbohydrate metabolism. Hormones influence on blood glucose level	-	6	-			interviews, surveys, case tasks solving, online tests

	Secondary pathways of glucose metabolism. Metabolism of fructose, galactose and ethyl alcohol Lab. work: Quantitative determination of blood glucose	-	3	-	Quantitative determination of blood glucose	written account of laboratory work	interviews, surveys, case tasks solving, online tests
	Colloquium «Introduction to metabolism. Central metabolic pathways. Biological oxidation. Carbohydrate metabolism»	-	3	-			Colloquium*
<b>5.</b>	<b>Lipid metabolism and functions</b>	-	<b>18</b>	-			
5.1.	Lipid classification. Lipid digestion and absorption. Transport of exogenous lipids Lipid metabolism: digestion, absorption. Transport of exogenous lipids. Lab. work: Evaluation of lipase activity	-	3	-			interviews, surveys, case tasks solving, online tests
5.2.	Cholesterol metabolism. Lipid synthesis in the liver Lipid transport in blood. Cholesterol metabolism. Storage and mobilization of lipids. Lab. work: Determination of plasma $\beta$ -lipoproteins	-	3	-	Determination of plasma $\beta$ -lipoproteins in blood serum	written account of laboratory work	interviews, surveys, case tasks solving, online tests
5.3	Intracellular metabolism of fatty acids. Ketone bodies. Regulation of lipid metabolism. Disorders of lipid metabolism	-	12	-			
	Intracellular metabolism of fatty acids. Ketone bodies. Lab. work: Quantitative determination of cholesterol in serum	-	3	-	Quantitative determination of cholesterol in serum	written account of laboratory work	interviews, surveys, case tasks solving, online tests
	Colloquium «Lipid metabolism and functions».	-	3	-			Colloquium*
	Control over practical skills of biochemical analysis: quantitative determination of protein and cholesterol in serum	-	3	-	Quantitative determination of protein and cholesterol in serum	written account of laboratory work, oral defense*	
	Final lesson «The chemistry of proteins, enzymes. Biological oxidation. Central metabolic pathways. Carbohydrate metabolism and functions. Lipid metabolism and functions»	-	3	-			Credit

		4 semester				
	<b>Lectures</b>	<b>15</b>	<b>-</b>	<b>9</b>		
1.	Structure of nucleic acids	-	-	1,5		Online tests
2.	Nucleic-acid metabolism	1,5	-	-		
3.	Matrix biosyntheses	1,5	-	-		
4.	Modern techniques of molecular biology	1,5	-	-		
5.	Introduction to endocrinology	1,5	-	-		
6.	Regulation of metabolism. Biochemistry of hormones	1,5	-	-		
7.	Biochemistry of hormones	1,5	-	-		
8.	Biochemistry of the liver	1,5	-	-		
9.	Integration of metabolism	1,5	-	-		
10.	Biochemistry of the blood	-	-	1,5		Online tests
11.	System of hemostasis.	1,5	-	-		
12.	Biochemistry of nutrition. Malnutrition	1,5	-	-		
13.	Biochemistry of nutrition. Vitamins	-	-	1,5		Online tests
14.	Biochemistry of nutrition. Water and mineral metabolism	-	-	1,5		Online tests
15.	Biochemistry of the connective tissue	-	-	1,5		Online tests
16.	Biochemistry of muscle and nervous tissue	-	-	1,5		Online tests
	<b>Laboratory classes</b>	<b>-</b>	<b>51</b>	<b>-</b>		
<b>6.</b>	<b>Simple protein and amino acid metabolism</b>	<b>-</b>	<b>6</b>	<b>-</b>		
6.1	Digestion and absorption of proteins. Lab. work: Analysis of gastric juice	-	3	-	Analysis of gastric juice acidity	written account of laboratory work interviews, surveys, case tasks solving, online tests
6.2.	Ammonia detoxification. Fates of the amino acids carbon skeletons. Characteristics of nitrogen metabolism Intracellular amino acid metabolism. Detoxification of ammonia. Abnormalities of amino acid metabolism Lab. work: Determination of non-protein nitrogen in blood and urea in urine	-	3	-	Quantitative determination of urea in urine	written account of laboratory work interviews, surveys, case tasks solving, online tests
<b>7.</b>	<b>Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Protein biosynthesis. Techniques of molecular biology</b>	<b>-</b>	<b>9</b>	<b>-</b>		

