FACULTY OF MEDICINE
STUDY PROGRAM 0912.1 MEDICINE
CHAIR OF BIOCHEMISTRY AND CLINICAL BIOCHEMISTRY

APPROVED
at the meeting of the Commission for Quality Assurance and Evaluation of the Curriculum Faculty of Medicine
Minutes No. 4 of 19.05.22
Chairman dr. hab., associated professor
Suman Sergiu _____

APPROVED
at the Council meeting of the Faculty of Medicne
Minutes No. 5 of 23.05.22
Dean of Faculty PhD, associated professor
Beţiu Mircea _____

APPROVED
approved at the meeting of the chair of Biochemistry and Clinical Biochemistry
Minutes No. 20 of 5.05.2022
Head of chair, PhD, associated professor
Stratulat Silvia _____

SYLLABUS
DISCIPLINE BIOCHEMISTRY

Integrated studies

Type of course: **Compulsory**

Curriculum authors:
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I. INTRODUCTION

General presentation of the discipline: place and role of the discipline in the formation of the specific competences of the professional / speciality training program

The aim of the Structural Biochemistry course is to provide students with theoretical background knowledge and general practical skills in medical biochemistry that are indispensable to the clinical work of all health professionals. Students will study biochemical bases of the existence and functioning of the human body, as well as biochemical features of organs under physiological conditions and in pathologies.

The activities during the study of the discipline will create the students' individual and team working skills, the ability to set and solve a task, to use certain laboratory equipments, to analyze and interpret the results of laboratory investigations, to apply theoretical knowledge in medical practice, integration of information from different disciplines (fundamental and clinical), etc..

Mission of the curriculum (aim) in professional training consists of studying:

1. the structure of the main chemical compounds of the living matter and the fundamental metabolic processes that underlie the functionality of the living organisms;
2. the particularities of the chemical compounds and of the metabolic processes that ensure the functioning of the organs and mechanisms underlying the disturbances of their functions;
3. biochemical investigation methods of clinical utility and training of laboratory data analisis and interpretation abilities.

Language(s) of the course: Romanian, English and Russian

Beneficiaries: students of the 1st year, Faculty of Medicine 2.

II. MANAGEMENT OF THE DISCIPLINE

Code of discipline		**F.03.O.020/F.04.0.028**	
Name of the discipline		**Biochemistry**	
Person(s) in charge of the discipline		**Olga Tagadiuc**	
Year	**I**	Semesters	**I-II**
Total number of hours, including:			**270**
Lectures	**60**	Practical/laboratory hours	**50**
Seminars	**40**	Self-training	**120**
Form of assessment	**E/E**	Number of credits	**5/4**

III. TRAINING AIMS WITHIN THE DISCIPLINE

At the end of the discipline study the student will be able to:

a) at the level of knowledge and understanding:

- know the structure and physico-chemical properties of the main chemical compounds of medical interest;
- know the fundamental metabolic processes that ensure the viability and reproduction of the human body;
- be familiar with the structural and metabolic features of the organs;
- know the influence of various factors (vitamins, pharmaceuticals, toxins) and metabolic disorders on biochemical processes;
- know the normal values and physiological variations of the main biochemical markers.

b) at the application level:

- to determine by itself some biochemical markers of general clinical-diagnostic utility;
- to effectuate by itself the collection of saliva and tear samples for biochemical investigation;
- to be able to work on the main devices used in the biochemical laboratory (simple and automatic pipettes, spectrophotometer, centrifuge, etc.);
- appreciate the usefulness of certain biochemical investigations in the diagnosis of specific pathologic conditions;
- to correctly interpret the results of biochemical investigations.

c) at the integration level:

- to appreciate the importance of Biochemistry in the context of Medicine;
- to know the correlations between Biochemistry and other fundamental and clinical disciplines;
- to objectify the connections and interdependence between structural, metabolic and clinical biochemistry;
- to appreciate the evolution of physiological metabolic processes and their disorders that condition various diseases.

IV. PROVISIONAL TERMS AND CONDITIONS

Biochemistry is a biomedical discipline, the study of which at the integrated studies stage will allow future medical professionals to:

- know the molecular bases of physiological metabolic processes, biochemical mechanisms for regulating vital functions;
- understand the causes and pathogenesis of hereditary and acquired diseases that cause damage to different organs;
- justify the need for biochemical investigation;
- evaluate the results of the laboratory examination and correlate them with clinical and functional data for diagnosis purposes;
- develop the lifecycle correction scheme;
- determine the principles of treatment of the disease, depending on its mechanisms of development.

To study the discipline students need thorough knowledge in the field of Chemistry and Biology, obtained in the pre-university studies, as well as in the field of Human Anatomy obtained in the

undergraduate studies.

Computer and Internet usage skills are also needed to identify the materials required for study and individual work, document processing, tables and presentations.

