ЗМІСТ

Biological and Bioorganic Chemistry: in 2 books. Book 1. Bioorganic Chemistry: textbook

Про книгу

The textbook contains the information about the structure, chemical properties and biological role of organic compounds which take part in human metabolic processes: low-molecular bioregulators (vitamins, hormones, other natural and synthetic biologically active compounds, including certain medications and toxic compounds) and biopolymers (carbohydrates, proteins and nucleic acids). This textbook is recommended for students and teachers of higher medical education establishments.

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BIOLOGICAL AND BIOORGANIC Chemistry

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IN 2 BOOKS
1
BOOK

BIOORGANIC CHEMISTRY

National textbook

Third edition

Approved by the Ministry of Education and Science of Ukraine
as a textbook for students of higher medical education establishments

Published pursuant to the Order of the Ministry of Health of Ukraine
No. 502 as of 22 June 2010 as a national textbook for students
of higher medical education establishments

Recommended by the Academic Council of Bogomolets National
Medical University as a textbook for students of higher medical
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CONTENTS

PREFACE

The academic discipline "Biological and Bioorganic chemistry" for students of medical and stomatological faculties is structured into three modules. The first involves the study of Bioorganic chemistry, which creates the necessary theoretical base for successful learning of Biological chemistry. The study of these two disciplines will help students at the molecular level to learn such medico-biological and medical subjects as "Physiology", "Pharmacology", "Internal medicine", "Genetics", "Allergology" and others. In recent years the teaching in higher medical institutions was transferred to the credit-modular system, therefore the curriculum in all disciplines was radically changed. So, the creation of the new national textbooks is important.

"Bioorganic chemistry" by B.S. Zimenkovsky, V.A. Muzychenko was taken into consideration when writing this tutorial, and it was created in accordance with modern pedagogical technologies.

In the textbook the presentation of factual material is preceded by the consideration of the theoretical aspects regarding nomenclature, structural and spatial isomerism of bioorganic compounds, electronic submissions in bioorganic chemistry, nature of chemical bonds, acidity and basicity of bioorganic compounds, classification of reagents and chemical reactions and, on the basis of this knowledge, about their mechanisms. This approach was suggested by Professor N.A. Tyukavkina ("Bioorganic chemistry". — M. : Medicine, 1985). As evidenced by years of teaching experience of bioorganic chemistry, this sequence of presentation is fully justified, because it facilitates the student to learn the material on the structure and chemical behavior of metabolic products.

With the aim of creating the necessary theoretical base to explore these such important and difficult to study bioorganic compounds, as heterofunctional, heterocyclic compounds, carbohydrates, proteins, nucleic acids, terpenes, carotenoids, steroids etc. at the beginning of the textbook there are more simple classes of organic compounds — hydrocarbons, their halogen and hydroxyl derivatives, aldehydes, ketones, carboxylic acids, and so on.

For increasing the professional motivation of students to master the knowledge of bioorganic chemistry in the textbook the medical terminology is often used with brief explanations; considerable attention is paid to the consideration of structures that are not only conventional representatives of a certain class of organic compounds, but also active participants in metabolic processes or important medicines. In this aspect chemical properties of all classes of organic compounds are represented. The maximal attention is paid to the reactions and chemical properties of compounds, which take place in the human body. In order to increase the professional interest of students in studying such important

chapters as "Proteins", "Lipids" and "Nucleic acids" at the beginning of each chapter there are data on the biological role of these compounds in the body.

For better understanding by students the biological role of various metabolites the Introduction contains a brief summary of some bioregulators (vitamins, hormones, enzymes, and coenzymes) to master certain classes of bioorganic compounds.

The chemical classification of bioorganic compounds is the basis used to installate this tutorial. In this regard such typical for the customary publications themes as "Vitamins", "Coenzymes" and "Antibiotics" were omitted. Some information about these metabolites was included into the chapters describing the corresponding classes of bioorganic compounds. This order of presentation will facilitate a deeper and more complete understanding of biochemical processes occurring in the body.

To avoid the fragmentation of knowledge the individual chapters were interconnected by numerous links to previous or next material. This will help the students to learn Bioorganic chemistry as a subject in general.

Due to the wide use of computer technology a simplified way of writing structural formulae has increasingly adopted in modern chemical literature. That's why the quantity of simplified formulae were being expanded gradually from section to section to adapt the student for modern requirements.

There are also models of the key molecules of biological structures that will help students to solve the issues concerning their structure. In connection with the transition to the credit-modular system of teaching after each chapter there are tasks and tests for self-control. It will facilitate the student adaptation to the test form of checking the knowledge in practical classes and during compilation of the final modules.

