Danylo Halytsky Lviv National Medical University

Department of Pharmaceutical, Organic and Bioorganic chemistry

SYLLABUS FOR
"BIOORGANIC CHEMISTRY"

Second (master's) educational level
Field: 22 " Healthcare "
Specialty 221 " Dentistry "

1. General information	
Faculty	Dentistry
Pprogram	22 Healthcare, 221 Dentistry the second (master's) level, full-time
Academic year	2023/2024
Subject	Bioorganic Chemistry, OK 9, Kaf_pharmchemistry@meduniv.lviv.ua
Department	Department Pharmaceutical, Organic and Bioorganic chemistry Pekarska 69, Lviv, Tel. +38(032)275-59-66, 275-59-77, 278-64-34 Kaf_pharmchemistry@meduniv.lviv.ua
Head of Department	Lesyk Roman, Doctor of Science, Professor roman.lesyk@gmail.com
Year of study	First
Semester	First
Type of course / module	Compulsory
Professors	Nataliya Zelisko, PhD, Associate Professor, NataljaZelisko@gmail.com Danylo Kaminskyy, PhD, Associate Professor, dankaminskyy@gmail.com Ivanna Subtelna , PhD, Associate Professor, subtelna@gmail.com
Erasmus yes/no	No
The person responsible for the syllabus	Nataliya Zelisko, PhD, Associate Professor, NataljaZelisko@gmail.com
Number of credits ECTS	3
Number of hours	90 (Lectures – 10 hours, Practical classes – 30 hours, Out of class work – 50 hours)
Language of study	English
Information about consultations	On schedule
Address, telephone and regulations of the clinical base, office ... (if necessary)	-

2. Short annotation to the course

The discipline "Bioorganic Chemistry" studies the structure and reactivity of different classes of organic substances, and on their basis the most important biologically active substances that are part of living organisms - low molecular weight biomolecules, biopolymers (proteins, nucleic acids, polysaccharides), natural and synthetic compounds (hormones, vitamins, drugs, toxic substances, etc.)

The tasks of bioorganic chemistry are to determine the structure of biomolecules, natural and synthetic bioregulators, to identify the relationship between their molecular, electronic structure and physiological, including pharmacological, effects, to identify patterns of their transformations.

3. The purpose and objectives of the course

1. **The purpose of the course "Bioorganic Chemistry" is:**

mastering by students of theoretical laws concerning chemical properties of bioorganic compounds in interrelation with their structure and on this basis understanding of biochemical processes which take place in biological systems;

acquaintance with the main methods of identification of bioorganic compounds as the main prerequisite for further mastering of laboratory methods of diagnosis and understanding of many pathological processes in the human body;

disclosure of practical aspects of bioorganic chemistry, ways and methods of using its achievements in medical practice**.**

2. **The objectives of the course "Bioorganic Chemistry" are:**

to teach students the general principles of chemical reactions of bioorganic compounds as the basis of biochemical processes in the human body; formation of the relationship between the structure and function of bioorganic compounds;

to reveal practical aspects of bioorganic chemistry, ways and methods of using its achievements in medical

practice.

ЗК – General competencies, ФК – Special responsibility, ПРН – Program learning outcomes

3. Competences and learning outcomes, the formation of which provides the study of the discipline.

General competencies:

ЗК 1. Ability to abstract thinking, analysis and synthesis.
ЗК 2. Knowledge and understanding of the subject area and understanding of professional activity.
ЗК 3. Ability to apply knowledge in practice.
ЗК.7. Ability to search, process and analyze information from various sources
ЗК 8. Ability to adapt and act in a new situation.
ЗК 9. Ability to identify, pose and solve problems.
ЗК 10. The ability to be critical and self-critical.
ЗК 11. Ability to work in a team.
ЗК 12. The desire to preserve the environment.
ЗК 13. The ability to act socially responsibly and consciously.
ЗК.15. Ability to preserve and increase moral, cultural, scientific values and achievements of society based on understanding the history and patterns of development of the subject area, its place in the general system of knowledge about nature and society and in the development of society, techniques and technologies. active recreation and healthy living.

Special (professional, subject) competencies.

ФК 2. Ability to interpret the results of laboratory and instrumental research.
ФК 13. Ability to assess the impact of the environment on the health of the population (individual, family, population).

Program learning outcomes:

ПРН 2. Collect information about the general condition of the patient, assess the psychomotor and physical development of the patient, the condition of the maxillofacial area, based on the results of laboratory and instrumental studies to assess information about the diagnosis.
ПРН 3. Prescribe and analyze additional (mandatory and optional) methods of examination (laboratory, radiological, functional and / or instrumental) of patients with diseases of organs and tissues of the oral cavity and maxillofacial region for differential diagnosis of diseases.
ПРН 17. Adhere to a healthy lifestyle, use the techniques of self-regulation and self-control.

4. Pre-details of the course

1. Medical and biological physics (4 credits).
2. Medical chemistry (4 credits).
3. Medical biology, parasitology and genetics (5.5 credits).

