MINISTRY OF EDUCATION AND SCIENCE OF RUSSIAN FEDERATION

PENZA STATE UNIVERSITY

MEDICAL INSTITUTE

APPROVED

DIRECTOR OF THE MEDICAL INSTITUTE

_____ A.N. MITROSHIN

«15» марта 2016 г.

THE PROGRAM OF ACADEMIC DISCIPLINE

C 1.1.13 BIOCHEMISTRY

Specialty	31.05.01 General Medicine
Graduate's qualification (degree)	General practitioner
Mode of study	Full-time

Penza 2016

1. DISCIPLINE LEARNING OBJECTIVES

The objective of the discipline is a study of metabolic pathways of the major classes of organic compounds, regulation of these pathways, the molecular mechanisms of the development of pathological processes, as well as the study of biochemical methods of disease diagnosis.

The purpuses of the study of the discipline Biochemistry are:

1) definition of the basic principles of molecular organization of cells and tissues;
2) studying of basic objective laws of metabolism, regulation of metabolism and its relationship with functional activity of functional systems;
3) studying of biochemical research methods; formation of competence to use the results for assessing human health state;
4) studying of pathogenetic mechanisms of development of pathological processes, taking into account the main types of inherited defects of metabolism;
5) studying of clinical and laboratory technologies and the skills of working with them.

2. DISCIPLINE POSITION IN THE STRUCTURE OF THE BASIC PROFESSIONAL EDUCATIONAL PROGRAM OF HIGHER EDUCATION

The discipline biochemistry relates to base part of **(C 1)** of the Basic professional educational program of Higher Education (BPEP HE).

The discipline Biochemistry is associated with the following disciplines: Biology, Chemistry, Anatomy, Physics, Mathematics, the Latin language.

Conceptual issues of discipline Biochemistry are necessary for the study of following disciplines: Normal physiology, Pathophysiology and clinical pathophysiology, Pharmacology, Physiology of functional systems, Microbiology and virology.

3. THE STUDENT COMPETENCIES BASED ON THE SUCCESSFUL COMPLETION OF THE DISCIPLINE BIOCHEMISTRY

The process of study is directed to the formation of the following competencies in accordance with the Federal State Educational Standard of higher education in this area:

Codes of competences	Name of competence	Structural elements of the competence (as a result of the development of the discipline the student should know, be able and acquire)
1	2	3
GCC-1	The ability to abstract thinking, analysis, synthesis	**To know** the basic concepts, laws and principles of biochemical knowledge in their logical integrity and consistency;
		Be able to use basic methods of collecting and analyzing of information about the structure and transformation of major organic substances in the composition of cells and tissues, to summarize, to reveal the relationship between the structure of substances and their functioning in a living system, systematize, interpret and comment on the obtained information
		Be skilled in obtaining, systematizing, using and updating

		biochemical knowledge from various sources
1	2	3
GPC-7	Readiness to use fundamental physical, chemical, mathematical and other science concepts and methods in solving professional problems	**To know** chemical processes occurring in a living organism at the molecular, cellular, tissue, and organ levels; the main metabolic pathways of the transformation of carbohydrates, lipids, amino acids, purine and pyrimidine bases; the role of cell membranes and their transport systems in metabolism; structure and functions of the most important chemical compounds (nucleic acids, proteins, water-soluble and fat-soluble vitamins, hormones, etc.); regulation of biochemical processes in normal and pathological conditions
		Be able to use of physical, chemical and biological equipment; to interpret the results of the most common methods of laboratory and functional diagnostics for the detection of pathological processes in organs and systems; to predict the direction and result of transformations of biologically important substances
		Be skilled in use of medical and biological conceptual framework; work with scientific medical information; preliminary analysis of the results of clinical, laboratory and instrumental methods examination of patients

4. Structure and content of the discipline BIOCHEMISTRY

4.1. Structure of the discipline BIOCHEMISTRY

The total complexity of the discipline is 7 credits, 252 hours.

№	Name of the section and the topic of discipline	Semester	Weeks of the semester	Kinds of study, including individual work of students *(in hours)*									Forms of the current control of progress *(by weeks of the semester)*							
				Classroom work				Individual work												
				Total	Lectures	Practical classes	Laboratory classes	Total	Preparation for classroom work	Essay, research papers etc.	Course project	Exam Preparation	Interlocution	Colloquium	Test grading	Paper grading	Essays and other creative works grading	Research paper grading	Course work (project)	Skill grading
	Basic biochemistry																			
1.	**Proteins**																			
1.1.	Structure of proteins	3	1	4		4		1	1				1							
1.2.	Physic-chemical properties of proteins	3	2	4	2	2		1	1				2							
1.3.	Nucleic acids. Template biosynthesis	3	3	4		4		2	2				3							
1.4.	The structure of complex proteins	3	4	4	2	2		2	2				4							
1.5.	Biochemistry of proteins		5	4		4		2	2					5	5					
2.	**Enzymes**																			
2.1.	The structure of enzymes Vitamins and cofactors.	3	6	4	2	2		2	2				6							
2.2.	Mechanism of enzyme action	3	7	4		4		2	2				7							
2.3.	Regulation of enzyme activity	3	8	4	2	2		2	2				8							
2.4.	Structure and properties of enzymes	3	9	4		4		2	2					9	9					
3.	**Membranes. Hormones**																			
3.1.	Membranes. Transport mechanisms.	3	10	4	2	2		2	2				10							
3.2.	General characteristics of hormones	3	11	4		4		2	2				11							
3.3.	The mechanism of hormones' action	3	12	4	2	2		2	2				12							
3.4.	Structure and functions of membrans and hormones	3	13	4		4		2	2					13	13					
4.	**Bioenergetics**																			
4.1.	Biological oxidation.	3	14	4	2	2		2	2				14							
4.2.	Lipid peroxidation. Antioxidant systems	3	15	4		4		1	1				15							

№	Name of the section and the topic of discipline	Semester	Weeks of the semester	Kinds of study, including individual work of students *(in hours)*									Forms of the current control of progress *(by weeks of the semester)*							
				Classroom work				Individual work												
				Total	Lectures	Practical classes	Laboratory classes	Total	Preparation for classroom work	Essay, research papers etc.	Course project	Exam Preparation	Interlocution	Colloquium	Test grading	Paper grading	Essays and other creative works grading	Research paper grading	Course work (project)	Skill grading
4.3.	Electron transport chain	3	16	4	2	2		1	1				16							
4.4.	Metabolism and metabolic pathways	3	17	4		4		2	2				17							
4.5.	The citric acid cycle	3	18	4	2	2		1	1				18							
4.6.	**Bases of bioenergetics**	3	19	4		4		1	1					19	19					
5.	**Carbohydrates**																			
5.1.	Digestion and absorption of carbohydrates	4	1	4	2	2		1	1				1							
5.2.	Glucose metabolism	4	2	4		4		2	2				2							
5.3.	Glycogen metabolism	4	3	4	2	2		2	2				3							
5.4.	Metabolism of carbohydrates	4	4	4		4		2	2					4	4					
6.	**Lipids**																			
6.1.	Digestion and absorption of lipids	4	5	4	2	2		2	2				5							
6.2.	Metabolism of fatty acids and triacylglycerols	4	6	4		4		2	2				6							
6.3.	Metabolism of cholesterol	4	7	4	2	2		2	2				7							
6.4.	Metabolism of lipids	4	8	4		4		2	2					8	8					
7.	**Nitrogen compounds**																			
7.1.	Metabolism of proteins. Nitrogen balance	4	9	4	2	2		2	2				9							
7.2.	General pathways of amino acid metabolism	4	10	4		4		1	1				10							
7.3.	Particular conversion of amino acids	4	11	4	2	2		2	2				11							
7.4.	Metabolism of nucleotides	4	12	4		4		2	2				12							
7.5.	Metabolism of ammonia	4	13	4	2	2		2	2				13							
7.6.	Metabolism of nitrogen compounds	4	14	4		4		2	2					14	14					
8.	**Specialized tissues**																			
8.1.	Biochemistry of the blood	4	15	4	2	2		2	2				15							
8.2.	Biochemistry of the liver	4	16	4		4		1	1				16							
8.3.	Water, electrolytes, and acid-base balance	4	17	4	2	2		1	1				17							

№	Name of the section and the topic of discipline	Semester	Weeks of the semester	Kinds of study, including individual work of students *(in hours)*									Forms of the current control of progress *(by weeks of the semester)*							
				Classroom work				Individual work												
				Total	Lectures	Practical classes	Laboratory classes	Total	Preparation for classroom work	Essay, research papers etc.	Course project	Exam Preparation	Interlocution	Colloquium	Test grading	Paper grading	Essays and other creative works grading	Research paper grading	Course work (project)	Skill grading
8.4.	Metabolism of the nervous system, muscle and connective tissue	4	18	4		4		1	1				18							
8.5.	Biochemistry of specialized tissues	4	19	4	2	2		1	1					19	19					
	Exam Preparation	4						36				36								
	Total labour, hours			152	38	114		100	64			36	Interim certification							
													Form			Semester				
													Pre-exam			*3*				
													Exam			*4*				

4.2. Content of the discipline Biochemistry

Introduction.

Subjects and objectives of biochemistry. The role of biochemistry in medicine. History of biochemistry. The main sections of medical biochemistry: static biochemistry, dynamic biochemistry, functional biochemistry, molecular biology.

Protein structure

Structure, classification and properties of amino acids. Peptide bond. Peptides and proteins. Simple and compex proteins. Levels of proteins organization: primary, secondary, tertiary, quaternary structures and domains. Genetic changes of the amino acids sequence, hereditary proteinopathies.

Properties of proteins: molecular mass, thermolability, solubility, amphoteric properties and net charge. Relationships between structure and function of proteins, selective interaction with ligands, ligand's recognition. Characteristics of proteins solutions. The purification and analysis of proteins: salting, dialysis, ultracentrifugation, chromatography, electrophoresis.

Simple proteins: histones, albumins, globulins, their functions and physical and chemical characteristics. Conjugated (complex) proteins: nucleoproteins, chromoproteins, phosphoproteins, glycoproteins, metalloproteins, lipoproteins. Hemoglobin, collagen, immunoglobulins, Ca^{2+}-binding proteins. Characteristics of amino acid composition in collagen, structure, properties and types of collagens.

Nucleic acids. The biosynthesis of nucleic acids and proteins

Structural components of the nucleic acids: nitrogenous bases, pentose sugar, phosphate group, their structure, properties. Nucleosides and nucleotides: structure, nomenclature, role.

Types of the nucleic acids: DNA, RNA, their distribution in the cell and biological role. Nucleic acids structure. DNA structures: primary, secondary, tertiary, nucleosomes, and chromatin. RNA structures: primary, secondary and tertiary. Structure of tRNA. General aspects of mRNA and rRNA structure.

Replication (synthesis of DNA): necessary compounds, the multienzymic system, stages, DNA repair. Transcription: necessary compounds, the multienzymic system, stages. Post-transcription modification of mRNA. Reverse transcription.