PART I

THEORETICAL BASIS OF ORGANIC AND BIOORGANIC CHEMISTRY. THE STRUCTURE OF ORGANIC AND BIOORGANIC COMPOUNDS

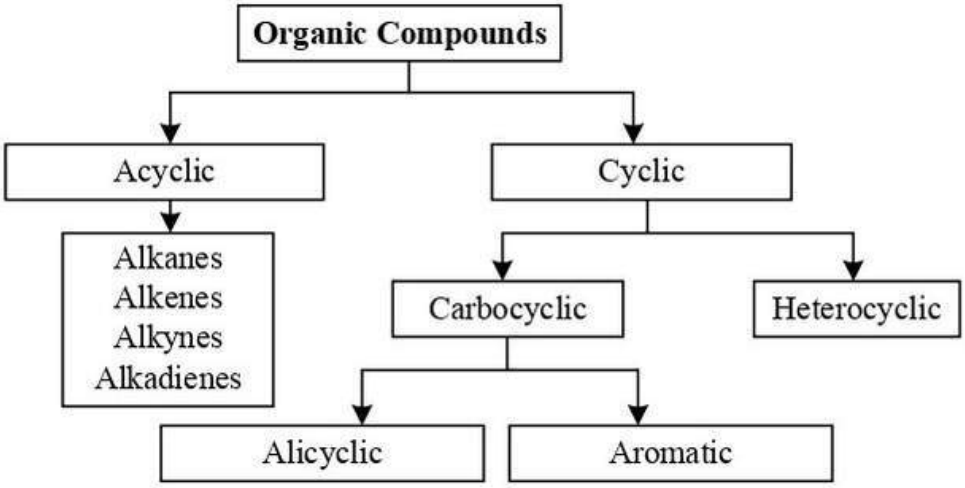
CHAPTER 1
CLASSIFICATION AND NOMENCLATURE OF ORGANIC COMPOUNDS

1.1. CLASSIFICATION OF ORGANIC COMPOUNDS

- **Structure of the Carbon Chain**
- **Nature of the Functional Group**

1.1.1. Classification Based on the Carbon Chain Structure

The diagram below shows the division of organic compounds on the structure based on the carbon skeleton.



Acyclic compounds are also called *aliphatic* and include substances with an open carbon chain. Acyclic compounds are divided into saturated (alkanes, paraffins) and unsaturated.

Cyclic compounds contain the rings (cycles) in their structure. If the cycle contains only the carbon atoms, then such compounds are called ***carbocycles***. If the rings are built from other atoms, such compounds are called ***heterocyclic*** (from Greek *γετερωσ — different*).

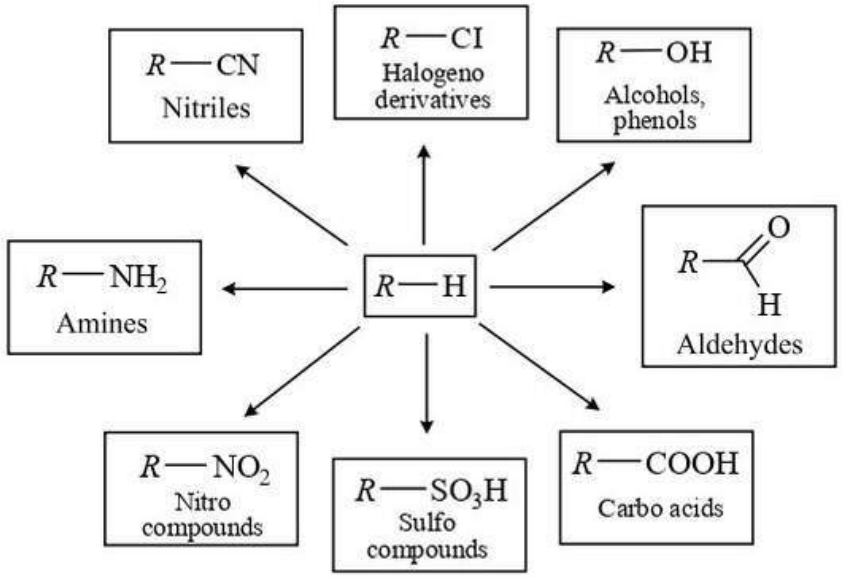
In turn, the carbocyclic compounds are divided into alicyclic and aromatic. *The saturated alicyclic hydrocarbons* (cycloalkanes) include *cyclopropane* and its homologues — cyclobutane, cyclopentane, cyclohexane, etc.

1.1.2. Classification Based on the Nature of the Functional Group

The functional group is a structural fragment of the molecule that determines its belonging to a particular class of organic compounds and characterizes its chemical properties. According to the functional group nature all organic compounds are divided into classes (Table 1.1).

