

**MINISTRY OF HEALTH OF UKRAINE
NATIONAL UNIVERSITY OF PHARMACY
Biological chemistry Department**



BIOLOGICAL CHEMISTRY

**Methodical recommendations
for the final module control to
higher education applicants
in specialties / educational program
«Pharmacy»**

Kharkiv

2017

NPhU

*Approved at the Biological Chemistry Department Meeting
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Biological chemistry: methodical recommendations for the final module control to higher education applicants for specialties / educational program "Pharmacy" / A.L. Zagayko, M.V. Voloshchenko, G.B. Kravchenko O.A. Krasilnikova. – Kharkiv: NUPh, 2017. – 19 p.

Methodical recommendations are developed in accordance with the working programs of compulsory discipline "Biological chemistry", educational-professional program of training and educational and qualification characteristics of specialist / master's degree in specialties / educational programs "Pharmacy", is studied by the applicants of higher education. Methodical recommendations contain theoretical questions and a list of the main information sources for the preparation of higher education graduates for the final module control, the criteria for assessing the knowledge of higher education graduates, the example of the examination paper.

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Introduction

Syllabus on Biological chemistry is created for universities of medicine (pharmacy) of Ukraine (III-IV levels of accreditation) for the speciality 8.110201 -“Pharmacy” in accordance with the plan of study, which was approved by order № 422 from 09.06.2011 at NUoP. Period of students’ study for such speciality is equal to 5,0 years. According to the plan of study preparing on biochemistry is realized in semesters V and VI.

Biological chemistry as discipline to study:

- a) is based on students’ knowledge of inorganic, analytic, physical and colloid, organic chemistry, botany, physiology and microbiology, and is integrated with such disciplines;
- b) supplies students with basic information on clinic biochemistry, laboratory diagnostics, biotechnology, that supposes certain integration of teaching with these disciplines and formation of skills to apply knowledge on biochemistry in the process of further education and in professional activity;
- c) supplies students with principles of healthy way of life, understanding for humans of importance of various biomolecules to prevent metabolism abnormalities in the processes of life activities.

Organization of study process is fulfilled on the credit-module system according to demands of the Bologna education process.

Program of the discipline “Biological chemistry” includes II Modules, which in turn are divided into 6 concept modules:

MODULE I. Structure of biological macromolecules. Principles of metabolism

Concept modules:

1. Structure, occurrence and biological role of proteins.
2. Structure and functions of biomolecules.
3. Introduction into metabolism

MODULE II. Metabolism and its regulation

Concept modules:

1. Metabolism of carbohydrates and lipids.
2. Metabolism of proteins.
3. Integration and regulation of metabolism.

GOALS OF THE DISCIPLINE STUDING

Biochemistry as a subject to study points such tasks:

- to prepare specialists-pharmacists which possess a sufficient extent of theoretical knowledge and practical skills as to biochemical basis of life: chemical structure of organic compounds and characteristics of metabolic pathways, which take place in the human organism;
- to form knowledge about structure of compounds, that form living organisms, and the relation to their main biochemical functions;

- to form contemporary knowledge about principles of structural organization of the main classes of biomacromolecules – proteins, nucleic acids and others;
 - to form knowledge about appropriateness of liberation, accumulation and use of energy in biological systems;
 - to form knowledge of the main metabolic pathways in the organism, their relationships and molecular mechanisms of regulation;
 - to form knowledge of molecular basis of genetic information transfer, protein biosynthesis and mechanisms of their regulation;
 - acquaintance with contemporary methods of biochemical diagnostics of metabolism state in the organism;
 - formation of scientific analysis skills and generalization of phenomena and facts which are observed;
 - to supply a theoretical base to study other medical and biological disciplines: pharmacology, pharmacotherapy with pharmacokinetics, clinic pharmacology and some pharmaceutical disciplines.
- .