The genetic code and its properties. Translation (protein synthesis). Activation of the amino acids: stages, enzymes, source of energy. Stages and mechanism of polypeptide chain synthesis. Post-translational modification of the proteins. Peculiarities of collagen and immunoglobulins biosynthesis. Protein folding. Control of protein synthesis in prokaryotes and eukariotes. Usage of the drugs as inhibitors of replication, transcription and translation.

General and medical enzymology .

Biological role of enzymes. Common properties and differences from chemical catalysts. Structure of the active center, the role in the catalytic act. Allosteric site: structure, role, modulators. Chemical nature of enzymes: simple and conjugated enzymes. Cofactors, coenzymes and prosthetic groups. The role of water–soluble vitamins as coenzymes (B1, B2, B6, B12, PP, folic acid, pantothenic acid, biotin, vit. C). Utility of provitamins and vitamins in therapy.

Mechanisms of enzyme catalysis. Regulation of enzymes: activation (partial proteolysis, addition of cofactor, covalent modification, allosteric, quaternary autoassembling) and inhibition: competitive, noncompetitive, allosteric, product inhibition (retroinhibition). Utility in medicine of competitive inhibitors as drugs (sulphanilamides, F-uracil, etc.).

Enzyme's properties: thermolability, pH influence, specificity (lock and key and induced-fit theories). Types of enzyme specificity. Genetic diversity of the enzymes: isoenzymes (LDH, CPK). Proenzymes. Organization of multienzymic systems. Compartmentalization. Enzyme nomenclature. Measurement and measures of enzymes activity. Methods of enzymes separation and purification. Affinity chromatography. Enzymes' activity assay in diagnostics. Enzymes as drugs. Immobilized enzymes.

Vitamins

The general concept of vitamins. History of the discovery and study of vitamins. The

biological role of vitamins. Vitamins as cofactors of enzymatic reactions. Methods of determining the concentration of vitamins. Classification of vitamins. Chemical structure, the functional significance. Dietary sources. The daily requirement. Clinical signs of hypovitaminosis and avitaminosis, prevention. The fat-soluble vitamins (A , D, E, K). Water-soluble vitamins (B_1, B_2, B_6, B_{12}, PP, H , C, folic acid, pantothenic acid). Vitamin-like substances (para-aminobenzoic acid, inositol, coenzyme Q, lipoic aci, choline, vitamins B15 and U). Biological role. Dietary sources.

Hormones.

The concept of hormones. Classification and nomenclature of hormones. The hierarchy of the regulatory systems in the human organism. The hormone-receptor interaction.

Mechanisms of hydrophilic hormone's action.The receptor-adenylate cyclase complex: 3',5'-cyclic AMP function, cyclic AMP-dependent protein kinase and phosphorylation of the cellular proteins. Diacylglycerol and inositol-1,4,5-triphosphate – the second messengers of the hormones. Role of protein kinase C and Ca^{2+} in hormonal function. Structure and role of calmodulin. Mechanisms of hydrophobic hormone's action. Regulation of transcription and protein biosynthesis.

Peptide and protein hormones. Hypothalamic hormones: liberins (releasing hormones, RH) and statins (releasing inhibiting hormones, RIH), chemical structure, biological role. Hypophyseal (pituitary) hormones (somatotropin, corticotropin, thyrotropin, et al.), structure, function, diseases associated with pituitary disorders and their correction. Vasopressin and oxytocin: chemical structure, metabolic effects. Pancreatic hormones: insulin and glucagon, structure, biosynthesis, mechanisms of action, metabolic effects. Mechanism activation of insulin. Diabetes mellitus: causes, types (I and II), metabolic changes in the patients and their correction.

Hormones are derivatives of tyrosine. Thyroid hormones: T3 and T4, structure, biosynthesis, mechanism of action, metabolic effects, disorders of synthesis and release. Parathyroid hormones: structure, biosynthesis, mechanism of action, metabolic effects. Catecholamine hormones (adrenalin, noradrenalin): structure, biosynthesis, metabolic effects, disorders.

Steroid hormones. Hormones of adrenal cortex. Glucocorticoids hormones (corticosterone, hydrocortisone, cortisol). Mineralocorticoids hormones (aldosterone, deoxycorticosterone). Sexual hormones (estradiol, progesterone, androsterone, testosterone). Structure, biosynthesis, metabolic effects, disorders.

Biological membranes

The concept of cell membranes. The chemical nature of biological membranes. Structural organization of membranes. The basic model of the membrane, a model of globular protomers, Sanger-Nicolson membrane structure. Composition and characteristics of membrane components. Membrane lipid composition and structure of the lipid bilayer. Diaphragm (integral) proteins. Biological functions of membranes. Key qualities: fluidity, lateral asymmetry, selective permeability.

The migration of substances through the membrane. Passive and active transport of substances through the membrane. Potassium-sodium pump. Violation of transport processes in pathology.

The free-radical processes. Peroxidation and endogenous fosfolipoliz as universal biochemical mechanisms of damage of biomembranes, underlying the pathogenesis of diseases. Cytotoxic calcium cascade. Antioxidant cellular system. Antioxidants as therapeutic drugs.

Introduction to metabolism. Biochemistry of nutrition.

Metabolism, its stages: anabolism and catabolism. Stages of catabolism: specific and final common pathways, their importance.

Basic nutrients: carbohydrates, fats, proteins; daily need; digestion; partial interchangeability of food ingredients. Essential components of basic nutrients. Essential amino acids, protein value. Essential fatty acids. Mineral components.

The concept of metabolism (anabolism and catabolism), metabolic pathways. The concept of the regulation of metabolism. Hormones and metabolism. Enzymes and metabolism. Concentrations of metabolites: limits changes in norm and in pathology. The transformation of chemical energy in the body. The main end-products of metabolism in humans: carbon dioxide and urea.

The scheme of catabolism of essential nutrients - carbohydrates, fats, proteins (amino acids); the concept of specific pathways of catabolism (the formation of pyruvate from carbohydrates and amino acids and acetyl-CoA formation from fatty acids and amino acids). General pathways of catabolism (oxidation of pyruvate and acetyl-CoA).

Oxidative decarboxylation of pyruvate, sequence of reactions, structure of pyruvate dehydrogenase complex. The citric acid cycle, sequence of reactions and enzymes' characteristic. The formation of carbon dioxide in tissue respiration.

The energy balance of the citrate cycle. The regulation of the citrate cycle. Anabolic functions of the citric acid cycle. The ratio between the concepts of energy metabolism, biological oxidation and tissue respiration.

Energy metabolism. Tissue respiration.

Bioenergetics: thermodynamic concepts, enthalpy, entropy, free energy. Dehydrogenation as the main energy source in the human organism.

High-energy phosphate compounds: phosphoenolpyruvate, phosphocreatine, ATP, chemical structure, importance, ATP-ADP cycle. Mechanisms of ATP biosynthesis in the cell: oxidative phosphorylation, substrate phosphorylation, photophosphorylation (photosynthesis).

The mitochondria structure. Mitochondrial electron transport chain (Respiratory Chain), its types. Organization of the electron transport chain. Oxidation–reduction (redox) potential and mechanism of ATP production.

ATP formation sites. A coupling of respiration with phosphorylation: oxidative phosphorylation, the P/O ratio. Chemiosmotic hypothesis by Mitchell. Uncouples of oxidation and phosphorylation. Agents affecting energy metabolism in cells (hormones, drugs, toxins).

Microsomal oxidation: microsomal electron transport chains (NAD-dependent and NADP-dependent chains), their organization. Role of cytochrome P450. Free-radical processes and lipid peroxidation. Protective antioxidative systems. Vitamins as antioxidants and their use in medicine.

Disturbance of energetic metabolism. Hypoxia. Hypoergic condition.

Carbohydrate's metabolism.

The main carbohydrates, their content in the tissues, biological role. The main dietary carbohydrates. The digestion of carbohydrates. Glucose as a major metabolite of carbohydrate metabolism. The General scheme of sources and ways of spending of glucose in the body.

Glycolysis: stages, reactions, enzymes and coenzymes, enzymic control of glycolysis. Anaerobic glycolysis. Aerobic glycolysis (aerobic oxidation of glucose): ATP production, role of glycerод 3-phosphate and malate-aspartate shuttle. Energy balance of glucose oxidation (to CO2 and H2O).

Glycogen metabolism: reactions, enzymes, hormonal regulation of glycogen biosynthesis and glycogenolysis. Genetic defects in glycogen metabolism (Von Gierke, Pompe, Forbes diseases, etc.).

Gluconeogenesis: reactions, energetics and substrates for gluconeogenesis. The Cory and glucose-alanine cycles. Hormonal control of gluconeogenesis and its pathology.

Pentose phosphate (apotomic) pathway decomposition of glucose: functional importance, chemical reactions for pentoses production, regulation and role. Metabolism of fructose, galactose and lactose: pathways, significance and hereditary defects. Biosynthesis of lactose: pathway, control and functional significance. Glucuronic acid synthesis: significance, pathway. Alcohol fermentation: reactions, energetic balance, significance.

Regulation of carbohydrate metabolism: metabolic and hormonal control of the blood serum glucose concentration. Diabetes mellitus: metabolic disturbances, mechanism ща hyperglycemia, glucosuria, ketonemia, ketonuria, diabetic coma. Correction of diabetes mellitus.

Lipids' metabolism

Nature, functions, classifications, structure and properties of fatty acids, acylglycerols, phosphoglycerides, sphingomyelin, sphingolipids, cholesterol and its esters. Fat-soluble vitamins (A, E, D, K): structure, role, disorders caused by their deficiency. Fat-soluble (liposoluble) vitamins as drugs and antioxidants. Digestive mechanism for the lipids and absorption in gastrointestinal

tract. Structure, functions and metabolism of the bile acids. Resynthesis of lipids, formation of chylomicrons, transport of lipids.

Lipoproteins metabolism, disorders of lipoproteins metabolism. Lypolysis of triacylglycerols in tissue: reactions, hormonal control of lipolysis in the different tissues and its disorders.

Fatty acids β-oxidation: reactions, enzymes and coenzymes, final products, ATP production. The specific β-oxidation of odd-numbered carbon atom and unsaturated fatty acids. Glycerol oxidation: the enzymic steps, ATP production, interrelation with glycolysis. Ketone bodies metabolism: nature of the ketone bodies, source for ketone bodies production and their oxidation. ATP production during oxidation of the ketone bodies. Ketoacidosis.

Biosynthesis of fatty acids: characteristics of polyenzymatic complex, reactions, source of acetyl-CoA and $NADPH^+$.

Cholesterol synthesis. Stages of the cholesterol synthesis (formation of mevalonic acid, squalen, lanosterol), regulation. Cholesterol as precursor of other compounds (bile acids, steroid hormones and vitamins). Cholesterol excretion from the human organism. Connection between cholesterol and blood plasma lipoproteins metabolism. Disorders of the cholesterol metabolism: hypercholesterolemia, cholelithiasis and atherosclerosis.