Table 1.1. **The Most Important Functional Groups and the Corresponding Classes of Organic Compounds**

Functional Group	The Name of the Group	The Class of Substances
–*Hal* (–F, –Cl, –Br, –I)	Halogeno	Halogeno derivatives of hydrocarbons
–OH	Hydroxy	Alcohols, phenols
–SH	Thio, mercapto	Thio alcohols
–O*R*	Alkoxy	Esters
>C=O	Carbonyl	Aldehydes, ketones
–COOH	Carboxyl	Carboxylic acids
$-SO_3H$	Sulfo	Sulfonic acids
–COO*R*	Alkoxycarbonyl	Esters
$-C(O)NH_2$	Amide	Amides of acids
$-NO_2$	Nitro	Nitro compounds
$-NH_2$	Amino	Amines



Classes of organic compounds

Substitution of hydrocarbon molecules of hydrogen atoms by a functional group a certain class of organic compounds is formed.

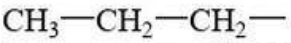
Based on the number of functional groups the organic compounds are divided into mono - and polyfunctional derivatives. *The monofunctional compounds* contain one functional group; the *polyfunctional ones have* two and more. In addition, polyfunctional organic compounds are divided into homo- and heterofunctional. Molecules of the *homofunctional compounds* contain the same functional groups, and *heterofunctional* — different.

1.2. NOMENCLATURE OF ORGANIC COMPOUNDS

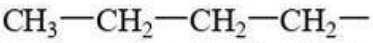
The most important nomenclature systems include the common (trivial empirical) names, rational and the IUPAC (International Union of Pure and Applied Chemistry) nomenclature.

The common (trivial empirical) names of organic compounds are random. The most often it indicates the source of obtaining a compound (malic acid, ethyl alcohol). In addition, the common name is often an indication of a specific property of a compound: fluorescein fluoresces, glycerol possesses the sweet taste (*glycys* means *sweet*). The common name also refers to a method of obtaining a compound (pyruvic (*pyros* means *heat*) acid is the grape acid after heat treatment), or application (the ascorbic acid, which is used against the scorbutus (scurvy).

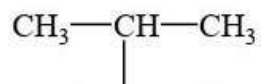
The Rational Nomenclature: *For successful learning the basis* of chemical nomenclature of organic compounds it's necessary to know such concept as radical. Hydrocarbon radicals are formed during the removal of the hydrogen atom from hydrocarbon molecules. Alkanes form *alkyl radicals,* and arenes form *aryl radicals*. During the creation of the names of alkyl radicals, the suffix ***-ane*** is replaced by ***-yl. Radicals*** are *denoted* ***by the letter R.*** To distinguish the ***alky***l radicals from others ***Alk*** is often used. The aromatic (aryl) radicals are ***the symbol Ar.*** The radicals may be *primary, secondary, and tertiary*. Let's show them on examples of the propane and butane radicals:



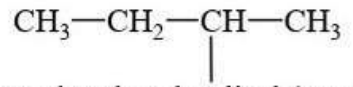
The primary propyl radical (*n*-propyl)



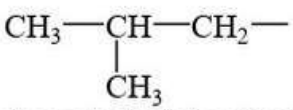
The primary butyl radical (*n*-butyl)



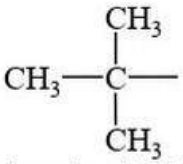
The secondary propyl radical ((isopropyl, *i*-propyl)



The secondary butyl radical (*sec*-butyl)



The primary isobutyl radical (*i*-butyl)



The tertiary butyl radical (*tert*-butyl)

When forming the names according to the rational nomenclature the organic compounds are considered as derivatives of the first member of homologous series of definite class of organic compounds.

CH_4 ;	$CH_3—CH_3$;	$CH_3—CH_2—CH_3$
Methane	Methyl-methane	Dimethylmethane

In modern chemistry the rational nomenclature is rarely used.

The IUPAC provides several ways of forming the names of organic compounds. Most often the radical-functional and substitutional approaches are used.

The radical-functional approach suggests the name of hydrocarbon radical and the nature of a functional group that assigns it to a particular class of organic compounds, for example, CH_3Cl — methyl chloride; C_2H_5OH — ethyl alcohol; $C_2H_5OC_2H_5$ — diethyl ether; $C_2H_5 — NH_2$ — ethylamine etc.

The substitutional approach describes compounds as derivatives of hydrocarbons or heterocyclic compounds (parent structures). Their nature is denoted in *the root* of the name. In the case of the substitution of hydrogen atoms with other atoms or atomic groups (substituents) different classes of organic compounds are formed. The substituents include hydrocarbon radicals and characteristic groups.