V. THEMES AND ESTIMATE ALLOCATION OF HOURS

Lectures, practical hours/ laboratory hours/seminars and self-training

No. d/o	THEME	Number of hours		
		Lectures	Practical hours	Self-training
1.	The importance of biochemistry for medical disciplines. Functional groups and types of chemical bonds specific to biomolecules. Amino acids - biomedical role, structure, classification and properties.	3	3	5
2.	Role, structure and classification of proteins.	2	3	5
3.	Physico-chemical properties of proteins. Methods of protein separation, purification and quantity assay.	2	3	5
4.	Nucleoproteins. Nucleic acids – classification, structure and functions. Nitrogen bases, nucleosides and nucleotides - structure, nomenclature and properties.	3	3	5
5.	**Concluding test on chapter „Structure of proteins and nucleic acids”**		3	5
6.	Chemical nature and structure of the enzymes. Vitamins as coenzymes. Mechanism of enzymes action. Nomenclature and classification of enzymes	3	3	5
7.	Kinetics of chemical reactions. Regulation of enzyme activity. Enzymes utilisation in medical practice.	2	3	5
8.	General concepts about metabolism. Oxidative decarboxylation of pyruvic acid. Krebs cycle.	3	3	5
9.	Biological oxidation. Respiratory chain and oxidative phosphorylation.	2	3	5
10.	**Concluding test on chapters „Enzymes” and "Bioenergetics"**		3	5
11.	Carbohydrates – biological role, classification and structure. Digestion and absorption of carbohydrates. Metabolism of glycogen.	3	3	5
12.	Metabolism of glucose.	6	3	5
13.	Pentose phosphate pathway. Fructose and galactose metabolism. Regulation and acquired disorders of carbohydrate metabolism.	3	3	5
14.	**Concluding test on chapter „Carbohydrates metabolism”**		3	5
15.	**Individual work evaluation**		3	5
16.	Lipids: structure, properties, biological role and classification. Lipid digestion	2	3	3

No. d/o	THEME	Number of hours		
		Lectures	Practical hours	Self-training
	and absorption. Disorders of digestion and absorption of lipids. Metabolism of triglycerides.			
17.	Metabolism of fatty acids and ketone bodies.	3	3	3
18.	Metabolism of structural lipids.	3	3	3
19.	**Concluding test on chapter "Metabolism of lipids"**		3	3
20.	Digestion and absorption of proteins. Putrefaction of amino acids in the intestine. General ways of amino acid metabolism.	3	3	3
21.	Biosynthesis of nonessential amino acids. The fate of carbon skeletons of amino acids. The final products of nitrate metabolism. Ammonia detoxification.	3	3	3
22.	Intermediary metabolism of some amino acids.	3	3	3
23.	Metabolism of nucleoproteins and chromoproteins.	2	3	3
24.	**Concluding test on chapter "Metabolism of simple and conjugated proteins"**		3	3
25.	DNA biosynthesis - replication. DNA repair and mutations. Biochemical mechanisms of gene expression – transcription.	2	3	3
26.	Biochemical bases of translation.	3	3	3
27.	Hormones. Structure, classification, biosynthesis, regulation of synthesis, mechanism of action.	3	3	3
28.	Steroid and thyroid hormones. Vitamins A and D. Eicosanoids	3	3	3
29.	**Concluding test on chapter „Genetic and hormonal regulation of metabolism”**		3	3
30.	**Individual work evaluation**		3	3
		60	90	120
Total		270		

VI. PRACTICAL SKILLS ACQUIRED AT THE END OF THE COURSE

1. Assessment of the biological value of proteins depending on their composition.
2. Correctly interpret the clinical diagnostic value of aminotransferase assessment.
3. Correctly interpret the clinical diagnostic value of isoenzymes determination (LDH, Creatine phosphokinase).
4. Substantiate the usefulness of determining blood glucose, free and glycated hemoglobin, ketone bodies, plasma albumins, urea, creatinine, uric acid, total/conjugated/non-conjugated

bilirubin, total cholesterol, triglycerides, LDL cholesterol and HDL cholesterol.

5. Assess the diagnostic value of determining the level of cortisol, aldosterone, T3, T4 and TSH
6. To appreciate the biochemical role of water- and fat-soluble vitamins.

VII. REFERENCE OBJECTIVES OF CONTENT UNITS

Chapter 1. „Structure of proteins and nucleic acids"

Objectives	Content units
1. Define the concepts of bioelement and biomolecule and identify the connections between them, their content in the body, the physico-chemical properties and their role in the organism 2. Know the functional groups as reactive zones of the biomolecule. 3. Know the nature of chemical bonds and their role in the stability of biomolecules 4. Know the structure, role and properties of amino acids. 5. Define the notions of proteinogenic and non-proteinogenic amino acids, stereoisomerism, and solubility. 6. Select amino acids according to all classification principles.	1. Introduction to biochemistry. Structural, metabolic and clinical biochemistry. The importance of biochemistry for medical education and practice. 2. Biomolecules - macro and micromolecules, complex molecules. 3. Functional group notions. Types of functional groups specific to biomolecules. Their overall feature. 4. Types of chemical bonds specific to biomolecules. Their overall features. 5. Amino acids - the role in living organisms. Proteinogenic and non-proteinogenic amino acids. 6. Classification of amino acids according to chemical structure, physico-chemical properties, biological importance. 7. Stereoisomerism, solubility and acid-base properties of amino acids. 8. Polypeptide theory of protein structure. The properties of the peptide bond. Notation and reading of amino acids in peptides and proteins. N- and C-terminal amino acids.
	1. The biological role of proteins. 2. Structural levels of the protein molecule: primary, secondary, tertiary and quaternary structures; their general characteristic, the chemical bonds specific to each structure. Methods for determining the composition and sequences of amino acids in the polypeptide chain. Structural domains concept. 3. Classification of proteins. 4. Simple proteins (albumins, histones) - properties and structural peculiarities. The biological role. 5. Conjugated proteins: nucleoproteins, phosphoproteins, lipoproteins, glycoproteins, metalloproteins, chromoproteins (hemo- and flavoproteins), their general characteristic. 6. Globular proteins. Hemoglobin - structure and biological role. 7. Fibrillar proteins: collagen and elastin - the peculiarities of the amino acid composition and structure. The biological role. 8. Ca^{2+} binding proteins (plasma clotting factors, Ca^{2+}-ATPase, calmodulin, collagen) - structural features that determine Ca^{2+} binding. Their biomedical role.