7.1.	Structure and metabolism of nucleoproteins Metabolism of nucleoproteins Lab. work: Determination of uric acid and total nitrogen in urine	-	3	-	Determination of uric acid and total nitrogen in urine	written account of laboratory work	interviews, surveys, case tasks solving, online tests
7.2.	Biosynthesis of nucleic acids and proteins. Modern techniques of molecular biology and their medical application	-	6	-			
	Matrix biosyntheses (synthesis of DNA, RNA, proteins). Lab. work: Analysis of yeast nucleoprotein hydrolysis products	-	3	-			interviews, surveys, case tasks solving, online tests
	Colloquium «Simple proteins and amino acids metabolism», «Nucleoprotein metabolism», «Structure and synthesis of nucleic acids», «Nucleoprotein metabolism. Structure and synthesis of nucleic acids. Techniques of molecular biology»	-	3	-			Colloquium*
<b>8.</b>	<b>Regulation of metabolism. Biochemistry of hormones</b>	-	<b>6</b>	-			
8.1.	Principal mechanisms of metabolism regulation. Mechanism of hormone action Hormones. General characteristic and peculiarities of biological action. Lab. work: Qualitative reactions for hormones	-	3	-			interviews, surveys, case tasks solving, online tests
8.2.	Influence of major hormones on metabolism Biochemistry of hormones. Lab. work: Glucose tolerance test	-	3	-			interviews, surveys, case tasks solving, online tests
<b>9.</b>	<b>Biochemistry of organs and tissues</b>	-	<b>3</b>	-			
9.2	Biochemistry of the liver Biochemistry of the liver Lab. work: Determination of protein colloid resistance and total bilirubin in serum	-	3	-	Determination of total bilirubin content in blood serum	written account of laboratory work	
<b>11.</b>	<b>Integration of metabolism</b>	-	<b>6</b>	-			
	Integration of metabolism	-	3	-			

	Lab. work: Effects of hormones on blood glucose level					
	Colloquium «Regulation of metabolism. Hormones. Biochemistry of the liver. Integration of metabolism»	-	3	-		Colloquium*
<b>9.</b>	<b>Biochemistry of organs and tissues</b>	-	<b>6</b>	-		
9.1.	Biochemistry of the blood	-	6	-		
	Biochemistry of the blood. Physical and chemical properties of the blood. Hemoglobinoses Lab. work: Studying of serum buffer properties. Determination of chlorides in serum	-	3	-		interviews, surveys, case tasks solving, online tests
	Blood plasma proteins. System of hemostasis. Lab. work: Separation of serum proteins by electrophoresis on acetyl cellulose. Determination of calcium in plasma	-	3	-	Quantitative determination of calcium in the blood	written account of laboratory work interviews, surveys, case tasks solving, online tests
<b>10.</b>	<b>Biochemistry of nutrition</b>	-	<b>9</b>	-		
10.1.	Essential nutritive factors. Vitamins. Causes and biochemical characteristics of protein-energy malnutrition Biochemistry of nutrition. Role of proteins, fats, carbohydrates, vitamins Lab. work: Qualitative reactions for vitamins. Determination of vitamin C in urine	-	3	-	Quantitative determination of vitamin C in urine	written account of laboratory work interviews, surveys, case tasks solving, online tests
10.2	Water and mineral salts. Calcium and phosphorus metabolism. Microelements	-	6	-		
	Biochemistry of nutrition. Mineral substances. Regulation of water and mineral balance. Lab. work: Determination of sodium and potassium in serum	-	3	-	Quantitative determination of sodium and potassium in serum	written account of laboratory work interviews, surveys, case tasks solving, online tests
	Colloquium «Biochemistry of nutrition. Biochemistry of the blood. Water and mineral metabolism»	-	3	-		Colloquium*
<b>9.</b>	<b>Biochemistry of organs and tissues</b>	-	<b>6</b>	-		
9.4.	Biochemistry of kidneys and urine	-	6	-		
	Biochemistry of the urine Lab. work: Determination of the urine physiological and	-	3	-	Qualitative determination of	written account of laboratory work interviews, surveys, case