The characteristic group is a functional group (OH —, NH_2 —, Hlal etc.), which is bounded to the *parent* ***structure or partially included to its composition (for example, carboxyl group —COOH, the carbon atom of which belongs to the*** *parent* ***structure).***

The substituent is designated either by the prefix or by the suffix of the name.

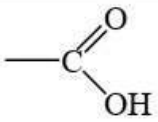
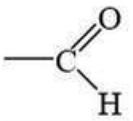
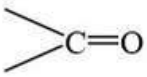
There are some characteristic groups (type one), where only the prefix is used; these are given in the Table 1.2. Other characteristic groups (type two) are denoted by the prefix and suffix. If the molecule has only one characteristic group of the second type, it's designated by the suffix, and if there are several groups, the main of them is represented by the suffix, and the rest — by the prefix.

Table 1.2. ***Some Characteristic Groups Marked only by the Prefix (Type One)***

Group	Name
–O*R*	Alkoxy-
–Br	Bromo-
–I	Iodine-
–NO	Nitroso-
$–NO_2$	Nitro-
–F	Fluoro-
–Cl	Chloro-
–S*R*	Alkylthio-

Hydrocarbon radicals are designated only by the prefix. The characteristic groups, where both the prefix and suffix are used, are given in decreasing order of precedence in the Table 1.3.

Table 1.3. ***Some Characteristic Groups Where the Prefix and Suffix Are Used for Designation (Type Two)***

Group	Symbols of the Prefix	Designation by the Suffix
	-Carboxy-	-oic acid
—SO_3H	Sulfo-	sulfonic acid
	Carbonyl- (Formyl-)	-al
	Oxo-	-one
—OH	Hydoxy-	-ol
—SH	Mercapto-	-thiol
—NH_2	Amino-	-amine

[1] The carbon atom is included into the name of the parent structure.

The parent structure is numbered to indicate the placement of the substituent. Numbering is done so that the eldest substituent of the second type received the smallest number. The substituents formed by the prefix in compounds names are listed alphabetically. If in the molecule there are only substituents designated only by the prefix, the numbering of the carbon atoms of the parent structures is carried out so that the substituent that indicated in the title first would receive the smallest number.

The fragment of a molecule that contains the longest carbon chain in the aliphatic compound or the cyclic structure in hydrocarbo- and heterocyclic compounds is chosen as a parent structure. To determine the parent structure in more complex cases fragments of the molecules are chosen that have:

1) The maximum number of substituents of type two;

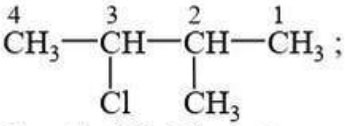
2) The maximum number of multiple bonds (the double bond is elder than triple);

3) The maximum length of the carbon chain;

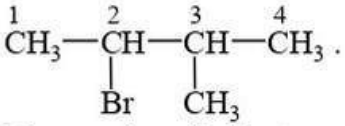
4) The maximum number of substituents designated only by prefixes (hydrocarbon radicals and substituents of the first type).

In some cases, the names of the substitutional nomenclature are rather difficult, so they can often be replaced by common names.

Examples of organic compounds according to the substitutional nomenclature are as follows:



2-methyl-3-chlorbutane



2-bromo-3-methylbutane

TESTS FOR SELF-CONTROL

1. Which characteristics are taken into account in the classification of organic compounds?
- A. Reactivity of the substance.
- B. The structure of the carbon chain.
- C. The nature of functional groups.
- D. Types of chemical bonds.
- E. The energy of the molecules.

2. What class of organic substances does the compound $(CH_3)_2CH — NH_2$ belong to?
- A. Nitro compounds.
- B. Amines.
- C. Alcohols.
- D. Amides.
- E. Nitryls.

3. Name the compound belonging to thio alcohols:
- A. *R*—S—*R*
- B. *R*—OH
- C. *R*—C(S)—*R*
- D. *R*—SH
- E. *R*—SO_3H.

4. Choose the criterion taken into account first and foremost when determining the parent structure:
- A. The length of the carbon chain.
- B. Multiple bonds.
- C. The substituents designated only by the prefix.
- D. The presence of substituents of the second type (designated in the prefix and suffix).
- E. Alkyl radicals.

TASKS FOR SELF-CONTROL

1. Name "Aminalon" on the IUPAC nomenclature — a substance, which takes part in metabolic processes of the brain and has a structure $H_2N–CH_2–CH_2–CH_2–COOH$.

2. Draw the structural formula of 2-oxobutanoic acid that is an intermediate of carbohydrate oxaloacetic acid metabolism.

3. Give examples of the primary, secondary and tertiary amines. Name them according to the radical-functional nomenclature.

4. Draw the structural formula of glycerol - the alcohol included in the fat composition and is 1,2,3-propantriol.