7. Can give examples of chemical reactions involving amino acids. 8. To justify the need to know the properties of amino acids 9. Explain the importance of proteins for living organisms, especially for human beings. 10. Define the notion of protein. 11. Know the levels of proteins structural organization and their main properties. 12. Identify the specific proteins of organs and their structural and functional particularities 13. Apply methods for protein separation and purification. 14. Explain the clinical-diagnostic value of the proteins. 15. Know the structures of DNA and RNA. 16. Identify the impact of the DNA and RNA structure disorders on the genesis of hereditary diseases.	1. Molecular weight of proteins. Basic methods used for molecular weight determination (ultracentrifugation, chromatography, mass spectrometry - their principle. 2. Amphoteric properties of proteins. Electrical charge of proteins. Factors that determine the protein charge. Isoelectric point and state. 3. Solubility of proteins. Hydrophilic properties of proteins based on amino acid composition, structural features, pH and temperature of the medium. Properties of protein solutions as colloidal one. Aggregation states of protein solutions (soil, gel, xerogel). The biomedical utilization of xerogels. 4. Protein denaturation, factors that cause denaturation. Structural modifications of the protein due to denaturation. The biomedical importance of denaturation. 5. Methods of separation, purification and analysis of proteins: a) salting; b) dialysis; c) electrophoresis; d) chromatography (principle of methods, biomedical importance).
	1. Nucleoproteins – structure, role. 2. Types of nucleic acids, their functions and their distribution in the cell. 3. Nucleic acids constituents: nitrogen bases, pentoses, phosphoric acid. 4. Nucleosides and nucleotides: structure, role, nomenclature. 5. Primary structure of nuclei acids (DNA and RNA) - polynucleotide chains. The phosphodiester bond. 6. Secondary DNA structure. The Watson - Crick model of the DNA double helix and its B, A, and Z conformations. Compaction levels of the prokaryote and eukaryotic DNA molecules (nucleosome, solenoid, chromatin, chromosomes). 7. Compaction levels of ribonucleic acids (RNA).
Chapter 2. Enzymes and energy metabolism	
Objectives	**Content units**
	1. Notion of enzymes and their biological role. Similarities and differences between enzymes and non-biological catalysts.

1. Know the structure of enzymes and their mechanism of action. 2. Specify the properties of the enzymes resulting from their protein nature. 3. Identify the importance of vitamins as coenzymes. 4. Apply methods for the separation and purification of proteins and the evaluation of enzyme activity. 5. Identify the type of enzyme specificity and its biomedical role. 6. Be able to represent the graphs of enzyme´s activity dependence on various environmental factors. 7. Identify types of inhibition and represent them graphically. 8. Be able to explain the mechanisms of regulation of enzyme activity. 9. Define the notion of isoenzymes and their biomedical role. 10. Be able to identify the enzymatic profile in the blood in various organ disorders. 11. Explain the clinical-diagnostic value of	2. The chemical nature of enzymes. Evidence of the protein nature of enzymes. Notion of ribozyme. 3. Structure of enzymes. Active and allosteric centers of enzymes. Simple and conjugated enzymes. The notion of holoenzyme, apoenzyme, cofactor, coenzyme, co-substrate and prosthetic group. 4. Coenzyme functions of vitamins and microelements. Structure of vitamins B1, B2, B6, PP, K, pantothenic acid, biotin, folic acid, and their role as coenzymes. 5. Mechanism of action of enzymes. The enzyme's active center and its role in the formation and transformation of intermediate complexes between enzyme and substrate. The role of reciprocal conformational changes of the enzyme and substrate molecules in the catalysis process. 6. Nomenclature and enzyme classification (IUBMB). The general characteristic of the main classes and subclasses of enzymes. Enzyme code number. 7. Specificity of enzymes (types, examples). 1. Enzyme kinetics. Influence of enzyme and substrate concentration, pH and temperature on enzyme activity. Michaelis-Menten equation and Km meaning 2. Activation and inhibition of enzymes: – activation of enzymes by partial proteolysis. Zymogens (proenzymes). – Inhibition of enzyme activity (specific and non-specific, reversible and irreversible, competitive and non-competitive). 3. Regulation of enzyme activity (allosteric regulation, covalent regulation). The importance of the retro inhibition principle. 4. Isoenzymes - the structural and functional particularities, their biomedical value. 5. Organization of enzymes in the cell (enzymatic assemblies, compartmentalization). 6. The differences in the enzymatic composition of organs and tissues. Organ specific enzymes. 7. Use of enzymes in medical practice: – Enzyme diagnostic. – Enzyme therapy. – The use of enzymes in the clinical laboratory. 8. Methods of enzymes separation and purification. Affinity chromatography.