pathological components				the urine pathological components: ketone bodies, glucose, protein, blood pigments. Quantitative determination of the urine pathological components: glucose, protein	work	tasks solving, online tests
Control over practical skills of biochemical analysis. Analysis of gastric juice and urine	-	3	-	Qualitative determination of the urine pathological components: ketone bodies, glucose, protein, blood pigments. Quantitative determination of the urine pathological components: glucose, protein. Analysis of gastric juice free and total acidity	written account of laboratory work, oral defense*	
<b>Total hours</b>	<b>33</b>	<b>105</b>	<b>15</b>			Examination

\* is a mandatory form of current certification

**INFORMATION AND INSTRUCTIONAL UNIT****LITERATURE****Basic:**

1. Textbook Biological Chemistry. Lecture notes / A. D. Taganovich, I. L. Kotovich, A. V. Kolb, N. N. Kovganko, T. Yu. Prinkova – Minsk : BSMU, 2017. – 162 p.

2. Gubsky, Yu. Biological Chemistry : textbook/ ed. Yu. Gubsky. – Vinnitsia : Nova Knyha, 2017. – 488 p.

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

The time allowed for independent work can be used by students for:  
preparation for lectures and laboratory classes;  
preparation for colloquia, credits and exam in the academic discipline;  
study of the questions recommended for student independent work;  
case tasks solving;  
research and creative work;  
preparation of thematic reports, abstracts, presentations;  
taking notes of original sources.

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

Main forms of supervised student independent work:  
studying topics and problems that have not been discussed at the lectures;  
computer testing.

**LIST OF AVAILABLE DIAGNOSTIC TOOLS**

The following forms are used for competences assessment:

test;  
online test;  
colloquium;  
interview;

case tasks solving;  
written account of laboratory work;  
survey.

**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**

Name of practical skills	Form of practical skills control
1. Quantitative determination of the protein content in blood serum	written account of laboratory work
2. Determination of amylase activity in urine	written account of laboratory work
3. Quantitative determination of pyruvate in the urine	written account of laboratory work
4. Quantitative determination of blood glucose	written account of laboratory work
5. Determination of plasma $\beta$ -lipoproteins in blood serum	written account of laboratory work
6. Quantitative determination of cholesterol in serum	written account of laboratory work
7. Analysis of gastric juice acidity	written account of laboratory work
8. Quantitative determination of urea in urine	written account of laboratory work
9. Determination of uric acid and total nitrogen in urine	written account of laboratory work
10. Determination of total bilirubin content in blood serum	written account of laboratory work
11. Quantitative determination of calcium in the blood	written account of laboratory work
12. Quantitative determination of vitamin C in urine	written account of laboratory work
13. Quantitative determination of sodium and potassium in serum	written account of laboratory work
14. Qualitive determination of the urine pathological components: ketone bodies, glucose, protein, blood pigments. Quantitative determination of the urine pathological components: glucose, protein	written account of laboratory work

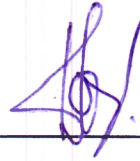


**PROTOCOL OF THE CURRICULUM APPROVAL  
BY OTHER DEPARTMENTS**

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. Pharmacology	Pharmacology	No proposals and remarks	protocol # 12 of 24.05.2024
2. Endocrinology	Endocrinology	No proposals and remarks	protocol # 12 of 24.05.2024

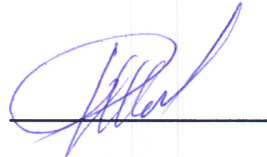
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Zh.A.Rutkovskaya

Curriculum content, composition and the enclosed documents comply with the established requirements.

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

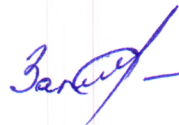
24.06. 2024



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24.06. 2024



S.V.Zaturanova