5. Program learning outcomes

List of learning outcomes

Learning outcome code	The content of the learning outcome	Reference to the code of the competence matrix
Зн – Knowledges Ум – skills АВ – independence and responsibility К – competence		ПРН – program learning outcomes
Зн-1	basic principles of classification, nomenclature, structural and spatial isomerism of bioorganic compounds	ПРН 2, ПРН 3
Зн-2	types of chemical bonds, conjugate systems, electronic effects, acidity and basicity of bioorganic compounds as a basic basis of their reactivity	ПРН 2, ПРН 3
Зн-3	principles of classification of organic reactions according to the direction, method of disconnection and mechanism of their course	ПРН 2, ПРН 3
Зн-4	structure, nomenclature, isomerism, chemical properties	ПРН 2, ПРН 3

	and biological role of hydrocarbons, halogen-, oxygen-, sulfuro- and nitrogen-containing derivatives of hydrocarbons, heterofunctional compounds, heterocyclic compounds, biopolymers and bioregulators	
Ум-1	to carry out qualitative reactions to multiple communication and the main functional groups;	ПРН 2, ПРН 3
Ум-2	to predict the chemical properties of bioorganic compounds in those reactions that have analogies in the human body.	ПРН 2, ПРН 3
К-1	have a scientific worldview and creative thinking	ПРН 2, ПРН 3, ПРН 17
К-2	have information management skills	ПРН 2, ПРН 3, ПРН 17 ПРН 2, ПРН 3, ПРН 17
АВ-1	have the ability to critically evaluate the results of their own research.	ПРН 2, ПРН 3, ПРН 17
АВ-2	be able to improve their own learning	ПРН 2, ПРН 3, ПРН 17
АВ-3	be able to learn new areas through self-study, using the acquired knowledge of bioorganic chemistry	ПРН 2, ПРН 3, ПРН 17

6. Format and scope of the course

Format of the course	Full-time course	
Вид занять	Number of hours	Number of groups
lectures	10	
practical	30	
seminars	-	-
out of class work	50	

7. Topics and content of the course

Class type code	Topic	Content of training	Code of result of training	Professor
Л – lecture, П – practical class, СРС – out of class work				
Л-1	Bioorganic chemistry. Classification of the chemical reactions. Reactivity of the hydrocarbons. Hydroxy-derivatives of the hydrocarbons. Thioles. Amines.	The subject of bioorganic chemistry. Chemical bond. Conjugate systems. Interaction of atoms: induction and mesomeric electronic effects. Classification of chemical reactions. Structure, nomenclature, isomerism, chemical properties and biological role of hydrocarbons, alcohols, phenols, thiols, amines.	Зн-1 Зн-2 Зн-3 Зн-4 Ум-2 К-1 К-2	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
Л-2	Carbonyl-	Structure, nomenclature, isomerism, chemical	Зн-4	Zelisko N., PhD,

	containig compounds. Carboxylic acids. Heterofunctiona l compounds	properties and biological role of aldehydes, ketones, carboxylic acids. Structure, nomenclature, isomerism, chemical properties and biological role of heterofunctional compounds (hydroxy-, oxo- and amino acids, amino alcohols and aminophenols). Their specific properties.	Ум-1 Ум-2	Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
Л-3	Lipids. Proteinogenous amino-acids. Peptides & proteins.	Structure, nomenclature, chemical properties and biological role of saponification and non-saponification lipids. Structure, nomenclature, chemical properties, in vivo formation and biological role of natural α-amino acids. Structure and properties of peptides and proteins. Qualitative reactions.	Зн-4 Ум-1 Ум-2	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
Л-4	Carbohydrates	Structure, nomenclature, isomerism, chemical properties and biological role of mono-, di- and polysaccharides.	Зн-4 Ум-1 Ум-2	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
Л-5	Heterocyclic compounds. Alkaloids. Nucleic acids.	Structure, nomenclature, isomerism, chemical properties and biological role of five-, six-membered and condensed heterocycles. The concept of nucleosides, nucleotides, nucleic acids. The structure of DNA and RNA. Alkaloids and their biological role.	Зн-4 Ум-1 Ум-2	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-1	Introduction. Classification and nomenclature of the bioorganic compounds. Classification of the chemical reactions and reagents. Structure of chemical bonds.	The main provisions of the theory of chemical structure of organic compounds and its significance for the development of organic chemistry.Classification of organic compounds by the structure of the carbon skeleton and the nature of the functional group. Fundamental concepts of organic chemistry: homology, isomerism, radical, substituent, functional group, ancestral structure, poly- and heterofunctionality. Nomenclature systems in organic chemistry - trivial, rational, radical-functional, substitute. Types of hybridization of the carbon atom. The structure of σ- and π-bonds. Classification of chemical reactions by direction (substitution, addition, cleavage, isomerization, oxidation, reduction). Classification of chemical reactions by the method of disconnection (homolytic and heterolytic). Intermediate reaction particles are intermediates (carbocations, carbanions and	Зн-1 Зн-2 Зн-3 К -1 К-2	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor

		free radicals). Electrophiles and nucleophiles. Reagent and substrate. The concept of mechanisms of chemical reactions and their designation.		
П-2	Structure of bioorganic compounds. Conjugated systems. Electron effects (mesomeric and inductive effects). Reactivity of hydrocarbons.	Configurations and conformations of molecules. Conformations of ethane, n-butane, ethylene glycol, cyclohexane. Geometric (cis, trans) and mirror isomerism. Stereochemical formulas. Chirality of molecules. Enantiomers and diastereomers. The relative configuration of chiral molecules. D- and L- stereochemical series of chiral molecules. Optical activity and racemates. Mesoforms. Relationship of spatial structure with biological activity. Conjugate systems. Interaction of atoms in molecules: induction and mesomeric effects. Electron-donor and electron-acceptor substituents. Aromatic conditions. Hückel's rule. Alkanes, cycloalkanes, alkadienes and arenes, their structure, isomerism, chemical properties and medical and biological significance. Reactions of free radical substitution (S_R), electrophilic addition (A_E) and electrophilic substitution (S_E). Markovnikov's rule and its modern interpretation. Approximate action of substituents in the benzene nucleus.	Зн-1 Зн-2 Зн-4 К -1 К-2	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-3	Acidic and basic properties of organic compounds. Reactivity of hydroxy derivatives of hydrocarbons, thiols, amines and carbonylic compounds.	Acid and basic properties of organic compounds. Bransted and Lewis theories. Types of organic acids (OH-, SH-, NH- and CH-acids). The concept of pKa. Factors affecting the acidity and basicity of organic compounds. Alcohols, their classification, nomenclature, isomerism, properties and medical and biological significance. Chemical properties of alcohols. Oxidation reactions, intermolecular and intramolecular dehydration. Zaitsev's rule. Nucleophilic substitution reactions at a tetragonal carbon atom and their pathways (S_N1, S_N2). Qualitative reaction to polyhydric alcohols. Phenols, their classification, nomenclature, isomerism, properties and medical and biological significance. Identification of phenolic hydroxyl. Acidic properties of phenols. Quinones. Ubiquinone. Vitamin K. The concept of thiols and their derivatives (sulfides, disulfides). Chemical properties of thiols (acidity, oxidation, formation of thioesters). Amines, their classification, nomenclature, isomerism, properties and medical and biological significance. Chemical properties of amines. Basicity, nucleophilicity, interaction with nitric acid, isonitrile reaction and its practical application. Aldehydes and ketones. Classification,	Зн-2 Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor

		nomenclature and isomerism. Electronic structure of carbonyl group. Nucleophilic addition (A_N) reactions for aldehydes and ketones - formation of hydrates, hemiacetals, cyanhydrins, hydrogen sulfite derivatives. Aldol condensation reaction and its biochemical significance. Interaction of carbonyl compounds with amino derivatives - formation of Schiff bases, oximes, phenylhydrazones, semicarbazones. Oxidation and reduction of carbonyl compounds. Some representatives: monohydric (methanol, ethanol) and polyhydric (ethylene glycol, glycerol, xylitol, sorbitol) alcohols, monohydric (phenol, cresol) and diatomic (pyrocatechol, resorcinol, hydroquinone) phenols, amines (methylamine, aniline).		
П-4	Biologically important carboxylic acids and their derivatives. Control work "Theoretical aspects of bioorganic chemistry. Structure and properties of the hydrocarbons and their monofunctional derivatives.	Classification, nomenclature and isomerism of monocarboxylic acids. The structure of the carboxyl group and the carboxylate anion. Acidic properties of carboxylic acids. The concept of the mechanisms of nucleophilic substitution reactions. Esterification reaction. Reactions for the formation of amides, anhydrides, acid halides. Decarboxylation reactions of monocarboxylic acids. Reactions involving the radical of saturated, unsaturated and aromatic acids. Properties of formic acid. Dicarboxylic acids, their structure, nomenclature, isomerism. Specific reactions of dicarboxylic acids (decarboxylation, formation of cyclic anhydrides). Medico-biological significance of carboxylic acids.	Зн-1 Зн-2 Зн-3 Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-5	Heterofunctional bioorganic compounds.	Amino alcohols - colamine, choline, acetylcholine. Structure, chemical properties and biological significance. n-Aminophenol and its derivatives - paracetamol, phenacetin. Extraction and medical and biological significance. Catecholamines - dopamine, norepinephrine, adrenaline, their synthesis and biological role. Hydroxy and oxo acids, their structure, classification, nomenclature. Spatial (configurational) isomerism of hydroxy acids (enantiomeric and diastereomeric, meso-forms, racemates). Optical activity, relative configuration, D- and L-stereochemical series. Fisher projections. Chemical properties of hydroxy acids with the participation of the hydroxyl group. Chemical properties of hydroxy acids with the participation of the carboxyl group. Specific properties of α, β and γ-hydroxy acids. Aromatic hydroxy acids. Salicylic acid, aspirin, methyl salicylate, salol. Chemical properties of oxoacids as bifunctional compounds. Specific properties of oxoacids: decarboxylation reactions, keto-enol tautomerism. Medico-biological significance of hydroxy and oxo acids. Amino acids. Spatial structure, acid-base properties, specific	Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor

		properties of α-, β- and γ-amino acids.Sulfanilic acid and its amides. White streptocide		
П-6	Amino-acids, peptides, proteins.	Structure and classification of natural (proteinogenic) amino acids. Stereoisomerism of α-amino acids. D- and L-Stereochemical series. Bipolar structure of α-amino acids. Isoelectric point. Biologically important reactions of α-amino acids (deamination, decarboxylation, transamination). Chemical properties of proteinogenic amino acids. Primary structure of peptides, proteins. Peptide bond. Its electronic structure. The concept of secondary, tertiary and Quaternary structure of proteins. The concept of peptide synthesis (protection of amino and carboxyl groups, carboxyl group activation). Analysis of peptides (determination of the N-terminus, C-terminus, amino acid sequence). Partial and complete hydrolysis of proteins. Qualitative reactions to natural amino acids, proteins.	Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-7	Saponifiable lipids.	Lipids and their classification Higher fatty carboxylic acids are important structural components of saponifying lipids, their structure, stereoisomerism, properties. The concept of biosynthesis of higher fatty carboxylic acids. Fats (triacylglycerols) as representatives of simple saponifying lipids, their structure, properties The concept of lipid peroxidation (LPO). Complex saponifying lipids, their structure, classification. Glycerophosphatides - derivatives of phosphatidic acids, their structure and properties. Representatives of glycerophosphatides - lecithin, cephalins, phosphatidylserines, plasmogen. Structure of sphingolipids: ceramides and sphingomyelins. Glycolipids. The concept of the structure of cerebrosides and gangliosides. Medico-biological significance of saponifying lipids.	Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-8	Nonsaponifiable lipids. Control work “Heterofunctional bioorganic compounds. Lipids”	Terpenes, their classification. Isoprene rule. Acyclic monoterpenes (geraniol, citral). Monocyclic monoterpenes (limonene, menthol), their medical value. Bicyclic monoterpenes (α-pinene). Camphor, structure, optical activity, properties and medical value. Carotenoids, their structure, biological significance. Retinol (vitamin A), β-carotene (provitamin A) Chemistry of the process of light perception in the body. Steroids, general characteristics, classification. The structure of the steran. Stereoisomerism. Conformations of cyclohexane rings; cis-,	Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor

		trans-articulation of nuclei in the structure of steran; 5α- and 5β- steroids. The structure of hydrocarbons underlying the classification of steroids (estrane, androstane, pregnane, holan, cholestan). Derivatives of cholesterol (sterols): cholesterol, ergosterol, vitamin D2. Derivatives of cholan (bile acids): cholic, deoxycholic, glycocholic acids. Derivatives of estrone (female sex hormones): estrone and estradiol. Their structure and biological role. Androstane derivatives (male sex hormones): androsterone and testosterone. Structure and biological role. Derivatives of pregnane (corticosteroids): corticosterone, deoxycorticosterone, hydrocortisone. Cardiac glycoside aglycones: digitoxygenin; strophanthidine. Prostaglandins, their structure and medical and biological significance		
П-9	Structure, chemical properties and functions of monosaccharides.	Monosaccharides, their structure, classification and nomenclature. Stereoisomerism. D- and L-Stereochemical series. Cyclo-oxo-tautomerism. Furanose and pyranose forms, α- and β-anomers. Haworth's formulas. The phenomenon of mutarotation. Conformations of cyclic forms of monosaccharides. Chemical properties of monosaccharides (reactions involving hemiacetal hydroxyl, esterification and esterification, oxidation and reduction). Types of fermentation of monosaccharides. Monosaccharide identification reactions. Representatives: pentoses (D-xylose, D-ribose, L-arabinose), hexoses (D-glucose, D-galactose, D-mannose, D-fructose), deoxy sugars (2-deoxyribose, D-digitoxose), amino sugars (glucosamine). Neuraminic acid. Ascorbic acid.	Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-10	Structure, chemical properties and functions di- and polysaccharides.	Disaccharides, their structure and nomenclature. Reducing disaccharides (maltose, cellobiose, lactose), the relationship between monosaccharide residues and its spatial orientation. Cyclo-oxo-tautomerism and mutarotation of reducing disaccharides. Chemical properties of reducing disaccharides. Non-reducing disaccharides (sucrose) and the type of bond between monosaccharide residues. Chemical properties of non-reducing disaccharides. Sucrose inversion. Polysaccharides, their classification and the principle of construction. Homopolysaccharides: starch (amylose, amylopectin), glycogen, cellulose, dextrans.	Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor

		Spatial structure of amylose and cellulose. Heteropolysaccharides, their structure. Structure and biomedical significance of glycosaminoglycans (mucopolysaccharides) - chondroitin sulfates, hyaluronic acid, heparin. Mixed biopolymers (glycoproteins, proteoglycans, glycolipids). The concept of blood group substances.		
П-11	Control work "Carbohydrates"	Generalization, systematization and consolidation of knowledge about the structure, isomerism, chemical properties and related biological activity of carbohydrates.	Зн-4 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-12	Biologically active 5-membered heterocyclic compounds.	Heterocyclic compounds, their classification and nomenclature. Five-membered heterocycles with one heteroatom. Aromatic character. The structure of the pyrrole atom of Nitrogen. π-Excess aromatic systems. Acidophobicity of pyrrole and furan. Chemical properties of five-membered heterocycles with one heteroatom. Features of halogenation, sulfonation and nitration reactions of acidophobic heterocycles. NH-Acidity of pyrrole. Addition reactions. Indole, structure, aromatic character, chemical properties. Tetrapyrrole systems (porphins, porphyrins), their structure. Five-membered heterocycles with two heteroatoms. Aromaticity. Electronic structure of the pyridine nitrogen atom. Acid-base properties of five-membered heterocycles with two heteroatoms	Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-13	Biologically active 6-membered heterocyclic compounds.	Six-membered heterocyclic compounds, their classification and nomenclature. Six-membered heterocycles with one nitrogen atom: pyridine, quinoline, isoquinoline, acridine. Their structure, aroma. Chemical properties of pyridine: basicity, nucleophilic, electrophilic and nucleophilic substitution reactions. Redox reactions. Quinoline, isoquinoline, acridine, their chemical properties. Six-membered heterocycles with one oxygen atom: α- and γ-pyran and their derivatives. Medico-biological significance of six-membered heterocyclic compounds. Six-membered heterocycles with two nitrogen heteroatoms, their structure and properties. Hydroxy derivatives of pyrimidine (uracil, thymine, cytosine, barbituric acid) and their tautomeric forms. Six-membered heterocycles with heteroatoms of Nitrogen and Sulfur, their structure. Medico-biological significance of six-membered heterocycles with two heteroatoms.	Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-14	Biologically	Classification and nomenclature of condensed	Зн-4	Zelisko N., PhD,

	active fused heterocyclic compounds. Alkaloids. Nucleic acids.	heterocyclic compounds. Purine (structure, aromaticity, tautomerism, amphotericity). Hydroxy derivatives of purine: hypoxanthine, xanthine, uric acid. Their tautomerism and acid-base properties Amino derivatives of purine (adenine, guanine), their tautomeric forms, biochemical significance in the formation of nucleotides and coenzymes. Methylated derivatives of xanthine (caffeine, theophylline, theobromine) as physiologically active compounds with action on the central nervous and cardiovascular systems. Murexide test is a qualitative reaction to compounds containing a purine nucleus. Pteridine. Folic acid. Its antagonism with sulfonamides. Alkaloids (definition, their value as biologically active substances and drugs). Representatives of alkaloids: pyridine groups (nicotine, lobeline), quinoline (quinine), isoquinoline (morphine, papaverine), tropane (atropine), indole (reserpine). Nucleic bases: purine, pyrimidine, minor. Lactime-lactam tautomerism of nucleic bases. Complementarity. Nucleosides, nomenclature and structure. Pseudouridine. Nucleotides. Their structure, nomenclature and properties. Classification and primary structure of nucleic acids. Higher structural organization of nucleic acids. Biological role of nucleic acids. ATP is an energy accumulator in biological systems, its structure, properties and role. Nucleotide coenzymes (NAD +, NADH, FAD, FADN, coenzyme A), structure and participation in metabolic processes.	Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
П-15	Control work “Heterocyclic compounds, alkaloids, nucleic acid”.	Generalization, systematization and consolidation of knowledge about the structure, chemical properties and biological activity of the most important heterocyclic compounds, alkaloids, nucleic acids.	Зн-4 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
СРС-1	Types of hybridisation of Carbon. Electronic structure of chemical bonds. Conjugated and aromatic systems.	Atomic and molecular orbitals. Types of hybridization: sp3, sp2, sp. Types of chemical bonds (covalent, ionic, coordination, semipolar). The concept of hydrogen bonding and its importance in the formation of structures of the molecule of proteins and nucleic acids. Electronic structure of σ- and π-bonds. Their characteristics (length, energy, polarity,	Зн-2 Зн-4 Ум-1 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor

	Reactivity of arens, alkanes, alkenes and cycloalkanes.	polarization. Conjugation and its types (π, π- and p, π-conjugation). Influence of electron delocalization on increasing the stability of conjugate systems. Conjugation energy. Coupled open and closed circuit systems. Aromaticity and its criteria. Reactivity of arenes, alkanes, alkenes and cycloalkanes.		
CPC-2	Reactions of polymerization and polycondensation of aldehydes and carboxylic acids	Aldehyde polymerization reactions. Formation of paraform, trioxane, paraldehyde and metaldehyde. Aldol condensation reaction. Conduction and mechanism. Aldol condensation reaction in the biosynthesis of higher fatty acids. Polymerization reactions of carboxylic acids. Polyacrylate. Polymethyl methacrylate. Formation of phenol-formaldehyde resins.	Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
CPC-3	Transformation of keto- and hydroxyacids (reactions of oxidation, reduction, decarboxylation, aldol condensation). Keto-enol tautomerism	Oxidation reactions of hydroxy acids. Ketone acid reduction reactions. Ketone acid decarboxylation reactions. Aldol addition reactions in the biosynthesis of long chain fatty acids. Keto-enol tautomerism of acetoacetic acid	Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
CPC-4	Simple and complex saponifiable lipids. Low-molecular weight bio-regulators – terpenes, carotenoids, steroids, prostaglandins	Structure, nomenclature, chemical properties and biological role of saponification and non-saponification lipids (terpenes, carotenoids, steroids, prostaglandins).	Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
CPC-5	Stereo-isomerism and tautomerism of monosaccharides. D & L row of monosaccharides. Enantiomers and diastereomers Anomers and epimers. Synthesis and hydrolysis of glicosides, ether and esters of monosaccharides.	Stereoisomerism and tautomerism of monosaccharides. Chemical properties of monosaccharides.	Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
CPC-6	Reducing and	Structure and properties of reducing and non-	Зн-4	Zelisko N., PhD,

	nonreducing sugars. Structure and properties of homo- (starch, celulouse, inulin) and heteropolysacharides (Hyaluronic acid, chondroitin sulfate, heparin)	reducing disaccharides. The most important homopolysaccharides: starch, fiber, inulin. The most important heteropolysaccharides: hyaluronic acid, chondroitin sulfate, heparin. Blood groups.	Ум-2 К -1 К-2 АВ-2 АВ-3	Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
СРС-7	Biologically active 5-membered heterocyclic compounds. Aromaticity. Reaction of nucleophilic and electrophilic substitution. Lactam-lactim and azole tautomerisms.	Structure, nomenclature, isomerism, extraction methods, chemical properties and biological role of five-membered heterocycles with one and two heteroatoms. Structure, nomenclature, isomerism, extraction methods, chemical properties and biological role of six-membered heterocycles with one and two heteroatoms.	Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
СРС-8	Pyridine-carboxylic acids based drugs	Pyridinecarboxylic (nicotinic and isonicotinic) acids and their derivatives (nicotinamide, cordiamine, isoniazid, ftivazide). Application in medicine.	Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
СРС-9	Alakoilds: structure, classification, properties	Structure, classification, chemical properties and medical and biological significance of alkaloids. Representatives of alkaloids: pyridine groups (nicotine, lobeline), quinoline (quinine), isoquinoline (morphine, papaverine), tropane (atropine), indole (reserpine).	Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor
СРС-10	Nucleotides, nucleosides and nucleic acids	Nucleic acids (DNA, RNA) as polynucleotides. The primary structure of DNA and RNA (nucleotide sequence). Secondary structure of DNA and factors that stabilize it.Genetic role of DNA.	Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	Zelisko N., PhD, Associate Professor, Kaminskyy, PhD, Associate Professor, Subtelna , PhD, Associate Professor

Teaching methods are explanatory-illustrative, problem-solving, partial-search. When studying bioorganic chemistry, students use textbooks, lecture notes, guidelines, chemical computer programs, models of molecules, laboratory equipment and utensils needed to perform experiments, appropriate reagents.

According to the curriculum, the methods of organization and implementation of educational

activities are:
a) lectures
b) practical classes
c) out of class work of students.
The topics of the lecture course reveal the problematic issues of the relevant sections of bioorganic chemistry.
Lecture material is presented using multimedia equipment, computer, video clips, graph projector, models of organic molecules and demonstration experiments.

Practical classes according to the methods of their organizations are laboratory, because they include: laboratory research on the extraction and detection of certain classes of organic compounds on the properties of their functional groups, conducting qualitative reactions. It is recommended that students in laboratory classes briefly record research protocols, indicating the purpose of the study and conclusions.
Students also use exercises and solve situational problems. The practical classes use computer programs ISIS DRAW, HyperChem, Chemistry in motion, video clips developed by the department, models of molecules.

The structure of the organization of practical classes includes:
1. Discussion and explanation of the most difficult issues of the topic;
2. Written survey;
3. Performance of practical (laboratory) works.
4. Registration of the protocol of practical employment.
5. The result of the lesson

Independent work of students includes:
1. Elaboration of literature on this topic.
2. Solving training exercises and tests.

8. Verification of learning outcomes

Current control

Carried out in each lesson according to specific goals, as well as during the individual work of the teacher with the student for those topics that the student develops independently and they are not part of the structure of the practical lesson. A standardized form of control of theoretical and practical training of students is used.

The standardized form of control of the theoretical part includes 10 tasks. Five of them of the first level are test (1 point each), and five tasks of the second level, to which in addition to the test answer you need to give a written answer (2 points each).

Assessment of practical training of students - as a result of the practical part - is made in the form of a protocol.

The final grade for the current educational activity is set on a 4-point (national) scale.