Phosphoglycerides metabolism. Biosynthesis *de novo* and salvage pathway: reactions, regulation, lipotropic factors. Modification and oxidation of phospholipids. Sphingolipids, chemical structure, role. Prostaglandins and their derivative compounds: biologic role, structure and biosynthesis.

Metabolism of nitrogen-containing compounds

Nitrogen balance, its types. Essential amino acids. Proteins digestion: proteolytic enzymes (endo- and exopeptidases). Proteases: secretion, mechanism activation, and specificity. Role of HCl, mechanism of secretion and its regulation. Gastric juce acidity assay: hypochlorhydria, hyperchlorhydria. Amino acids absorption into small intestine: Na^+-simport mechanism and γ-glutamate cycle. Bacterial putrefaction of the amino acids in large intestine: production of toxic compounds (indol, scatol, cresol, cadaverine, putrescine, etc.) and their inactivation in the liver. Mechanism of conjugation, production of indicane. Proteolysis (catabolism) of proteins in the tissues, its regulation.

Amino acids degradation (intracellular catabolism). The disposal of nitrogen from amino acids: oxidative deamination (direct and indirect), enzymes, coenzymes, biologic role. Transamination of the amino acids; role, enzymes, coenzymes and mechanism of the reaction. Diagnostic meaning of aminotransferases' activity assay: alanine transaminase (ALT) and aspartate transaminase (AST).

Amino acids decarboxylation, enzymes, coenzymes, final products. Biogenic amines: serotonine, histamine, dopamine and g-aminobutyric acid (GABA), their biological activity and inactivation. The fate of the amino acids carbon skeletons.

Ammonia production and toxicity. The urea cycle, reactions, regulation and importance. Interrelationship between urea cycle and Krebs cycle. Specific metabolic pathways of amino acids: gly, ser, thr, cys, met, phe, tyr, trp, glu, asp. Molecular diseases associated with abnormal amino acids' metabolism: phenylketonuria, tyrosinemia, alkaptonuria, maple syrup disease, etc.

Nucleoprotein metabolism: digestion and absorption in small intestine. Nucleotide metabolism. synthesis *de novo* of purine and pyrimidine nucleotides: substrates, pathways, regulation. Deoxyribonucleotides' formation. Salvage pathway for purine and pyrimidine bases. Degradation of purine and pyrimidine nucleotides. Diseases associated with defects of nucleotide metabolism (gout, orotic aciduria).

Exchange of water and mineral salts

Mineral substances of human tissue. Intake of minerals in the body. Biological functions of minerals.

Water-salt metabolism. Electrolyte composition of body fluids. Mechanisms of regulation of volume, electrolyte composition and pH of body fluids. Role of the kidney in the regulation of water-salt exchange. Antidiuretic hormone, aldosterone and renin-angiotensin system (RAS).

Mechanism to restore blood volume after blood loss. Biochemical mechanisms of renal hypertension. Conditions and mechanisms of acidosis and alkalosis, dehydration, edemas.

Sodium and potassium. Biological role in metabolism. Transmembrane gradient of ions of sodium and potassium; the sodium-potassium pump (Na^+,K^+-ATP-ase) and its function. Metabolic disorders of sodium and potassium.

Phosphate and calcium metabolism. Mineral and organic phosphates. The functional activity of calcium ions. The mineral composition of the bone. Vitamin D_3: structure, daily need, impact on the exchange of calcium and phosphate. Violations of calcium phosphate metabolism in rickets. Regulation of phosphate-calcium exchange by parathyroid hormone and calcitonin. Hyperparathyroidism, gipoparatiroidism. The exchange and the biological role of iron, copper, zinc, cobalt, selenium.

Biochemistry of blood and urine

Structure and chemical composition of the red blood cells. Hemoglobin, oxyhemoglobin; blood oxygen transport. Carboxyhemoglobin. Methemoglobin. Transport of carbon dioxide in blood. Fetal hemoglobin (HbF-hemoglobin) and its physiological significance. The biosynthesis of heme. Iron exchange; trasferrin and ferritin. Iron-deficient anemia.

Serum proteins, Albumins and other transport proteins. Globulins. Enzymes in blood. Kinin system. "The acute phase proteins", nature, diagnostic significance. Clinical significance of biochemical blood analysis.

General properties of urine. Organic substances in urine: urea, creatinine, creatine, creatine index, amino acids, uric acid. Mineral components of urine: electrolytes, bicarbonate, phosphate, sulphate, ammonia. Abnormal urine components: protein, blood, sugar, ketone bodies, bilirubin, urobilin, porphyrins. Clinical significance of biochemical analysis of urine.

Liver biochemistry

The role of liver in metabolism of carbohydrates, lipids, amino acids. Blood plasma protein synthesis in the liver.

Neutralization (detoxification) of substances in the liver; oxidation (hydroxylation and conjugation). Detoxification of bilirubin. The "direct" and "indirect" bilirubin. Metabolic disorders of bilirubin. Jaundices: haemolytic jaundice, obstructive jaundice, hepatocellular jaundice. Jaundice in newborns. Diagnostic value of determination of serum bilirubin and other bile pigments in the blood and urine.

Inactivation of hormone in liver (insulin, steroid hormones, catecholamines).

Biochemistry of connective tissue

Collagen: characteristics of amino acid composition, secondary structure, biosynthesis. Role of ascorbic acid for hydroxylation of proline and lysine. Manifestation of vitamin C. The formation of collagen fibers. Glycosaminoglycans of connective tissue. Role of proteoglycans in the exchange of water. Changes of connective tissue with age, collagenoses, wound healing.

Biochemistry of the nervous tissue

The chemical composition of the nervous tissue. The myelin membrane: features and structure. Energy metabolism in nerve tissue; the aerobic decomposition of glucose. Exchange of pyruvic acid and polyneuritis. Molecular mechanisms of synaptic transmission. Neurotransmitters: acetylcholine, catecholamines, serotonin, g-aminobutyric acid, glutamic acid, glycine, histamine. Physiologically active peptides in the brain. Metabolism of biogenic amines in mental diseases.

Muscle biochemistry

The major proteins of myofibrils: myosin, actin, tropomyosin, troponin. Molecular structure of myofibrils. Biochemical mechanisms of muscle contraction and relaxation. The role of calcium ions in regulation of muscle contraction. Myoglobin: its structure and function. Muscle extracts. Characteristics of energy metabolism in the muscles. The biological role of phosphocreatine.

5. EDUCATION TECHNOLOGIES

The learning outcomes of the discipline Biochemistry is achieved through the use of active and interactive methods and technologies of students competencies formation in learning process:

1. classes with laboratory equipment and visual aids with biochemical schemes;
2. computer testing;
3. multimedia lectures;
4. solution of case problems;
5. self-guided work with literature and biochemical schemes.

5.1. Active learning methods

5.1.1. Non-simulation methods

5.1.1.1. Lectures-visualizations

III semester

Conformation of the protein
Lipoproteins, proteoglycans, nucleoproteins
Active site of enzyme
Allosteric regulation
Liquid-mosaic membrane model
Active and passive transmembrane transport
Messenger systems
Hemioosmotic theory of Mitchell

5.1.1.2. Lectures with case problem

IV semester

The state of carbohydrate metabolism after meal, with exercise, under stress
Triglyceride and cholesterol metabolism after meal and physical exercise
The state of nitrogen equilibrium with uptaking of dietary proteins with different amino acid composition
Toxic action of ammonia, causes and consequences of hyperammonemia
Disorders of hemoglobin and bilirubin metabolism
Discussion of acid-base state at meal, breathing, changing the metabolism of carbohydrates, lipids and ammonia

5.1.2. Simulation methods

5.1.3. Professional simulation

IV semester

Determination of glucose concentration in biological fluids
Determination of the concentration of total cholesterol in biological fluids
Determination of the concentration of total lipids in biological fluids
Determination of the concentration of total protein in biological fluids
Determination of hemoglobin concentration in blood
Determination of urea concentration in biological fluids
Determination of the concentration of uric acid in biological fluids
Determination of the activity of amylase in biological fluids
Determination of aminotransferase activity in biological fluids

5.1.4. Case problems

III semester

The effect of hydrogen ions concentration on affinity of hemoglobin for oxygen;
Analysis of enzyme activity changes under covalent modification and by allosteric effectors;
The state of the mitochondrial respiratory chain at the presence of oxygen and drugs.

IV semester

Synthesis and breakdown of glycogen at physical activity, starvation, different hormonal status;
The state of lipid metabolism during physical exertion, fasting, changes in hormonal status;
The ratio of synthesis and decomposition of proteins for different types of nutrition;
The mechanism of intoxication with increasing ammonia synthesis; Analysis of different types of jaundice;

The mechanism of development of acidosis and alkalosis.

5.1.5. Solution of case problems

III semester

The solution of case problems in the biochemistry of proteins, enzymology, hormonal regulation and bioenergetics.

IV semester

Solution of case problems for carbohydrate, lipid and nitrogen metabolism.

5.2 For realization of individual approach to tutoring of the students who are carrying out educational process on characteristic trajectory within the individual working plan, studying of this discipline is based on the following features: providing of out-of-class work with students including in the e-learning using the appropriate equipment and software, distance learning, Internet resources, individual consultations, etc.

6. TRAINING AND METHODOLOGICAL SUPPORT OF STUDENTS' INDIVIDUAL WORK. EVALUATION TOOLS FOR MONITORING PROGRESS, INTERMEDIATE CERTIFICATION ON THE BASIS OF THE DEVELOPMENT OF THE DISCIPLINE.