enzymes in general and of individual enzymes used in medical practice. 12. Define the notions of metabolism, anabolism, catabolism and amphibolic phase of metabolism. Identify the connections between them. 13. Apply the laws and main principles of thermodynamics to living organisms. 14. Know the biological importance of the main energy processes in the human body. 15. Know the main bio-energetic processes in human cells - pyruvate oxidative decarboxylation, Krebs cycle, electron transport chain and oxidative phosphorylation 16. Know the regulatory enzymes of each metabolic pathway, levels and types of their regulation. 17. Explain the mechanism of oxidation and phosphorylation coupling. 18. Be able to calculate the energy yield of	9. Principle of enzyme activity assay. Units of enzymes activity (international unit, katal, specific activity). 1. Notion of metabolism. Anabolism and catabolism. Metabolic pathways. The amphibolic stage of metabolism, its role. 2. Methods of metabolism study. 3. The laws of thermodynamics. Enthalpy, entropy and free energy. Standard free energy, its significance. Endergonic and exergonic reactions. 4. High-energy compounds: role, main representatives, structural particularities. Super high-energy compounds. 5. Chemical structure and role of ATP. The ATP cycle. Variants of ATP hydrolysis. ATP synthesis mechanisms. 6. Energy regulation of cellular metabolism. Energy state of the cell indices. 7. Oxidative decarboxylation of pyruvate: polyenzyme complex, coenzymes, overall reaction, steps, process regulation, Krebs cycle and respiratory chain. The role of biomedical. 8. Tricarboxylic acid cycle (Krebs): functions, reactions, enzymes, overall reaction, connection with the electron transport chain, energy output, regulation. Anaplerotic reactions (their significance). 1. Relation between free energy and oxidation-reduction potential. 2. Biological oxidation. Dehydrogenation of substrates - the main energy source for ATP synthesis. Reactions, enzymes and coenzymes of dehydrogenation. 3. Electron transport chain - location, biological significance. a) Structure and oxidoreduction properties of major proton and electron acceptors (NAD+, FAD, FMN, CoQ). Notions about the structure of cytochromes and Fe-S proteins. b) Oxidation-Reduction Potential of Respiratory Chain Components. Relation between free energy and oxidation-reduction potential. c) Scheme of the electron transport chain. Enzymatic complexes. Electron transport chain inhibitors. 4. Oxidative phosphorylation. Phosphorylation points. Regulation of the intensity of the electron transport chain function. P/O coefficient. 5. Mechanism of oxidation with phosphorylation coupling (Mitchell hypothesis). ATP synthase. ATP-synthase inhibitors. Role of internal mitochondrial membrane in ATP biosynthesis. Transport of adenyl

pyruvate oxidative decarboxylation and Krebs cycle. 19. Explain the mechanism of electron transport chain inhibition and uncoupling of oxidative phosphorylation. 20. Define microsomal oxidation and free radicals oxidation. 21. To be able to assess the impact of microsomal oxidation disturbances and excessive formation of reactive oxygen species. 22. To be able to explain the biological role of antioxidant systems. 23. To present the connections between the main energy processes in the cell, as well as their impact on cell viability and homeostasis.	nucleotides and phosphate through the mitochondrial internal membrane. 6. Uncoupling of oxidation and phosphorylation processes. Uncoupling compounds, their mechanism of action. Examples of physiological and pathological uncoupling. 7. Microsomal oxidation. The role of cytochrome P450 in oxido-reduction reactions. 8. Oxidative stress. The oxygen reactive species: synthesis, physiologic and pathologic effects. Enzymatic and non-enzymatic antioxidant systems

Chapter 3. Carbohydrates metabolism

Objectives	Content units
1. Define carbohydrates and appreciate their biomedical role. 2. Know the classification of carbohydrates.	1. The biological role of carbohydrates. 2. Classification and structure of carbohydrates: - monosaccharides (glyceraldehyde, dihydroxyacetone, ribose, deoxyribose, glucose, galactose, fructose). - disaccharides (maltose, lactose, sucrose) - homopolysaccharides (glycogen, starch, cellulose) - heteropolysaccharides (hyaluronic acid, heparin)

3. Understand the differences between different types of monosaccharides 4. Understand which structural particularities underlie the polymerization of carbohydrates 5. Know the link between structure, properties and the role of oligo- and polysaccharides 6. Identify the stages of carbohydrates digestion, absorption and associated disorders. 7. To know the ways of carbohydrate metabolism under different physio-logic and pathological conditions and the mechanisms involved. 8. Understand the connections between the carbohydrate and energy metabolism processes and the reciprocal regulatory influences. 9. Be able to calculate the energy output of anaerobic and aerobic oxidation of individual carbohydrates (glucose, galactose, fructose, sucrose, lactose).	3. Biochemical mechanisms of digestion and absorption of carbohydrates. Disaccharides intolerance. 4. Transport of blood glucose into tissues - glucose transporters (GLUT). Use of carbohydrates in tissues. 5. Metabolism of glycogen: glycogenogenesis and glycogenolysis. Reactions, enzymes, mutual regulation of processes. 6. Glycogenoses (von Gierke's disease, Pompe syndrome). 1. Glycolysis: biological role, reactions, enzymes, summary raction. 2. Aerobic glucose oxidation 3. Glycerol-phosphate and malate-aspartate shuttle systems of reducing equivalents transport from cytosol into mitochondria. Their importance. 4. Energy output of aerobic and anaerobic glucose oxidation. 5. Particularities of glucose oxidation in erythrocytes. 2,3-bisphospho-glyceride pathway (Rapoport-Luebering). 6. Gluconeogenesis - substrates, reactions, enzymes, overall reaction. Cori and glucose-alanine cycles. 7. Mutual regulation of glycolysis and gluconeogenesis. 8. Hormonal regulation of glucose metabolism: the influence of insulin, glucagon, catecholamines and glucocorticoids. 9. Regulation of carbohydrate metabolism in postprandial and in incipient stages. 1. Pentose phosphate glucose oxidation pathway. Biological role of the process, reactions of the oxidative step, enzymes, coenzymes. The overall reactions of stages I and II and of the whole process. 2. Fructose metabolism - hepatic and muscular pathways: reactions, enzymes, biological role. Hereditary disorders of fructose metabolism. 3. Metabolism of galactose - reactions, enzymes, biological role. Hereditary disorders of galactose metabolism. 4. Metabolism of lactose - reactions, enzymes and biological importance of the process. 5. Synthesis of glucuronic acid. Biological importance of the process. 6. Disorders of carbohydrate metabolism in diabetes mellitus, steroid-induced diabetes and chronic alcohol consumption. 7. The diagnostic significance of glucose metabolism assessment - glycaemia, glucose tolerance test, insulin, C-peptide and glycated hemoglobin.