Criteria for evaluating current learning activities:

A grade of "5" (excellent) is given to a student who actively participated in the discussion of the most difficult questions on the topic of the lesson, gave at least 90% correct answers to standardized test tasks, answered written tasks without errors, did practical work and drew up a protocol.

Grade "4" (good) is given to the student who participated in the discussion of the most difficult questions on the topic, gave at least 75% correct answers to standardized test tasks, made some minor mistakes in answering written tasks, did practical work and drew up a protocol.

Grade "3" (satisfactory) is given to a student who did not participate in the discussion of the most difficult questions on the topic, gave at least 60% correct answers to standardized test tasks, made significant mistakes in answering written tasks, did practical work and drew up a protocol.

Grade "2" (unsatisfactory) is given to a student who did not participate in the discussion of the most difficult questions on the topic, gave less than 60% of correct answers to standardized test tasks, made gross mistakes in answering written tasks or did not answer them at all. performed practical work and did not draw up a protocol.

Learning outcome code	Code of the type of classes	Method of verification of learning outcomes	Enrollment criteria
Зн-1 Зн-2 Зн-3 К -1 К-2	П-1	1. Acquaintance with the organization and procedure for conducting practical classes in bioorganic chemistry. 2. Acquaintance with safety precautions and rules of work in chemical laboratory. 3. Consideration of the basic principles of classification and nomenclature of	evaluation according to the established criteria on a traditional 4-point scale

		organic compounds. 4. Consideration of the basic principles of classification and nomenclature of chemical reactions and reagents. 5. Performing training exercises and tests.	
Зн-1 Зн-2 Зн-4 Ум-1 К -1 К-2 АВ-2 АВ-3	П-2 СРС-1	1. Homework control. 2. Answers to students' questions and consideration of the main points of the topic 3. Consideration on models, computer programs and tables of the spatial structure of organic compounds, conformations and configuration states of molecules and methods of their representation. Compilation of models of chiral molecules of lactic and tartaric acids; assembly on the conformation models of ethane, butane and ethylene glycol. 4. Execution of experiments. 5. Control of assimilation of material and derivation of the general estimation.	evaluation according to the established criteria on a traditional 4-point scale
Зн-2 Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-3 СРС-2	1. Homework control. 2. Answers to students' questions and consideration of the main points of the topic 3. Execution of experiments 4. Control of mastering the topic of theoretical and practical material 5. Making an overall assessment**.**	evaluation according to the established criteria on a traditional 4-point scale
Зн-1 Зн-2 Зн-3 Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-4 СРС-2	1. Answers to students' questions and consideration of the main points of the topic. 2. Execution of experiments. 3. Control of mastering the topic of the performed experiments. 4. Control of students' knowledge on topics 1-4. 5. Exposition of the general estimation of mastering of themes of the semantic module «Theoretical aspects of bioorganic chemistry. Hydrocarbons and homofunctional bioorganic compounds ".	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-5 СРС-3	1. Answers to students' questions and consideration of the main points of the topic 2. Control of students' knowledge 3. Execution of experiments 4. Control of mastering the topic from the performed experiments 5. Exposing a general assessment of mastering the topic.	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-1 Ум-2	П-6	1. Answers to students' questions and consideration of the main points of the topic	evaluation according to the established criteria on a traditional 4-point

К -1 К-2 АВ-1 АВ-2 АВ-3		2. Control of students' knowledge 3. Execution of experiments 4. Control of mastering the topic from the performed experiments 5. Exposing a general assessment of mastering the topic.	scale
Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-7 СРС-4	1. Answers to students' questions and consideration of the main points of the topic 2. Control of students' knowledge 3. Execution of experiments 4. Control of mastering the topic from the performed experiments 5. Exposing a general assessment of mastering the topic.	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-8 СРС-4	1. Answers to students' questions and consideration of the main points of the topic. 2. Execution of experiments. 3. Control of mastering the topic of the performed experiments. 4. Control of students' knowledge on topics 5-8. 5. Presentation of the general assessment of mastering the topics of the content module "Heterofunctional bioorganic compounds. Biopolymers and bioregulators "	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-9 СРС-5	1. Answers to students' questions and consideration of the main points of the topic 2. Control of students' knowledge 3. Execution of experiments 4. Control of mastering the topic from the performed experiments 5. Exposing a general assessment of mastering the topic.	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-10 СРС-6	1. Answers to students' questions and consideration of the main points of the topic 2. Control of students' knowledge 3. Execution of experiments 4. Control of mastering the topic from the performed experiments 5. Exposing a general assessment of mastering the topic.	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	П-11	1. Homework control. 2. Answers to students' questions. 3. Control of students' knowledge on topics 9-10. 4. Exposition of the general estimation of mastering of subjects of the semantic module "Structure and biological functions of carbohydrates".	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-1 Ум-2 К -1 К-2	П-12 СРС-7	1. Answers to students' questions and consideration of the main points of the topic 2. Control of students' knowledge 3. Execution of experiments	evaluation according to the established criteria on a traditional 4-point scale