6.1. Plan of students' individual work

№.	Topic	Type of individual work (according to table 4.1)	Task	Suggested literature	Hours for individual work (according to table 4.1)
III семестр					
1.1	Structure of proteins	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
1.2	Physic-chemical properties of proteins	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
1.3	Nucleic acids. Template biosynthesis	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
1.4	The structure of complex proteins	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
1.5	Biochemistry of proteins	Preparing for colloquium	Study the theoretical issues of the section. Answer questions for the control class Solve case problems on the topic of the section	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
2.1	The structure of enzymes Vitamins and cofactors.	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
2.2	Mechanism of enzyme action	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
2.3	Regulation of enzyme activity	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2

№.	Topic	Type of individual work (according to table 4.1)	Task	Suggested literature	Hours for individual work (according to table 4.1)
2.4	Structure and properties of enzymes	Preparing for colloquium	Study the theoretical issues of the section. Answer questions for the control class Solve case problems on the topic of the section	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
3.1	Membranes. Transport mechanisms.	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
3.2	General characteristics of hormones	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
3.2	The mechanism of hormones' action	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
3.4	Structure and functions of membrans and hormones	Preparing for colloquium	Study the theoretical issues of the section. Answer questions for the control class Solve case problems on the topic of the section	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
4.1	Biological oxidation.	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
4.2	Lipid peroxidation. Antioxidant systems	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
4.3	Electron transport chain	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
4.4	Metabolism and metabolic pathways	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2

№.	Topic	Type of individual work (according to table 4.1)	Task	Suggested literature	Hours for individual work (according to table 4.1)
4.5	The citric acid cycle	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
4.6	Bases of bioenergetics	Preparing for colloquium	Study the theoretical issues of the section. Answer questions for the control class Solve case problems on the topic of the section	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
IV семестр					
5.1	Digestion and absorption of carbohydrates	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
5.2	Glucose metabolism	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
5.3	Glycogen metabolism	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
5.4	Metabolism of carbohydrates	Preparing for colloquium	Study the theoretical issues of the section. Answer questions for the control class Solve case problems on the topic of the section	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
6.1	Digestion and absorption of lipids	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
6.2	Metabolism of fatty acids and triacylglycerols	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
6.3	Metabolism of cholesterol	Preparing for classroom	Study the theory on the topic of the class Answer control questions	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2

№.	Topic	Type of individual work (according to table 4.1)	Task	Suggested literature	Hours for individual work (according to table 4.1)
		work	Make practical task on the topic of the classes		
6.4	Metabolism of lipids	Preparing for colloquium	Study the theoretical issues of the section. Answer questions for the control class Solve case problems on the topic of the section	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
7.1	Metabolism of proteins. Nitrogen balance	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
7.2	General pathways of amino acid metabolism	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
7.3	Particular conversion of amino acids	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
7.4	Metabolism of nucleotides	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
7.5	Metabolism of ammonia	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
7.6	Metabolism of nitrogen compounds	Preparing for colloquium	Study the theoretical issues of the section. Answer questions for the control class Solve case problems on the topic of the section	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
8.1	Biochemistry of the blood	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	2
8.2	Biochemistry of the	Preparing for	Study the theoretical material on the topic of the	The Medical Biochemistry Page 1996-2017	1

№.	Topic	Type of individual work (according to table 4.1)	Task	Suggested literature	Hours for individual work (according to table 4.1)
	liver	classroom work	class Answer questions for self-monitoring in guidelines Make practical work on the topic of classes	https://themedicalbiochemistrypage.org/home.html	
8.3	Water, electrolytes, and acid-base balance	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
8.4	Metabolism of the nervous system, muscle and connective tissue	Preparing for classroom work	Study the theory on the topic of the class Answer control questions Make practical task on the topic of the classes	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1
8.5	Biochemistry of specialized tissues	Preparing for colloquium	Study the theoretical issues of the section. Answer questions for the control class Solve case problems on the topic of the section	The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html	1

6.2. Methodical instructions on the organisation of individual work of students

Individual work of students questions on specific sections of the discipline are placed the in methodical recommendations for practical exercises in the educational and methodological package of the discipline.

6.3. Materials for current control progress, intermediate and final assessment of students

Control development of competencies

№	Type of control	Controlled section	Competence, the components of which are controlled
1.	Test grading	Section 1, 2, 3, 4, 5, 6, 7, 8	GCC-1, GPC-7
2.	Interlocution	Section 1, 2, 3, 4, 5, 6, 7, 8	GCC-1, GPC-7
3.	Colloquium	Section 1, 2, 3, 4, 5, 6, 7, 8	GCC-1, GPC-7

Examples of test tasks

1. The molecule of a peptide is composed of:
   1) fatty acids
   2) glucose
   3) nucleotides
   4) amino acids
   5) glycerol
2. Which phenomenon is observed during proteins' denaturation?
   1) loss of biological activity
   2) decrease of solubility
   3) destruction of primary structure
   4) increase of charge
3. Activity of enzymes may be regulated by:
   1) full hydrolysis of the enzyme
   2) partial proteolysis of proenzyme
   3) covalent modification of one enzyme by the other
   4) feed-back inhibition of allosteric enzyme by products of the reaction
4. Which of the following components are monomeric units of nucleic acids?
   1) amino acid
   2) monosaccharide
   3) nucleotide
   4) peptide
   5) dinucleotide
5. Uric acid is the end product of catabolism of:
   1) pyrimidine bases
   2) aromatic amino acids
   3) purine bases
   4) heme
   5) urea
6. Which of the following enzymes participate in microsomal oxidation?
   1) cytochrome oxidase
   2) NADPH-cytochrome P_{450}-reductase
   3) peroxidase
   4) cytochrome P_{450}
   5) cytochrome c

7. Catabolism is:
    1) the breakdown of molecules into smaller units
    2) hydrolysis of biopolymers
    3) the synthesis of more complex substances from simpler ones
    4) photosynthesis
8. Which of the following properties are characteristic of biological membranes?
    1) symmetry
    2) high electric resistance
    3) selective permeability
    4) amphoteric character
9. Which of the following are macroergic compound?
    1) glucose 6-phosphate
    2) ATP
    3) fatty acids
    4) creatine phosphate
    5) phosphoenolpyruvate
10. Which enzyme of the TCA cycle catalyzes reaction of substrate-level phosphorylation?
    1) citrate synthase
    2) isocitrate dehydrogenase
    3) succinate dehydrogenase
    4) succinyl-CoA synthetase

Criteria of Test Evaluation

«Excellent» («5») – 91% of correct answers to test questions.
«Good» («4») – 81-90% of correct answers to test questions.
«Satisfactory» («3») – 70-80% of correct answers to test questions.
«Failed» («2») – 69% and less of correct answers to test questions

Questions for Interlocution

1. Proteins
    1.1. Structure of proteins
        1.1.1. Structure and classification of amino acids.
        1.1.2. Peptide bond formation. Primary structure of proteins.
        1.1.3. Determination of primary structure of proteins.
        1.1.4. Levels of protein's structure (secondary structure, tertiary structure , quaternary structure of proteins).
        1.1.5. Color reactions of amino acids and proteins. Methods for the quantitative measurement of proteins in a solution.
    1.2. Physic-chemical properties of proteins
        1.2.1. Physicochemical properties of proteins. Shape of proteins. Molecular mass of proteins: methods for estimation.
        1.2.2. Precipitation reactions of proteins. Factors responsible for the stability of proteins in solution. Salting out.
        1.2.3. Denaturation of proteins.
        1.2.4. Proteins solutions: types, properties and peculiarities.
        1.2.5. The purification and analysis of proteins: salting, dialysis, ultracentrifugation, chromatography, electrophoresis.
        1.2.6.
    1.3. Nucleic acids. Template biosynthesis
        1.3.1. Structure and function of DNA and RNA
        1.3.2. DNA-replication, recombination and repair
        1.3.3. Transcription and translation
        1.3.4. Regulation of gene expression
        1.3.5. Recombinant DNA and biotechnology

1.4. The structure of complex proteins
   1.4.1. Simple proteins: histones, albumins, globulins, their functions and physicochemical characteristics.
   1.4.2. Conjugated (complex) proteins: nucleoproteins, chromoproteins, phosphoproteins, glycoproteins, metalloproteins, lipoproteins (brief characteristics).
   1.4.3. Hemoglobin, immunoglobulins, Ca^{2+}-binding proteins: peculiarities of structure and function.
   1.4.4. Collagen. Peculiarities of amino acid composition in collagen, structure, properties and types of collagens.

2. Enzymes
   2.1. The structure of enzymes Vitamins and cofactors.
      2.1.1. Structure of enzymes. An enzyme active site of the enzyme.
      2.1.2. Simple and complex enzymes. Cofactors of enzymes. Co-enzymatic functions of vitamins.
      2.1.3. Biological role, symptoms of deficiency, daily requirements, dietary sources of fat-soluble vitamins: A, D, E, and K
      2.1.4. Biological role, symptoms of deficiency, daily requirements, dietary sources of water-soluble vitamins: B-complex (thiamin, riboflavin, niacin, pyridoxine, folate, vitamin B12, biotin, pantothenic acid) and vitamin C.
      2.1.5. Specificity of enzyme action. Types of specificity.
      2.1.6. Enzyme nomenclature Classification of enzymes. Modern classification of enzymes and nomenclature of enzymes (systematic and working names). Enzyme code. General characteristic of classes.
   2.2. Mechanism of enzyme action
      2.2.1. Mechanism of enzyme catalysis. The mechanism of enzyme action.
      2.2.2. Factors affecting enzymatic reaction rate (temperature, pH, substrate concentration and enzyme concentration).
      2.2.3. Laboratory methods for measuring enzymatic activity. Units of enzyme activity.
      2.2.4. The kinetics of enzymatic reactions. Michaelis–Menten equation and the Lineweaver–Burk plot. The Michaelis-Menten constant.
      2.2.5. Isozymes (multiple forms of enzymes), examples, their biological role.
   2.3. Regulation of enzyme activity
      2.3.1. Kinds of inhibition (irreversible and reversible, competitive, non-competitive, uncompetitive), characteristic, examples. Activation of enzymes.
      2.3.2. General properties of enzyme regulation. The regulatory enzymes.
      2.3.3. Regulation of enzyme concentrations
      2.3.4. Allosteric enzymes and feedback inhibition
      2.3.5. Regulation of enzyme activity by covalent modification.
      2.3.6. Other effectors of catalytic activity (multienzyme complexes, compartmentation of processes).

3. Membranes. Hormones
   3.1. Membranes. Transport mechanisms.
      3.1.1. Concept of biological membranes
      3.1.2. Biological functions of cell membranes
      3.1.3. Common features of biological membranes
      3.1.4. Chemical composition of membrane. Structure of membrane lipids and proteins
      3.1.5. The fluid mosaic model of membrane
      3.1.6. Membrane transport: passive diffusion, facilitated diffusion, primary active and secondary active transport; endocytosis.
   3.2. General characteristics of hormones
      3.2.1. The role of endocrine system in metabolism.
      3.2.2. Concept hormone
      3.2.3. Structure of hormones
      3.2.4. Biological action of different hormones

3.2.5. Specific hormone receptors
3.2.6. Feed-back regulation of hormones secretion

3.3. The mechanism of hormones' action
3.3.1. Lipid-derived (lipid soluble) hormones' action
3.3.2. Second messenger systems
3.3.3. Adenylate cyclase messenger system
3.3.4. Triphosphoinositol and Ca^{2+} messenger system
3.3.5. Mechanism of insulin receptor action

4. Bioenergetics

4.1. Biological oxidation.
4.1.1. The general concept of biological oxidation
4.1.2. Enzymes of biological oxidation
4.1.3. Classification of oxidoreductases
4.1.4. Monooxygenase oxidation
4.1.5. Macroergic substances

4.2. Lipid peroxidation. Antioxidant systems
4.2.1. Reactive oxygen species or ROS
4.2.2. Generation of free radicals
4.2.3. Lipid peroxidation. The biological role of lipid peroxidation
4.2.4. Enzymatic antioxidants
4.2.5. Non-enzymatic antioxidants
4.2.6. Antioxidant system of erythrocytes

4.3. Electron transport chain
4.3.1. Respiratory chain.
4.3.2. The redox potentials of electron carriers.
4.3.3. Phosphorylation of ADP (Substrate and oxidative phosphorylation).
4.3.4. The mechanism of oxidative phosphorylation.
4.3.5. Odds-phosphorylation.
4.3.6. Breathing-control.