10. To know the regulating enzymes of glycogenolysis, glycogenogenesis, glycolysis, gluconeogenesis and glucose oxidation pentose phosphate pathways, their levels and types of regulation. 11. Can appreciate glucose metabolism disorders based on main biochemical investigations (physiological and pathological hypo- and hyperglycemia). 12. Demonstrate the pathogenic mechanisms responsible for the development of diabetes mellitus.	

Chapter 4. Metabolism of lipids

Objectives	Content units
1. Define lipids and their biomedical role. 2. Identify the stages of lipid digestion, absorption, resynthesis and transport, and associated disorders. 3. Know the metabolic pathways of lipids in different tissues and the mechanisms involved.	1. Biological role of lipids. The importance of lipids in food. Unsaturated fatty acids (vit. F) 2. Classification of lipids (structural, functional, according to physico-chemical properties). 3. Structure and physico-chemical properties of lipids: – saturated and unsaturated fatty acids – acylglycerols – mono-, di- and triacylglicerides – glycerophospholipids - phosphatidylserine, phosphatidyl-ethanolamine, phosphatidylcholine, phosphatidylinositols – sphingophospholipids – sphingomyelin – glycolipids – galacto- and glucocerebroside, sulfatides, gangliosides. 4. Food lipid digestion and absorption:

4. Understand the connections between the processes of lipid, carbohydrate and energy metabolism and the reciprocal regulatory influences. 5. Demonstrate the ways of mutual transformations glucose ↔ lipids. 6. Be able to appreciate lipid metabolism disorders based on main biochemistry investigations (hypo- and hyperlipidemia, hypercholesterolemia, lipidemia). 7. Demonstrate the pathogenic mechanisms of tissue and organs disorders in lipid pathology (obesity, atherosclerosis).	– structure and role of bile acids. Cleavage of triglycerides, phospholipids, cholesterides: enzymes, hydrolysis products. – absorption of food lipids hydrolysis products. – regulation of lipid digestion (action of colecistokinin, secretin). – disorders of digestion and absorption of lipids. Pancreatic, hepatic and intestinal steatorrhea . 5. Resynthesis of lipids in enterocytes. Chylomicron formation, role and metabolism 6. Triglycerides metabolism. Triglycerides biosynthesis and catabolism: localization, reactions, enzymes and coenzymes, hormonal regulation (action of catecholamines, glucagon, insulin, glucocorticoids). 7. Glycerol metabolism – sources and ways of use. Glycerol oxidation: reactions, enzymes, energy output.
	1. Fatty acid biosynthesis - location, steps, reactions, enzymes, coenzymes, regulation: – saturated with even number of carbon atoms; – unsaturated with even number of carbon atoms; – arachidonic acid biosynthesis (general notions). 2. Beta-oxidation of fatty acids - reactions, enzymes, energy output: – saturated by even number of carbon atoms (location, stages, reactions, enzymes, coenzymes, energy output, regulation); – unsaturated and with odd number of carbon atoms (peculiarities); – in peroxisomes (peculiarities), the biological role. 3. Ketone bodies: – representatives, chemical structure, biological role; – biosynthesis - site, substrate, reactions; – use - tissues, reactions, end products, energy output; – ketonemia and ketonuria - causes, mechanism of occurrence. 4. Neuro-hormonal regulation of lipid metabolism. Action of catecholamines, glucagon, insulin, glucocorticoids, thyroid hormones.
	1. Structure, properties and biomedical role of cholesterol, glycerophospholipids, sphingomyelin and glycolipids. 2. Cholesterol biosynthesis - steps, first step reactions (up to mevalonic acid), enzymes, coenzymes, regulation. Catabolism and excretion of cholesterol (general notions). 3. Biosynthesis of glycerophospholipids: localization, reactions, enzymes and coenzymes. Lipotrope substances, their role.

	4. Biosynthesis of sphingophospholipids and glycolipids: precursors, main reactions, enzymes. 5. Tissue catabolism of glycerophospholipids, sphingomyelins and glycolipids (site, enzymes, hydrolysis products). 6. Notions about ketogenic diet and ethanol metabolic pathway 7. Hereditary tissue lipidoses (Neimann-Pick, Tay-Sachs) - causes, biochemical changes, clinical manifestations. 8. Blood transport of lipids. Plasma lipoproteins: structure, separation methods, types (chylomicrons, VLDL, LDL and HDL), chemical composition (lipids and apoproteins), metabolism, functions. 9. Normal plasma lipid values. The diagnostic significance of plasma triglycerides, total cholesterol, HDL- and LDL-cholesterol assay. 10. Relationship between energy, glucose and lipid metabolism.
Chapter 5. Metabolism of simple and conjugated proteins	
Objectives	**Content units**
1. Identify the stages of protein digestion and absorption in GIT. 2. Define the types of nitrogen balance and describe the people for whom it is specific. 3. Be aware of the biomedical importance of the transamination process and enzymes. 4. Describe the main processes that generate ammonia and its toxicity mechanisms. 5. To know the ways of temporary and final detoxification of ammonia, elimination of the detoxification products and the diseases associated	1. Daily requirements of dietary proteins. Biological value of food proteins. The dynamic state of protein metabolism. The nitrogen balance. Protein deficiency. Parenteral protein nutrition. 2. Digestion and absorption of proteins: a. digestion of proteins in the stomach. Gastric proteolytic enzymes - representatives, activation and their specificity of action. The role of hydrochloric acid. HCl secretion and its regulation (H+, K+-ATP-ase). The composition of gastric juice and its changes in pathology. Gastric secretion inhibitors. b. Digestion of proteins in the intestine. Pancreatic and intestinal proteolytic enzymes – representatives, activation and their specificity of action. Regulation of proteins digestion in the intestine. c. absorption of amino acids in the intestine. Active secondary and facilitated transport of amino acids. 3. Putrefaction of the amino acids into the large intestine. The putrefaction products. Mechanisms of detoxification of toxic products in the liver (microsomal oxidation, conjugation). Conjugation agents, enzymes. 4. The fate of the absorbed amino acids. Common metabolic pool of amino acids. Transport of amino acids into cells. The gamma-glutamyl cycle.