АВ-1 АВ-2 АВ-3		4. Control of mastering the topic from the performed experiments 5. Exposing a general assessment of mastering the topic.	
Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-13 СРС-7 СРС-8	1. Answers to students' questions and consideration of the main points of the topic 2. Control of students' knowledge 3. Execution of experiments 4. Control of mastering the topic from the performed experiments 5. Exposing a general assessment of mastering the topic.	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-1 Ум-2 К -1 К-2 АВ-1 АВ-2 АВ-3	П-14 СРС-9 СРС-10	1. Answers to students' questions and consideration of the main points of the topic 2. Control of students' knowledge 3. Execution of experiments 4. Control of mastering the topic from the performed experiments 5. Exposing a general assessment of mastering the topic.	evaluation according to the established criteria on a traditional 4-point scale
Зн-4 Ум-2 К -1 К-2 АВ-2 АВ-3	П-15	1. Homework control. 2. Answers to students' questions. 3. Control of students' knowledge on topics 12-14. 4. Presentation of the general assessment of mastering the topics of the content module "Structure and biological functions of heterocyclic compounds, alkaloids, nucleosides, nucleotides and nucleic acids".	evaluation according to the established criteria on a traditional 4-point scale

Final control		
General evaluation system	Participation in the work during the semester / exam - 60% / 40% on a 200-point scale	
Rating scales	Traditional 4-point scale, multi-point (200-point) scale, ECTS rating scale	
Conditions of admission to the final control	The student attended all practical (laboratory, seminar) classes and received at least 72 points for current performance	
Type of final control	Methods of final control	Enrollment criteria
Exam	The exam is held during the examination session according to the schedule and includes: Written answers to 20 standard level I test tasks, each of which has one or more correct answers out of the five suggested. Written answers to 20 standard test tasks of the second level, the solution of which involves both a literal answer and the completion of a written task.	Enrollment of the test task of the I level: correct answer -1 point, incorrect answer - 0 points. The answer to the theoretical problem of the II level is estimated from 0 to 3 points: correct letter answer -1 point, incorrect letter answer - 0 points. The written task is evaluated from 0 to 2 points. **The maximum number of points** that a student can score when taking the exam is 80. **The minimum number of points** in the exam - not less than 50.

The maximum number of points that a student can score for the current academic activity for admission to the exam is 120 points.
The minimum number of points that a student must score for the current academic activity for admission to the exam is 72 points.

The calculation of the number of points is based on the grades received by the student on a 4-point (national) scale during the study of the discipline, by calculating the arithmetic mean (CA), rounded to two decimal places. The resulting value is converted into points on a multi-point scale as follows:

$$x = \frac{\text{CA} \times 120}{5}$$

9. Course policy

The student must independently complete homework, training exercises and tests, tasks of current and final control. It is not allowed to spy on another student's work, write off, use a textbook, notebook or mobile phone while writing a test, final or exam paper, use cheat sheets, copy your work by other students. Omissions of practical classes are not allowed. If a student misses classes for good reasons, which are documented, he has the right to practice them.

10. Literature

The main literature

1. B.S.Zimenkovsky, V.A. Muzychenko, I.V.Nizhenkovska, G.O.Syrova. Biological and bioorganic chemistry.Aus Medicine Publishing. Kyiv.2018. – 288 p.
2. J. Komarytsia. Organic Chemistry. Handbook for medical students. Lviv 2005.-74 p.
3. Stoker, H.S. (2001). Organic and biological chemistry. Houghton Mifflin. 2001. 556p.

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The additionary literature

1. L.G. Wade Jr. Organic Chemistry. 8th edition. - Pearson. 2013. - 547p.
2. T. Graham Solomons, Craig B. Fryhle. Organic Chemistry. Tenth edition. Hoboken, NJ. – 2011. - John Willey and Sons, Inc.- 1218 p.
3. David C. Eaton. Laboratory investigation in Organic Chemistry. – McGRAW-HILL BOOK COMPANY. – New York – Toronto. – 893 p.

Information resources

1. www.ncbi.nlm.nih.gov/PubMed – free access to the database of scientific research in the field of biomedical sciences.
2. https://pubchem.ncbi.nlm.nih.gov/ free access to the database of scientific data in the field of biomedical sciences.
3. http://www.orgsyn.org - has provided the chemistry community with detailed, reliable, and carefully checked procedures for the synthesis of organic compounds.
4. http://www.organic-chemistry.org - offers an overview of recent topics, interesting reactions, and information on important chemicals for organic chemists.
6. www.bioorganica.org.ua - a scientific publication that presents works on bioorganic and medical chemistry.

11. Equipment, logistics and software of the discipline

Equipment for laboratory work in the discipline, chemical utensils, reagents, multimedia projector for classes, overhead projector, computers, Internet for individual tasks, platform for distance learning MISA; thematic tables, molecule models, methodical instructions for practical and independent work are posted on the MISA distance learning service and are freely available to students.

12. Additional information

The department has a permanent student research group.

The Syllabus was developed by:
Nataliya Zelisko, PhD, Associate Professor

Head of Department of Pharmaceutical, Organic
and Bioorganic chemistry
Prof. R.B. Lesyk