4.4. Metabolism and metabolic pathways
4.4.1. Basic principles of metabolism: catabolism, anabolism
4.4.2. Common pathways of catabolism
4.4.3. Pyruvate dehydrogenase reaction
4.4.4. Regulation of pyruvate dehydrogenase complex

4.5. The citric acid cycle
4.5.1. Reactions of the Krebs cycle or the tricarboxylic acid cycle (TCA)
4.5.2. Biochemical role of TCA
4.5.3. Regulation of the citric acid cycle

5. Carbohydrates

5.1. Digestion and absorption of carbohydrates
5.1.1. Dietary carbohydrates
5.1.2. Digestion of dietary carbohydrates
5.1.3. Dietary fiber
5.1.4. Absorption of sugars
5.1.5. Glucose transport through the blood-brain barrier and into neurons

5.2. Glucose metabolism
5.2.1. Glycolysis
5.2.2. Functions of glycolysis. Regulation of glycolysis
5.2.3. Lactic academia
5.2.4. The pentose phosphate pathway
5.2.5. Glucose metabolism in the liver
5.2.6. Gluconeogenesis
5.2.7. Changes in blood glucose levels after a meal

5.3. Glycogen metabolism

5.3.1. Structure of glycogen
5.3.2. Function of glycogen in skeletal muscle and liver
5.3.3. Synthesis and degradation of glycogen
5.3.4. Disorders of glycogen metabolism
5.3.5. Regulation of glycogen synthesis and degradation

6. Lipids
   6.1. Digestion and absorption of lipids
      6.1.1. Digestion of triacylglycerols
      6.1.2. Absorption of dietary lipids
      6.1.3. Synthesis of chylomicrons
      6.1.4. Transport of dietary lipids in the blood
      6.1.5. Fate of chylomicrons
   6.2. Metabolism of fatty acids and triacylglycerols
      6.2.1. Fatty acids as fuels. Fatty acid oxidation
      6.2.2. Metabolism of ketone bodies
      6.2.3. Fatty acid synthesis
      6.2.4. Synthesis of triacylglycerols and very low-density lipoprotein
      6.2.5. Release of fatty acids from adipose triacylglycerols
      6.2.6. Metabolism of glycerophosphoupids and sphingoupids
   6.3. Metabolism of cholesterol
      6.3.1. Intestinal absorption of cholesterol
      6.3.2. Cholesterol synthesis
      6.3.3. Several fates of cholesterol
      6.3.4. Synthesis of bile salts
      6.3.5. Transport of cholesterol by the blood
      6.3.6. Anatomic and biochemical aspects of atherosclerosis
7. Nitrogen compounds
   7.1. Metabolism of proteins. Nitrogen balance
      7.1.1. Protein digestion
      7.1.2. Absorption of amino acids
      7.1.3. Protein turnover and replenishment of the intracellular amino acid pool
      7.1.4. Types of nitrogen balance
   7.2. General pathways of amino acid metabolism
      7.2.1. Glucogenic and Ketogenic Amino Acids
      7.2.2. Deamination of amino acids. Types of deamination.
      7.2.3. Transamination of amino acids.
      7.2.4. Decarboxylation of amino acids. Types and biological role of decarboxylation.
   7.3. Particular conversion of amino acids
      7.3.1. The role of folic acid in amino acid metabolism
      7.3.2. Amino acids derived from intermediates of glycolysis
      7.3.3. Amino acids related to tca cycle intermediates
      7.3.4. Amino acids that form acetyl coa and acetoacetate
   7.4. Metabolism of nucleotides
      7.4.1. Purines and pyrimidines
      7.4.2. Purine biosynthesis
      7.4.3. Synthesis of the pyrimidine nucleotides
      7.4.4. The production of deoxyribonucleotides
      7.4.5. Degradation of purine and pyrimidine bases
   7.5. Metabolism of ammonia
      7.5.1. Sources of ammonia in human body
      7.5.2. The reasons for toxicity of ammonia. Ways of the detoxification of ammonia
      7.5.3. Urea cycle. The sequence of reactions. Hereditary disorders of the urea cycle.
8. Specialized tissues
   8.1. Biochemistry of the blood

8.1.1. Erythrocyte metabolism
8.1.2. Synthesis of heme. Regulation of heme synthesis
8.1.3. Hemoglobinopathies, hereditary persistence of fetal hemoglobin, and hemoglobin switching
8.1.4. Plasma proteins
8.1.5. Proper distribution of water between blood and tissues
8.1.6. The plasma contains proteins that aid in immune defense

8.2. Biochemistry of the liver
8.2.1. Major functions of the liver
8.2.2. Degradation of heme. Jaundice. Signs, symptoms and differential diagnosis
8.2.3. Diseases of the liver

8.3. Water, electrolytes and acid-base balance
8.3.1. Composition of body fluids
8.3.2. Movement of fluids between compartments
8.3.3. Water balance, regulation of water intake, regulation of water output
8.3.4. Influence of aldosterone, ADH, disorders of water balance
8.3.5. Electrolyte balance (role of sodium in fluid and electrolyte balance, regulation of sodium balance)
8.3.6. Regulation of potassium balance
8.3.7. Regulation of calcium balance
8.3.8. Acid-base balance (buffer systems: bicarbonate (blood ph), phosphate (urine ph), and protein buffers)

8.4. Metabolism of the nervous system, muscle and connective tissue
8.4.1. Neuronal signals to muscle
8.4.2. Glycolysis and fatty acid metabolism in muscle cells
8.4.3. Fuel use in cardiac and skeletal muscle
8.4.4. The blood-brain barrier
8.4.5. Synthesis of small nitrogen-containing neurotransmitters
8.4.6. Lipid synthesis in the brain and peripheral nervous system
8.4.7. Composition of the extracellular matrix
8.4.8. Adhesion proteins

Criteria for Interlocution

«Excellent» – the answer is comprehensive, meaningful, logically correct; structure, characteristics, functions and transformations of substances are described correctly, with free use of research terminology; answers to additional questions are short and precise.

«Good» – the answer partly lacks logical coherence with rare mistakes in details; characteristics, functions and transformations of substances are described but not in full; answers to additional questions are correct but not explicit enough.

«Satisfactory» – the answer is not full, lacks correctness in details; structure, characteristics, functions and transformations of substances are described unclearly and not exhaustively; answers to additional questions are not precise, there are mistakes in details.

«Failed» – the answer lacks coherence and meaning, with serious mistakes; structure, characteristics, functions and transformations of substances are described incorrectly; no knowledge of biochemistry terminology; answers to additional questions are wrong.

Questions for the colloquium

1.1 Topic «Biochemistry of proteins»

1. Functions of proteins with examples.
2. Structure and classification of amino acids. Peptide bond formation.
3. Physicochemical properties of proteins.
4. Precipitation reactions of proteins. Denaturation of proteins.
5. Colour reactions of amino acids and proteins. Methods for the quantitative measurement of

proteins in a solution.
6. Primary structure of proteins. Determination of primary structure of proteins.
7. Secondary structure of proteins. Types of secondary structure; bonds which stabilize secondary structure.
8. Tertiary structure of proteins. Three-dimensional structure of protein. Native structure of proteins. Protein folding.
9. Quaternary structure of proteins. Cooperative interactions of subunits in hemoglobin. Domaine structure of proteins.
10. Methods for separation and purification of proteins.
11. Simple and complex proteins; representatives, characteristics, biological functions.
12. Structure, bond of prosthetic group with an apoprotein, biological role of chromoproteins, nucleoproteins, lipoproteins, metalloproteins, glycoproteins, phosfoproteins.
13. DNA: composition, structure, cell localization, biological role. Denaturation of DNA.
14. RNA: types, composition, structures, cell localization, biological role.
15. Biosynthesis of DNA in eukaryotic cells: scheme, enzymes, regulation.
16. Biosynthesis of RNA in eukaryotic cells: stages, enzymes. Processing of RNA.
17. Biosynthesis of proteins. The genetic code: its characteristic features.
18. Regulation of protein synthesis. Operon concept. Antibiotics as inhibitors of protein synthesis.

1.2 Topic «Structure and properties of enzymes

1. Structure and properties of enzymes.
2. Mechanism of enzyme catalysis. Active and allosteric centers in enzymes. Specificity of enzymes.
3. Simple and complex enzymes. Cofactors of enzymes. Co-enzymatic functions of vitamins.
4. Classification and nomenclature of enzymes. Isoenzymes.
5. The kinetics of enzymatic reactions. Michaelis–Menten equation and the Lineweaver–Burk plot. The Michaelis-Menten constant
6. Factors affecting enzymatic reaction rate (temperature, pH, substrate concentration and enzyme concentration).
7. Methods for examination of enzyme activity. Units of enzyme activity.
8. Activation of enzyme activity.
9. Inhibition of enzyme activity. Application of inhibitors in medical practice (the inhibitors of enzymes as drugs).
10. Regulation of enzyme activity. Allosteric activators and inhibitors, covalent modification, selective proteolysis.
11. Tissue-specific enzymes. Intracellular localization of enzymes.
12. Origin of serum enzymes. Serum enzymes which used in clinical diagnostics. Enzymes in genetic diseases.
13. Use of enzymes as drugs.
14. Biological role, symptoms of deficiency, daily requirements, dietary sources of fat-soluble vitamins: A, D, E, and K
15. Biological role, symptoms of deficiency, daily requirements, dietary sources of water-soluble vitamins: B-complex (thiamin, riboflavin, niacin, pyridoxine, folate, vitamin B_{12}, biotin, pantothenic acid) and vitamin C.

1.3 Topic «Structure and functions of membrans and hormones»

1. Biological membranes, their types. Structural components of cellular membranes and their role in the organisation of structure and functional activity biomembranes.
2. Modern model of the structural organisation of cellular membranes. Properties of membranes (fluidity, asymmetry, selective permeability).
3. Membrane functions (transport, reception, control of selective transport of substances, participation in transfer of hormonal influence).
4. Transport function of membrane. Passive transport. Active transport.
5. Transmembrane transfer of macromolecules.

6. Free-radical reactions and peroxidation of membrane lipids. Active forms of oxygen.
7. Antioxidant systems of an organism. Protection of membranes from lipid peroxidation. The role of vitamins in this process.
8. Biological role of hormones in an organism. Principles of organization of hormonal regulation system (hierarchical principle, feedback principle).
9. Classification of hormones by the chemical nature and nature of the second intermediary.
10. Chemical structure and the mechanism of action of hormones penetrating into cell.
11. Common mechanisms of secondary messenger systems (cAMP system, phosphoinositol system). Role of Ca^{2+}-ions in secondary messenger systems.
12. Hormones of hypothalamus, their chemical nature, the mechanism of action and a role in activity of glands of internal secretion.
13. Hormones of pituitary gland, chemical nature, action mechanism, biological role.
14. Hormones thyroid and parathyroid glands, chemical nature, mechanism of their action, biological role.
15. Hormones of adrenal cortex and adrenal medulla, chemical structure, mechanism of their action, biological role.
16. Pancreas hormones, chemical nature, action mechanism, biological role.
17. Sexual hormones, chemical nature, action mechanism, biological role.