with the disturbances of these processes. 6. Explain the clinical importance of urea assay in urine and blood. 7. Know the pathways of each amino acid use, the sources and mechanisms of synthesis of the non-essential ones and the ways of their metabolism. 8. Differentiate the main types of jaundice (prehepatic, hepatic and posthepatic) by the level of bile pigments 9. Know the pathway of hemoglobin biosynthesis and differentiate the main types of porphyrias 10. Differentiate the main types of anemias by laboratory markers	5. Transamination of amino acids: mechanism, enzymes, coenzymes, process significance. Diagnostic value of blood transaminase activity (ALT and AST). 6. Amino acid deamination. Types. a. Direct deamination of amino acids. Oxidative deamination of glutamic acid (reaction, enzyme, coenzymes, process importance). b. Indirect amino acid deamination. Stages. Enzymes, coenzymes. The biological role 1. Metabolism of alpha-ketoacids obtained by deamination of amino acids. Ketogenic and glucogenic amino acids. 2. Biosynthesis of non-essential amino acids (transreamination, biosynthesis from essential amino acids). 3. Biochemical mechanisms of ammonia toxicity. Ammonia detoxification: carbamoyl phosphate synthesis, reductive amination of alpha-ketoglutarate. 4. Synthesis and role of glutamine. Kidney glutaminase. Formation of ammonium salts. 5. Biosynthesis of urea. Reactions, enzymes, overall reaction. Enzymatic deficiencies of the urea synthesis cycle. 6. Hyperammonemia and uremia (causes, clinical manifestations, treatment principles). 1. Decarboxylation of amino acids (reactions, enzymes, coenzymes). Biosynthesis of histamine, serotonin, dopamine, gamma-aminobutyric acid, their biological role. Neutralization of biogenic amines. 2. Tetrahydrofolic acid. Structure and metabolic role. Its role in the synthesis of serine, methionine, glycine, purine and pyrimidine nucleotides. Megaloblastic anemia. 3. Metabolism of methionine and cysteine. Synthesis and use of S-adenosylmethionine. Synthesis and role of creatine-phosphate. Hyperhomocysteinemia. 4. Metabolism of glycine, serine and threonine (biosynthesis, metabolic role, catabolism). Hyperoxaluria. 5. Role of arginine. NO synthesis: reaction, enzymes, biological role. 6. Metabolism of phenylalanine and tyrosine. The role of these amino acids in the synthesis of other biologic important compounds. Hereditary pathology of phenylalanine and tyrosine metabolism (phenylketonuria, alcaptonuria, albinism).

7. Metabolism of tryptophan. His role in the synthesis of biologically active substances (serotonin, melatonin).
8. Metabolism of dicarboxylic amino acids – Asp, Asn, Glu, Gln. Synthesis, metabolic role, catabolism.
9. Metabolism of branched amino acids – valine, leucine and isoleucine (general notions).
10. Disorders of protein metabolism: hereditary amino acids disorders.
11. Relationships of protein, carbohydrate and lipid metabolisms. The role of liver in metabolism integration.

1. Digestion and absorption of nucleic acids.
2. Nucleotide biosynthesis and reutilization:
    a. Purine nucleotide biosynthesis: purine ring atoms sources, phosphoribosylamine synthesis reactions, IMP structure, AMP and GMP synthesis reactions, synthesis of nucleoside diphosphates and triphosphates. Regulation of the process.
    b. Pyrimidine nucleotide biosynthesis: sources of atoms in the pyrimidine ring, UTP and CTP biosynthesis. Biosynthesis of deoxyribonucleotides. Biosynthesis of thymidine nucleotides. Regulation
    c. Reutilization of purines and pyrimidines.
3. Nucleotide catabolism:
    a. catabolism of purine nucleotides (uric acid synthesis). Gout - causes, clinical manifestations, treatment principles.
    b. The final products of pyrimidine nucleotide catabolism, their fate.
4. Structural analogs of purines and pyrimidines as antiviral and antitumoral medicines.
5. Structure and biological role of chromoproteins
6. Digestion and absorption of chromoproteins. Iron metabolism.
7. Hemoglobin metabolism:
    a. Hemoglobin biosynthesis: site, substrates, first two reactions, process regulation. Porphyria (general notions).
    b. Catabolism of hemoglobin. Bilirubin: formation, conjugation, biliary excretion, metabolism in the intestine, urine excretion.
    c. Hyperbilirubinemia. The main types of jaundice (prehepatic, hepatic and posthepatic). The importance of blood, urinary and faecal pigments assay in the diagnosis and differentiation of the jaundices.