Topic «Bases of bioenergetics»

1. Metabolism and metabolic pathways. Major end products of metabolism in human organism. Nutrition and metabolism.
2. The common and specific pathways of catabolism. Interrelation between anabolism and catabolism.
3. The oxidative decarboxylation of pyruvate. Structure of pyruvate dehydrogenase complex, its regulation.
4. The tricarboxylic acid cycle (TCA cycle) or the Krebs cycle. The citric acid cycle is a central metabolic pathway which generates NADH and $FADH_2$ for use in electron transport chain.
5. Regulation and biological role of the citric acid cycle.
6. Bioenergetics of the cell. Free energy. Structure and biological role of high-energy compounds.
7. General characteristics of oxidation processes. Types of oxidation.
8. Structure and biological role of ATP, ways of ATP formation.
9. Electron transport chain (ETC), its structural organization and functioning. Regulation of ETC.
10. Structure and biological role of NAD (NADP)-dependent dehydrogenases.
11. Structure and biological role of FAD (FMN)-dependent dehydrogenases.
12. Structure and biological role of coenzyme Q and cytochromes.
13. Oxidative phosphorylation. The chemiosmotic theory of oxidative phosphorylation. The Phosphate/Oxygen Ratio (P/O).
14. Activators and inhibitors of the electron transport chain. Uncoupling agents.
15. Microsomal oxidation: scheme, biological role.

1.5 Topic «Metabolism of carbohydrates»

1. Structure and functions of carbohydrates.
2. Digestion and absorption of carbohydrates in gastrointestinal tract.
3. The general scheme of glucose metabolism. Biological role of glucose phosphorylation.
4. Reactions, enzymes and biological significance of aerobic glycolysis. Regulation of aerobic glycolysis.
5. Reactions, enzymes and biological significance of anaerobic glycolysis.
6. Reactions, enzymes, biological significance and regulation of gluconeogenesis.
7. Reactions, enzymes and biological significance of pentose phosphate pathway.
8. Structure and physiological role of glycogen.
9. Synthesis of glycogen. Regulation of glycogenesis.

10. Reactions, enzymes, biological significance and regulation of glycogenolysis.
11. Disorders of glycogen metabolism. Glycogenosises.
12. Regulation of glucose level in serum. Hyperglycemia and hypoglycemia, their causes.
13. Disorders of carbohydrate metabolism in diabetes mellitus. Glucose tolerance test.

1.6 Topic «Metabolism of lipids»

1. Classification of lipids. Lipids of human tissues. Biological functions of lipids.
2. The digestion and absorption of lipids in gastrointestinal tract.
3. Intracellular lipolysis (mobilization of fats).
4. Classification, representatives, biological functions of fatty acids in human tissues. Essential fatty acids.
5. Activation of fatty acids, transport of acyl-CoA into mitochondrion.
6. β-Oxidation of saturated fatty acids: reactions, energy result of β-oxidation, connection with citric acid cycle and electron transport chain. Oxidation of unsaturated fatty acids.
7. Reactions of synthesis and utilization of ketone bodies. Hyperketonemia in diabetes mellitus and carbohydrate starvation. Ketoacidosis
8. Biosynthesis of fatty acids: sources of acetyl-CoA and NADPH in the cytoplasm, synthesis of malonyl CoA, Structure of fatty acid synthase.
9. Metabolism of triacylglycerols. Biosynthesis and catabolism of triacylglycerols, regulation.
10. Biosynthesis of sphingolipids. Disorders of sphingolipid metabolism.
11. Biosynthesis of phospholipids: initial substrates, relations with biosynthesis of triacylglycerols.
12. Biosynthesis of cholesterol: main steps, reactions of mevalonate biosynthesis. Regulation of cholesterol synthesis.
13. Metabolism of cholesterol in the human body. Cholesterol as the precursor of other steroids.
14. Transport of lipids in the blood. Lipoproteins of blood serum: structure, composition, metabolism.
15. Hyperlipoproteinemia. Hypercholesterolemia and atherosclerosis. Biochemical principles of treatment

1.7. Topic « Metabolism of nitrogen compounds»

1. Metabolism of proteins. Nitrogen balance. Sources of amino acids in the human organism and ways of their use.
2. General pathways of amino acid metabolism.
3. Deamination of amino acids. Types of deamination.
4. Oxidative deamination. Biological role of glutamatedehydrogenase.
5. Transdeamination or indirect deamination; its biological role.
6. Transamination of amino acids, biological role. Coenzyme functions of vitamin B_6. Mechanism of transamination. Clinical significance of transaminases activity testing in the blood serum.
7. Decarboxylation of amino acids. Types and biological role of decarboxylation.
8. Biogenic amines: synthesis, functions, oxidation of biogenic amines.
9. Formation and neutralization of ammonia. Tissular detoxification of ammonia.
10. Biosynthesis of urea (urea cycle). Disorders of the urea synthesis. Normal urea level in the blood and urine.
11. Metabolism of methionine. Role of methionine in transmethylation reactions. Synthesis of creatine.
12. Metabolism of phenylalanine and tyrosine. Disorders of phenylalanine and tyrosine metabolism (phenylketonuria, alkaptonuria, albinism).
13. Biosynthesis of purine nucleotides: synthesis of phosphoribosylamine, origin of atoms in the purine ring. Inosinic acid as a precursor for synthesis of AMP and GMP. Regulation of purine synthesis.
14. Degradation of purine nucleotides. Hyperuricemy. Podagra.
15. Biosynthesis of pyrimidine nucleotides: synthesis of orotic acid. Synthesis of

deoxyribonucleotides.
16. Degradation of pyrimidine nucleotides.

1.8 Topic « Biochemistry of specialized tissues»

1. Water distribution in human organism. Volume and osmotic pressure of biological fluids. The water balance.
2. Mineral components of tissues: representatives, biological role. Trace elements.
3. Regulation of sodium and water balance. Role of aldosterone, renin-angiotensin system, antidiuretic hormone, atrial natriuretic peptides.
4. Regulation of acid-base balance and pH in biological fluids. Buffer systems of the body. Respiratory and renal mechanisms of pH regulation.
5. Blood, general characteristics and functions. Specific features of chemical composition, structure and metabolism of erythrocytes and leukocytes.
6. Hemoglobin, structure, its derivatives. Transport of oxygen and carbon dioxide. Heme synthesis.
7. Blood plasma and serum. Plasma proteins: albumin, globulins, transport proteins, inhibitors of proteolysis, immunoglobulins; their characteristics.
8. Role of the liver in carbohydrate, lipid, amino acid and protein metabolism. Synthesis of plasma proteins in the liver.
9. Neutralizing functions of the liver.
10. Degradation of heme. Bilirubin metabolism.
11. Disorders in bilirubin metabolism: jaundice, its types
12. Chemical composition of nervous tissue. Transport of substrates into the brain, role of the blood/brain barrier.
13. Biochemical mechanisms of formation and transmission of nervous impulses. Molecular mechanisms of synaptic transmission.
14. Structure and composition of muscle tissue. Muscle proteins, their functions.
15. Biochemical mechanisms of muscle contraction and relaxation. Role of ions in regulation of muscle contraction.
16. Muscle energy metabolism. Sources of ATP, role of creatine phosphate, creatine kinase. Biochemistry of muscle fatigue.
17. Chemical composition and structure of extracellular matrix (ground substance). Collagen, elastin; specific features of their structure and metabolism, role of ascorbic acid.
18. Proteoglycans and glycoproteins of connective tissue; features of their synthesis and degradation, biological role.

Criteria for Colloquium Assessment

«Excellent» – the answer is comprehensive, meaningful, logically correct; structure, characteristics, functions and transformations of substances are described correctly, with free use of research terminology; answers to additional questions are short and precise.

«Good» – the answer partly lacks logical coherence with rare mistakes in details; characteristics, functions and transformations of substances are described but not in full; answers to additional questions are correct but not explicit enough.

«Satisfactory» – the answer is not full, lacks correctness in details; structure, characteristics, functions and transformations of substances are described unclearly and not exhaustively; answers to additional questions are not precise, there are mistakes in details.

«Failed» – the answer lacks coherence and meaning, with serious mistakes; structure, characteristics, functions and transformations of substances are described incorrectly; no knowledge of biochemistry terminology; answers to additional questions are wrong.

Questions for Pre-exam Oral Examination

1. Functions of proteins with examples.
2. Physicochemical properties of proteins. Denaturation of proteins.
3. Primary structure of proteins. Determination of primary structure of proteins.

4. Secondary structure of proteins. Types of secondary structure; bonds which stabilize secondary structure.
5. Tertiary structure of proteins. Three-dimensional structure of protein. Native structure of proteins. Protein folding.
6. Quaternary structure of proteins. Cooperative interactions of subunits in hemoglobin. Domaine structure of proteins.
7. Structure, bond of prosthetic group with an apoprotein, biological role of chromoproteins, nucleoproteins, lipoproteins, metalloproteins, glycoproteins, phosfoproteins.
8. Structure and properties of enzymes.
9. Mechanism of enzyme catalysis. Active and allosteric centers in enzymes. Specificity of enzymes.
10. Simple and complex enzymes. Cofactors of enzymes. Co-enzymatic functions of vitamins.
11. Classification and nomenclature of enzymes. Isoenzymes.
12. The kinetics of enzymatic reactions. Michaelis–Menten equation and the Lineweaver–Burk plot. The Michaelis-Menten constant
13. Factors affecting enzymatic reaction rate (temperature, pH, substrate concentration and enzyme concentration).
14. Methods for examination of enzyme activity. Units of enzyme activity.
15. Inhibition of enzyme activity. Application of inhibitors in medical practice (the inhibitors of enzymes as drugs).
16. Regulation of enzyme activity. Allosteric activators and inhibitors, covalent modification, selective proteolysis.
17. Biological role, symptoms of deficiency, daily requirements, dietary sources of fat-soluble vitamins: A, D, E, and K
18. Biological role, symptoms of deficiency, daily requirements, dietary sources of water-soluble vitamins: B-complex (thiamin, riboflavin, niacin, pyridoxine, folate, vitamin B12, biotin, pantothenic acid) and vitamin C.
19. Biological membranes, their types. Structural components of cellular membranes and their role in the organisation of structure and functional activity biomembranes.
20. Modern model of the structural organisation of cellular membranes. Properties of membranes (fluidity, asymmetry, selective permeability).
21. Membrane functions (transport, reception, control of selective transport of substances, participation in transfer of hormonal influence).
22. Transport function of membrane. Passive transport. Active transport.
23. Biological role of hormones in an organism. Principles of organization of hormonal regulation system (hierarchical principle, feedback principle).
24. Classification of hormones by the chemical nature and nature of the second intermediary.
25. Chemical structure and the mechanism of action of steroid hormones.
26. Common mechanisms of secondary messenger systems (cAMP system, phosphoinositol system). Role of Ca^{2+}-ions in secondary messenger systems.
27. Hormones of hypothalamus, their chemical nature, the mechanism of action and a role in activity of glands of internal secretion.
28. Metabolism and metabolic pathways. Major end products of metabolism in human organism. Nutrition and metabolism.
29. The oxidative decarboxylation of pyruvate. Structure of pyruvate dehydrogenase complex, its regulation.
30. The tricarboxylic acid cycle (TCA cycle) or the Krebs cycle. Regulation and biological role of the citric acid cycle.
31. Bioenergetics of the cell. Free energy. Structure and biological role of high-energy compounds.
32. General characteristics of oxidation processes. Types of oxidation.
33. Structure and biological role of ATP, ways of ATP formation.
34. Electron transport chain (ETC), its structural organization and functioning. Regulation of ETC.
35. Oxidative phosphorylation. The chemiosmotic theory of oxidative phosphorylation. The Phosphate/Oxygen Ratio (P/O).

Criteria for Pre-exam Oral Examination

«Excellent» – the answer is comprehensive, meaningful, logically correct; structure, characteristics, functions and transformations of substances are described correctly, with free use of research terminology; answers to additional questions are short and precise.

«Good» – the answer partly lacks logical coherence with rare mistakes in details; characteristics, functions and transformations of substances are described but not in full; answers to additional questions are correct but not explicit enough.

«Satisfactory» – the answer is not full, lacks correctness in details; structure, characteristics, functions and transformations of substances are described unclearly and not exhaustively; answers to additional questions are not precise, there are mistakes in details.

«Failed» – the answer lacks coherence and meaning, with serious mistakes; structure, characteristics, functions and transformations of substances are described incorrectly; no knowledge of biochemistry terminology; answers to additional questions are wrong.

Examination questions

1. History of biochemistry. Major objectives, branches and research trends of biochemistry. Role of biochemistry in medical education.
2. Proteins as the major components of the cell. Functions of proteins.
3. Structure of amino acids. Classification. Peptide bond formation. Hydrolysis of proteins.
4. Physicochemical properties of proteins. Shape of proteins. Molecular mass of proteins: methods of its estimation.
5. Precipitation reactions of proteins. Factors of proteins' stability in solution. Salting out. Denaturation of proteins.
6. Colour reactions of amino acids and proteins. Methods for the quantitative measurement of proteins in a solution. Total serum protein.
7. Primary structure of proteins. Determination of primary structure of proteins.
8. Secondary structure of proteins: types, bonds which stabilize secondary structure.
9. Tertiary structure of proteins. Factors which stabilize tertiary structure. Three-dimensional structure of protein. Native structure of proteins. Protein folding.
10. Quaternary structure of proteins. Factors which stabilize quaternary structure. Cooperative interactions (in hemoglobin). Domaine structure of proteins.
11. Methods for separation and purification of proteins.
12. Simple proteins; representatives, characteristics, biological functions.
13. Complex proteins; representatives, characteristics, biological functions.
14. Structure, bond of prosthetic group with an apoprotein, biological role of chromoproteins, nucleoproteins, lipoproteins, metalloproteins, glycoproteins, phosfoproteins.
15. DNA: composition, structure, cell localization, biological role. Denaturation of DNA.
16. RNA: types, composition, structures, cell localization, biological role.
17. Biosynthesis of DNA in eukaryotic cells: scheme, enzymes, regulation.
18. Biosynthesis of RNA in eukaryotic cells: stages, enzymes. Processing of RNA.
19. Biosynthesis of proteins. The genetic code: its characteristic features.
20. Activation of amino acids. Adaptor function of tRNA. Formation and structure of tRNA. Role of ribosomes in protein synthesis.
21. Regulation of protein synthesis. Operon concept. Antibiotics as inhibitors of protein synthesis.
22. Structure and properties of enzymes.
23. Mechanism of enzyme catalysis. Active and allosteric centers in enzymes. Specificity of enzymes.
24. Simple and complex enzymes. Cofactors of enzymes. Co-enzymatic functions of vitamins.
25. Classification and nomenclature of enzymes. Isoenzymes.
26. The kinetics of enzymatic reactions. Michaelis–Menten equation and the Lineweaver–Burk plot. The Michaelis-Menten constant
27. Factors affecting enzymatic reaction rate (temperature, pH, substrate and enzyme concentration).

28. Methods for examination of enzyme activity. Units of enzyme activity.
29. Activation and inhibition of enzymes.
30. Inhibition of enzymes. Application of inhibitors in medical practice (the inhibitors of enzymes as drugs).
31. Regulation of enzyme activity. Allosteric activators and inhibitors, covalent modification, selective proteolysis.
32. Tissue-specific enzymes. Intracellular localization of enzymes.
33. Origin of serum enzymes. Serum enzymes which used in clinical diagnostics. Enzymes in genetic diseases.
34. Use of enzymes as drugs.
35. Biological role, symptoms of deficiency, daily requirements, dietary sources of fat-soluble vitamins: A, D, E, and K
36. Biological role, symptoms of deficiency, daily requirements, dietary sources of water-soluble vitamins: B-complex (thiamin, riboflavin, niacin, pyridoxine, folate, vitamin B_{12}, biotin, pantothenic acid) and vitamin C.
37. Biological membranes, their types. Structural components of cellular membranes and their role in the organisation of structure and functional activity biomembranes.
38. Modern model of the structural organisation of cellular membranes. Properties of membranes (fluidity, asymmetry, selective permeability).
39. Membrane functions (transport, reception, control of selective transport of substances, participation in transfer of hormonal influence).
40. Transport function of membrane. Passive transport. Active transport.
41. Transmembrane transfer of macromolecules.
42. Free-radical reactions and peroxidation of membrane lipids. Active forms of oxygen.
43. Antioxidant systems of an organism. Protection of membranes from lipid peroxidation. The role of vitamins in this process.
44. Biological role of hormones in an organism. Principles of organization of hormonal regulation system (hierarchical principle, feedback principle).
45. Classification of hormones by the chemical nature and nature of the second intermediary.
46. Chemical structure and the mechanism of action of hormones penetrating into cell.
47. Common mechanisms of secondary messenger systems (cAMP system, phosphoinositol system). Role of Ca^{2+}-ions in secondary messenger systems.
48. Hormones of hypothalamus, their chemical nature, the mechanism of action and a role in activity of glands of internal secretion.
49. Hormones of pituitary gland, chemical nature, action mechanism, biological role.
50. Hormones thyroid and parathyroid glands, chemical nature, mechanism of their action, biological role.
51. Hormones of adrenal cortex and adrenal medulla, chemical structure, mechanism of their action, biological role.
52. Pancreas hormones, chemical nature, action mechanism, biological role.
53. Sexual hormones, chemical nature, action mechanism, biological role.
54. Metabolism and metabolic pathways. Major end products of metabolism in human organism.
55. The common and specific pathways of catabolism. Interrelation between anabolism and catabolism. Nutrition and metabolism.
56. Regulation of metabolism.
57. Integration of metabolism. Interrelation of proteins', lipides' and carbohydrates' metabolism.
58. The oxidative decarboxylation of pyruvate. Structure of pyruvate dehydrogenase complex, its regulation.
59. The tricarboxylic acid cycle (TCA cycle), or the Krebs cycle. The citric acid cycle is a central metabolic pathway which generates NADH and $FADH_2$ for use in electron transport chain.
60. Regulation and biological role of the citric acid cycle.
61. Bioenergetics of the cell. Free energy. High-energy compounds: structure, biological role.
62. General characteristics of oxidation processes. Types of oxidation: enzymes, biological role.
63. ATP: structure, biological role; the ways of its formation and use.

64. Biological oxidation and tissue respiration.
65. Electron transport chain (ETC), its structural organization and functioning. Regulation of ETC.
66. NAD(NADP)-dependent dehydrogenases, structure, biological role.
67. FAD (FMN)-dependent dehydrogenases, structure, biological role.
68. Coenzyme Q, structure, biological role. Cytochromes, structure, biological role.
69. Oxidative phosphorylation. The chemiosmotic theory of oxidative phosphorylation. The The Phosphate/Oxygen Ratio (P/O).
70. Activators and inhibitors of the electron transport chain. Uncoupling agents.
71. Microsomal oxidation: scheme, biological role.
72. Structure and functions of carbohydrates.
73. Digestion and absorption of carbohydrates in the gastrointestinal tract.
74. The general scheme of glucose metabolism. Reaction of glucose phosphorylation, its biological role.
75. Anaerobic glycolysis: reactions, enzymes and biological significance.
76. Aerobic glycolysis: reactions, enzymes. Energy-producing reactions and biological role of aerobic glycolysis. Regulation of aerobic glycolysis.
77. Gluconeogenesis: scheme, metabolic precursors of glucose, biological role, regulation.
78. Pentose phosphate pathway: oxidative and non-oxidative reactions, scheme, biological role.
79. Structure and physiological role of glycogen.
80. Synthesis of glycogen. Regulation of glycogenesis.
81. Glycogen degradation, reactions, enzymes, biological significance, regulation.
82. Disorders of glycogen metabolism. Glycogenosises, its types
83. Regulation of glucose level in serum. Hyperglycemia and hypoglycemia, their causes.
84. Disorders of carbohydrate metabolism in diabetes mellitus. Glucose tolerance test.
85. Classification of lipids. Lipids of human tissues. Biological functions of lipids.
86. The digestion and absorption of lipids in the gastrointestinal tract.
87. Intracellular lipolysis (mobilization of fat).
88. Fatty acids of human tissues: classification, representatives, biological functions. Essential fatty acids.
89. Activation of fatty acids, transport of acyl-CoA into mitochondrion.
90. β-Oxidation of saturated fatty acids: reactions, energy result of β-oxidation, connection with citric acid cycle and electron transport chain. Oxidation of unsaturated fatty acids.
91. Reactions of synthesis and utilization of ketone bodies. Hyperketonemia in diabetes mellitus and carbohydrate starvation. Ketoacidosis
92. Biosynthesis of fatty acids: sources of acetyl-CoA and NADPH in the cytoplasm, synthesis of malonyl CoA, Structure of fatty acid synthase.
93. Metabolism of triacylglycerols. Biosynthesis and catabolism of triacylglycerols, regulation.
94. Biosynthesis of sphingolipids. Disorders of sphingolipid metabolism.
95. Biosynthesis of phospholipids: initial substrates, scheme, relations with biosynthesis of triacylglycerols.
96. Biosynthesis of cholesterol: main steps, reactions of mevalonate biosynthesis. Regulation of cholesterol synthesis.
97. Metabolism of cholesterol in the human body. Cholesterol as the precursor of other steroids.
98. Transport of lipids in the blood. Lipoproteins of blood serum: structure, composition, metabolism.
99. Hyperlipoproteinemia. Hypercholesterolemia and atherosclerosis. Biochemical principles of treatment
100. Metabolism of proteins. Nitrogen balance. Sources of amino acids in the human organism and ways of their use.
101. General pathways of amino acid metabolism.
102. Deamination of amino acids. Types of deamination.
103. Oxidative deamination. Biological role of glutamatedehydrogenase.
104. Transdeamination or indirect deamination; its biological role.