Chapter 6. Genetic and hormonal regulation

Objectives	Content units
1. Know the pathways of the metabolic use of nucleotides in general, their sources and mechanisms of synthesis and metabolism. 2. Present the molecular biochemical mechanisms and identify the similarities and differences of the replication, transcription and translation processes. 3. Explain the clinical importance of uric acid assay in urine and blood. 4. Be able to differentiate the types of hyperuricemia according to laboratory results. 5. Identify the major pathogenic mechanisms of gout. 6. Prescribe pathogenetic treatment in gout. 7. Define the notion of hormones and know their general properties. 8. Know the biomedical importance of hormonal regulation.	1. Replication of DNA in prokaryotes - matrix, substrates, enzymes and proteic factors. Biochemical mechanism and stages of DNA biosynthesis. Replication inhibitors - mechanism of action and biomedical role (acyclovir, foscarnet, doxorubicin). 2. Peculiarities of eukaryotic replication. Telomeres and telomerase. Telomerase structure. The biomedical role of telomerase. 3. Biochemical mechanisms of DNA repair. Enzymes involved. 4. The biochemical mechanisms of the single nucleotide mutations. The biomedical role of mutations. Disease caused by mutations (sickle cell anemia, phenyl ketonuria). 5. The peculiarities of the gene structure in prokaryotes and eukaryotes. Structural and regulatory genes. 6. Prokaryote transcription: matrix, substrates, enzymes, biochemical mechanism. Transcription inhibitors (rifampicin, nalidixic acid, α-amanitin). 7. Peculiarities of transcription in eukaryotes. Post-transcriptional modifications of mRNA. 8. Biochemical mechanisms that regulate gene expression in prokaryotes and eukaryotes. 9. Reverse transcription. Biochemical mechanism and biomedical role.
	1. The composition and structure of ribosome in pro- and eukaryotes. 2. Biochemical bases of the genetic code. Its properties. 3. Protein biosynthesis in prokaryotes. Steps: a) activation of amino acids; b) translation - initiation; elongation; termination. 4. Particularities of protein biosynthesis in eukaryotes - translational factors and post-translational modifications of synthesized proteins. Folding of synthesized proteins. 5. Regulation of protein biosynthesis in prokaryotes and eukaryotes. Translation inhibitors (tetracycline, chloramphenicol, erythromycin, streptomycin, diphtheria toxin). The medical role. 6. Polymorphism of proteins (hemoglobin variants, blood groups). 7. Biochemical bases of hereditary diseases. Biochemical diagnostic approaches.
	1. Hormones (notions). General properties and role of hormones in the body.

9. Describe the main mechanisms of action of hormones. 10. Identify the particular steps of different structure hormones mechanisms of action . 11. Know the individual hormones, their role, mechanism of action and the effects on the main metabolic processes. 12. Be able to distinguish the main disorders of hormonal secretion. 13. Present the biochemical mechanisms responsible for the effects of various secretion abnormalities for each individual hormone. 14. Can appreciate hormonal disturbances based on biochemistry investigations.	2. Hormone classification. 3. Mechanisms of hormones synthesis, secretion and action regulation a) the concept of feed-back regulation systems b) hormonal biorhythms. 4. Mechanisms of action of protein hormones and catecholamines: a) structure of membrane receptors b) interactions between hormone and receptor. c) structure, classification and role of G proteins d) effector enzymes and their activation mechanisms (Adenylate/Guanylate cyclase, Phospholipase C); e) the mechanisms for generating second messengers: cyclic AMP, cyclic GMP, calcium ions, diacylglycerols, inositol triphosphates; f) the activation mechanisms of protein kinases A, B, C; g) key metabolism enzymes regulated by phosphorylation/dephosphorylation. 5. Effects of hormones: a) hypothalamus and pituitary gland; b) catecholamines; c) insulin and glucagon; d) parathormone and calcitonin. 6. Growth factors (EGF, FGF, IGF, TGF, PGF, PDGF) and cytokines (chemokines, interferons, interleukins). General notions of structure, synthesis, mechanism of action and effects
	1. Cytosolic-nuclear mechanism of action of steroid and thyroid hormones (T3 and T4): a) structure of cytosolic and nuclear receptors; b) interactions between hormones and receptors; c) regulation of gene expression by the hormone-receptor complex 2. The effects of hormones: a) glucocorticoids; b) mineralocorticoids c) sexual hormones d) thyroid (T3 and T4) hormones 3. Vitamins A and D: a) structure, properties b) metabolic role

	c) hypo- and hypervitaminoses (causes, metabolic and clinical manifestations). 4. Eicosanoids (HETE, leukotrienes, prostanoids). Classification, general notions of structure, synthesis, mechanism of action, effects.

VII. PROFESSIONAL (specific (Sc)) and TRANSVERSAL (Tc) COMPETENCES AND STUDY OUTCOMES

Professional (specific) (Sc) competences

Sc1. Knowledge, understanding and use of language specific to medical biochemistry.
Sc2. General knowledge of key vital chemical compounds for the human body. Explaining the outcome of major metabolic processes that ensure the viability of the body and the mechanisms of the most important disease-specific disorders. Advanced knowledge of the peculiarities of chemical composition and organ metabolism under physiological conditions and in most important diseases.
Sc5. Knowledge of the principles of biochemical laboratory methods, the diagnostic value of the main laboratory indices and the ability to interpret the results of basic laboratory investigations. Ability to work at the main laboratory equipment (spectrophotometer, centrifuge, pipette).

Transversal competences (tc)

Tc1. Communication skills, written and oral, in the field of medicine and biochemistry.

Tc2. Individual and team work skills.