105. Transamination of amino acids, biological role. Coenzyme functions of vitamin B_6. Mechanism of transamination. Clinical significance of transaminases activity testing in the blood serum.
106. Decarboxylation of amino acids. Types of decarboxylation, biological role.
107. Biogenic amines: synthesis, functions, oxidation of biogenic amines.
108. Formation and neutralization of ammonia. Tissular detoxification of ammonia.
109. Biosynthesis of urea (urea cycle). Disorders of the urea synthesis. Normal urea level in the blood and urine.
110. Metabolism of methionine. Role of methionine in transmethylation reactions. Synthesis of creatine.
111. Metabolism of phenylalanine and tyrosine. Disorders of phenylalanine and tyrosine metabolism (phenylketonuria, alkaptonuria, albinism).
112. Biosynthesis of purine nucleotides: synthesis of phosphoribosylamine, origin of atoms in the purine ring. Inosinic acid as a precursor for synthesis of AMP and GMP. Regulation of purine synthesis.
113. Degradation of purine nucleotides. Hyperuricemy. Podagra.
114. Biosynthesis of pyrimidine nucleotides: synthesis of orotic acid. Synthesis of deoxyribonucleotides.
115. Degradation of pyrimidine nucleotides.
116. Water distribution in human organism. Volume and osmotic pressure of biological fluids. The water balance.
117. Mineral components of tissues: representatives, biological role. Trace elements.
118. Sodium, potassium; their biological role, metabolism, regulation of balance.
119. Calcium, phosphate; their biological role, metabolism, regulation of balance.
120. Regulation of sodium and water balance. Role of aldosterone, renin-angiotensin system, antidiuretic hormone, atrial natriuretic peptides.
121. Regulation of acid-base balance and pH in biological fluids. Buffer systems of the body. Respiratory and renal mechanisms of pH regulation.
122. Kidney, biochemical functions, metabolism of the kidney. Role of kidney in regulation of pH balance.
123. General characteristics and composition of urine. Pathologic components of urine. Role of urine analysis in diagnostics.
124. Blood, general characteristics and functions. Specific features of chemical composition, structure and metabolism of erythrocytes and leukocytes.
125. Hemoglobin, structure, its derivatives. Transport of oxygen and carbon dioxide. Heme synthesis.
126. Blood plasma and serum. Plasma proteins: albumin, globulins, transport proteins, inhibitors of proteolysis, immunoglobulins; their characteristics.
127. Blood serum enzymes, its diagnostic importance. Acute phase proteins.
128. Role of the liver in carbohydrate, lipid, amino acid and protein metabolism. Synthesis of plasma proteins in the liver.
129. Neutralizing functions of the liver.
130. Degradation of heme. Bilirubin metabolism.
131. Disorders in bilirubin metabolism: jaundice, its types
132. Chemical composition of nervous tissue. Transport of substrates into the brain, role of the blood/brain barrier.
133. Specifics of carbohydrate, lipid and amino acid metabolism in nervous tissue. Energy metabolism in the brain.
134. Biochemical mechanisms of formation and transmission of nervous impulses. Molecular mechanisms of synaptic transmission.
135. Neurotransmitters: acetylcholine, catecholamines, serotonin, GABA (γ-aminobutyric acid). Synthesis and metabolism of neurotransmitters in nervous tissue, functions.
136. Structure and composition of muscle tissue. Muscle proteins, their functions.
137. Biochemical mechanisms of muscle contraction and relaxation. Role of ions in regulation of

muscle contraction.

138. Muscle energy metabolism. Sources of ATP, role of creatine phosphate, creatine kinase. Biochemistry of muscle fatigue.
139. Chemical composition and structure of extracellular matrix (ground substance). Collagen, elastin; specific features of their structure and metabolism, role of ascorbic acid.
140. Proteoglycans and glycoproteins of connective tissue; features of their synthesis and degradation, biological role.

Criteria for Oral Examination

«Excellent» – the answer is comprehensive, meaningful, logically correct; structure, characteristics, functions and transformations of substances are described correctly, with free use of research terminology; answers to additional questions are short and precise.

«Good» – the answer partly lacks logical coherence with rare mistakes in details; characteristics, functions and transformations of substances are described but not in full; answers to additional questions are correct but not explicit enough.

«Satisfactory» – the answer is not full, lacks correctness in details; structure, characteristics, functions and transformations of substances are described unclearly and not exhaustively; answers to additional questions are not precise, there are mistakes in details.

«Failed» – the answer lacks coherence and meaning, with serious mistakes; structure, characteristics, functions and transformations of substances are described incorrectly; no knowledge of biochemistry terminology; answers to additional questions are wrong.

Examples of Case Problem

Case Problem 1

Sickle-cell anemia is the hereditary blood disorder, characterized by red blood cells that assume an abnormal, rigid, sickle shape. This sickling occurs because of a mutation in the hemoglobin gene. Sickle-cell anemia is caused by a point mutation in the β-globin chain of hemoglobin, causing the amino acid Glutamic acid to be replaced with the amino acid Valine at the sixth position. Explain the changing of erythrocyte shape in sickle-cell anemia.

Case Problem 2

Why an overdose of barbiturates (sodium amytal) significantly reduced the rate of the reactions of the Krebs cycle?

Criteria for Case Problem SolutionAssessment

«Excellent» – the answer is comprehensive, meaningful, logically correct; structure, characteristics, functions and transformations of substances are described correctly, with free use of research terminology; answers to additional questions are short and precise.

«Good» – the answer partly lacks logical coherence with rare mistakes in details; characteristics, functions and transformations of substances are described but not in full; answers to additional questions are correct but not explicit enough.

«Satisfactory» – the answer is not full, lacks correctness in details; structure, characteristics, functions and transformations of substances are described unclearly and not exhaustively; answers to additional questions are not precise, there are mistakes in details.

«Failed» – the answer lacks coherence and meaning, with serious mistakes; structure, characteristics, functions and transformations of substances are described incorrectly; no knowledge of biochemistry terminology; answers to additional questions are wrong.

7. METHODOLOGICAL AND INFORMATION COURSEWARE BIOCHEMISTRY

a) main references:

1. The Medical Biochemistry Page 1996-2017 https://themedicalbiochemistrypage.org/home.html
2. Biochemistry of Metabolism by Joyce Diwan http://www.rpi.edu/dept/bcbp/molbiochem/MBWeb/mb1/MB1index.html

b) additional references:

1. Fundamentals of bioorganic chemistry [Electron resource] / Zurabyan S.E. - M. : GEOTAR-MEDIA, 2012. http://www.studmedlib.ru/ru/book/ISBN9785970421406.html
2. Problem sets and Tutorial on biochemistry by The University of Arizona http://www.biology.arizona.edu/biochemistry/biochemistry.html

c) software and the Internet resources:

1. Scientific electronic library eLibrary.ru - http://elibrary.ru/
2. Electronic library system "Consultant of a student" - http://www.studmedlib.ru
3. Department's of Human Physiology Website http://dep_fizch.pnzgu.ru
4. Electronic educational environment http://moodle.pnzgu.ru
5. Kaspersky Anti-Virus 2015-2016, registration number KL4863RAUFQ, valid from 2015 to 2016.
6. "Kaspersky Anti-Virus" 2016-2017, registration number KL4863RAUFQ, the agreement № ХП-567116 of August 29, 2016
7. Kaspersky Anti-Virus for the years 2017-2018. Contract No. 030-17-223 of November 22, 2017
8. "Microsoft Windows" (subscription DreamSpark / Microsoft Imagine Standard); registration number 00037FFEBACF8FD7. Contract No. SD-130712001 of July 12, 2013 (subscription from September 1, 2013 to August 31, 2017),
9. Renewal of Microsoft Imagine Standard KDF-00031 (subscription from September 1, 2017 to August 31, 2020).
10. "Microsoft" (subscription Eopen); license № 63167487, license № 61853322: license № 63167487, license № 61853322 unlimited.
11. Free software: Open Office; Adobe Acrobat Reader

8. MATERIAL AND TECHNICAL SUPPORT OF THE DISCIPLINE

№	Special rooms and rooms for independent work	Equipment of special rooms and rooms for independent work
1.	Room 10-301, 10-th building of Penza State University, 28 м^2	A set of educational furniture: tables, chairs, whiteboard. Pull out drobe A set of tests on sections of discipline and the discipline as a whole. Demonstration tables. Colorimeter, centrifuge, technical scales, torsion balance Equipment (chemical tripods, burettes) Glassware (flasks, glasses, test tubes, pipettes, funnels, mortars with pestles, cylinders, burettes, Petri dishes, vials)
2.	Room 10-302, 10-th building of Penza State University, 26 м^2	A set of educational furniture: tables, chairs, whiteboard. Pull out drobe A set of tests on sections of discipline and the discipline as a whole. Demonstration tables. Colorimeter, centrifuge, technical scales, torsion balance Equipment (chemical tripods, burettes) Glassware (flasks, glasses, test tubes, pipettes, funnels, mortars with pestles, cylinders, burettes, Petri dishes, vials)
3.	Room for independent preparation of students, 10-204	Set of school furniture: tables, chairs, educational board.

The program of the discipline BIOCHEMISTRY is prepared in accordance with the requirements of Federal State Educational Standard of higher education in this area 31.05.01 General Medicine

The developer of the program:
Schetinina Natalia Viktorovna, associate professor of the Department of Human physiology, candidate of biological sciences _____

The Program is approved by the Department of Human physiology

No. protocol 12 «4» 03 2016

Department chair _____ N. I. Mikulyak

The program is coordinated with the an of the Faculty of General Medicine I.YA. Moiseeva

Dean of the Faculty of General Medicine _____ I.Y. Moiseeva

Program is approved by the methodical commission of the Medical institute.

No. protocol 7 «5» 03 2016

Chairman of the methodical commission of the Medical institute

_____ O.V. Kalmin

Verification, correction: Department of Foreign Languages
Ass. Professor _____ E.V. Shepelera

Сведения о переутверждении программы на очередной учебный год и регистрации изменений

Учебный год	Решение кафедры (№ протокола, дата, подпись зав. кафедрой)	Внесенные изменения	Номера листов (страниц)		
			заменен-ных	новых	аннулиро-ванных
2016/2017	Протокол №1 от 2.09.2016 г. Зав. каф.	Рабочая программа переутверждена без изменений			
2016/2017	Протокол № 13 от 17.05.2017 г. Зав. каф.	На основании приказа Министерства образования и науки РФ № 320 от 10.05.2017 квалификация «Врач общей практики» заменяется на «Врач-лечебник»	1		
2017/2018	Протокол №1 от 4.09.2017 г. Зав. каф.	Добавлено в п.5 описание применения образовательных технологий к обучающимся с ограниченными возможностями здоровья и инвалидам	13		
2017/2018	Протокол №1 от 4.09.2017 г. Зав. каф.	Рабочая программа переутверждена с изменениями			
2018/2019	Протокол №13 5.06.2018 Зав. каф.	Рабочая программа переутверждена без изменений			
2019/2020	Протокол №11 17.06.2019 Зав. каф.	Рабочая программа переутверждена без изменений			