Tc3. The ability to apply effectively information technology to medical activity as well as to identify sources of information and continuous education in the field of activity.

Tc4. Understanding and the ability to apply the principles and values of general and professional ethics in action.

Study outcomes

Upon completion of the course, the student will:

1. know the structure and physico-chemical properties of the main chemical compounds of medical interest (proteins, carbohydrates, lipids, nucleic acids and vitamins);
2. know the fundamental metabolic processes that ensure the viability and reproduction of the human body,
3. know the structural and metabolic peculiarities of different organs;
4. know the normal values and the physiological changes of the main biochemical markers;
5. assess the usefulness of certain biochemical investigations in the diagnosis of specific diseases and interpret correctly the results of biochemical investigations.
6. be able to determine independently some biochemical markers of general clinical and diagnostic utility;
7. solve individual case studies in medical biochemistry.

VIII. STUDENT'S SELF-TRAINING

No.	Expected product	Implementation strategies	Assessment criteria	Implementation terms
1.	Work with information sources	Selection of basic information and details regarding the study questions of the practical lesson by reading the lecture, the material in the textbook and additional information sources on the topic. Full reading of text and systematization of essential content. Wording of generalizations and conclusions regarding the importance of the theme/subject.	Level of information assimilation and volume of work	During the semester
2.	Study cases solved	Self-solving of individual work items and study cases in accordance with the Practical Guide, with subsequent verification by the teacher in non-auditory hours.	Mark	At the end of each chapter
3.	Self-assessment tests solved	Self-solving of the self-assessment tests in accordance with the Practical Guide, with subsequent verification by the teacher in non-auditory hours.	Mark	At the end of each chapter
	Project developed (individual; group)	Elaboration of a project on a topic from the discipline. The project topic is assigned to the students in the first 2 weeks of the semester. The project is presented in the last seminar of the semester.	Mark	Upon completion of each semester
4.	Work with on-line materials	Studying the teaching materials on the Chair site and completing information on the studied subject	Level of information assimilation and volume of work	During the semester

IX. METHODOLOGICAL SUGGESTIONS FOR TEACHING-LEARNING-ASSESSMENT

Teaching and learning methods used

Biochemistry is taught in accordance with the classical academic standard: courses, laboratory lessons and seminars.

The course holders hold the course.

Laboratory lesson is carried out in order to study the principles and methods for qualitative and quantitative biochemical analysis of the main laboratory markers; the work ends by completing the protocol and analyzing the results obtained.

Theoretical subjects according to practical guide are discussed, study cases and tests are solved. Interactive teaching and learning methods such as observation, analysis, comparison, classification / model / figure development, modeling, deduction and experiment are applied.

Applied teaching strategies / technologies

Teaching classical didactic strategies (inductive, deductive, analogous, algorithmic and heuristic) are applied in Biochemistry discipline teaching, which are achieved with the help of several teaching-learning methods (active-participative, individual study, verification and evaluation) such as explanation and didactic conversation, work with the text-book, theoretical problem and laboratory work, case study, test solving, etc. For the implementation of the strategies and methods, a set of technical means of training are used both in the courses and seminars, as well as in the laboratory lessons.

Methods of assessment

Current: Various current assessment methods are used for each laboratory lessons and seminars: control papers, problem solving and testing, practical problem solving, etc.

There are 6 concluding tests during one year of Biochemistry study (3 per each semester).

Concluding test I: "Enzymes"

Concluding test II: "Enzymes and energy metabolism" and

Concluding test III: "Carbohydrates metabolism"

Concluding test IV: "Lipids metabolism"

Concluding test V: "Metabolism of simple and complex proteins".

Concluding test VI: "Genetic and hormonal regulation"

The 4th mark in both semesters will be awarded for individual work and involvement in the discussion during the practical hours

Final*:* The final mark for the semester will consist of the average grade from 3 concluding tests and the grade for the individual work (0.5 share) and the final test (E) in the computerized system (0.5 share).

The average annual mark and the mark of final examination (computer assisted) - are expressed in numbers according to the mark scale (according to the table), and the final mark obtained is expressed in number with two decimals, which is transferred to student's record-book.

Marks at different assessment stages

Intermediate marks scale (annual average, marks from the exam)	National Assessment System	ECTS Equivalent
1,00-3,00	**2**	**F**
3,01-4,99	**4**	**FX**
5,00	**5**	**E**
5,01-5,50	**5,5**	
5,51-6,0	**6**	
6,01-6,50	**6,5**	**D**
6,51-7,00	**7**	
7,01-7,50	**7,5**	**C**
7,51-8,00	**8**	
8,01-8,50	**8,5**	**B**
8,51-8,00	**9**	
9,01-9,50	**9,5**	**A**
9,51-10,0	**10**	

NOTE. *Absence on examination without good reason is recorded as "absent" and is equivalent to 0 (zero). The student has the right to have two re-examinations of the failed exam.*

X. RECOMMENDED literature:

A. Compulsory:

1. Rodwell V.W., Bender D.A., Botham K.M. et al. HARPER´s illustrated biochemistry. 31st edition. Mc Graw Hill Education. 2018.
2. Champe P. C., Harvey R. A. Biochemistry. Lippincott's Illustrated Reviews. 7th edition, 2017.
3. Gavriliuc Ludmila. Biochemistry. Lectures for students of Medical Departments. 2009.

B. Additional

1. Bhagavan N. V., Ha Chung-Eun. Essentials of Medical Biochemistry With Clinical Cases. 2nd Edition. Academic Press. 2015
2. Nelson D. L., Cox M.M. Lehninger Principles of Biochemistry. 8th ed., 2021