QUESTIONS FOR FINAL MODULE

1. Proteinogenous amino acids: definition, chemical classification. Write and name certain amino acids.
2. Physico-chemical classification of the proteinogenous amino acids. Give examples. Write and name certain amino acids.
3. Name essential amino acids, explain the term “essential”, give examples. Write formulas and name certain amino acids.
4. Name nonessential amino acids, explain the term “nonessential”, give examples. Write and name formulas of certain amino acids.
5. Peptide bond, principle of its formation, features. Write and name certain amino acids.
6. Primary structure of protein molecule, its definition, the bond which stabilizes it. Write and name certain amino acids.
7. Secondary structure of protein molecule, definition, types, the bond which stabilizes it. Write and name certain amino acids.
8. Tertiary structure of protein molecule, definition, types, the bonds which stabilize it. Write and name certain amino acids.
9. Quaternary structure of protein molecule, definition, the bonds which stabilize it. Write and name certain amino acids.
10. Physico-chemical properties of proteins: dialysis, salting-out; definition, principle, use in practice. Write and name certain amino acids.
11. Denaturation of proteins and factors that cause it. Properties of denaturated proteins. Write and name certain amino acids.
12. Give definition to proteins. Point the main functions of proteins in the human organism. Write and name certain amino acids.
13. Carbohydrates: definition, occurrence in nature, functions in the organism.
14. Pentoses. Chemical structure and biological significance of ribose and deoxyribose.
15. Hexoses. Write the formulas of linear and cyclic forms of glucose, fructose and galactose. Point biological significance of the named hexoses.
16. Oligosaccharides. Chemical structure and native sources of sucrose, lactose, maltose. Point the linkages that stabilize that structures.
17. Homopolysaccharides. Important substances for humans. Write a fragment of the glycogen structure. What linkages do stabilize a glycogen molecule?
18. Homopolysaccharides starch and cellulose. Their occurrence in nature, biological significance. What's common and different in their structure?
19. Lipids: definition, occurrence in nature, main functions in the organism.
20. Triacylglycerols. Structure, physico-chemical properties, biological significance.
21. Sterols and sterides. Their chemical structure, biological role, representatives. Chemical structure and biological role of cholesterol.
22. Saturated and unsaturated fatty acids. Their native sources, physico-chemical properties. Write the formulas of stearic, palmitic, oleic, linoleic and linolenic acids.
23. Glycerophospholipids: chemical structure, examples, biological functions. Write the formula of lecithin.
24. Sphingolipids: composition, occurrence in nature.
25. Glycolipids. Characteristics of the main groups, their biological role.
26. Conjugated proteins: definition, classification, importance for human organism vital activity (give examples).

27. Chromoproteins: definition, subclasses, examples. Briefly characterize myoglobin and write the structure of heme b.
28. Hemoglobin: biological functions, structure, functional forms, pathological forms.
29. Glycoproteins: chemical characteristics, structure. Their functions, occurrence in nature, some examples.
30. Proteoglycans: composition, functions, main classes, occurrence. Write a fragment (dimer) of the hyaluronic acid structure.
31. Heparin: place in the system of classification, biological functions. Write a fragment of the heparin structure.
32. Lipoproteins: classification, composition. Give a short characteristics to the main fractions of blood lipoproteins. Atherosclerosis.
33. Phosphoproteins: their composition, occurrence, biological role, some examples.
34. Metaloproteins. Their principal functions, occurrence, some representatives in the human organism.
35. Give classification and characterize protein components of nucleoproteins that are included in DNP (deoxyribonucleoprotein) in the cell.
36. What is a nucleoside? Give definition, write the structures of all (4) ribonucleosides.
37. What is a nucleotide? Give definition, write and name any 2 deoxyribonucleotides.
38. Nucleic acids: definition, classification, functions. Write a mononucleotide.
39. Primary structure of the nucleic acids. Differences between DNA and RNA. Write a mononucleotide.
40. The Chargaff rules. What nucleic acid these rules are true for? Write a mononucleotide.
41. Secondary structure of the nucleic acids. What bonds do stabilize such a structure? Write a mononucleotide.
42. Tertiary structure of the nucleic acids. What bonds do stabilize such a structure? Write a mononucleotide formula.
43. RNA: definition, classification, biological functions. Write the structural formula of ATP (Adenosine triphosphate), its biological role.
44. DNA: definition, peculiarities of structure, biological role. Write the formula of cAMP (cyclic Adenosine-3',5'- monophosphate).
45. Enzymes: definition, biological significance, classification.
46. Similarity and difference between enzymes and nonenzymatic catalysts.
47. Nomenclature and classification of enzymes. Features of the main classes, examples.
48. General knowledge about enzymatic catalysis, its stages and description.
49. Chemical nature of enzymes. Enzyme parts: apoenzyme, coenzyme (prosthetic group), holoenzyme. Role of coenzyme in enzymatic catalysis; examples of coenzymes.
50. Specificity of enzyme action and theories that explain such an important feature.
51. Zymogens and isozymes: definition, biological significance, examples.
52. Active site of enzyme. How is it composed? What amino acids are more frequently included in its structure? Allosteric site of enzyme.
53. Multienzyme systems: definition, their organization, examples, biological importance of such ensembles.
54. Kinetics of enzymatic reactions: dependence of reaction rate on concentrations of enzyme and substrate. Show graphically and explain.

55. Kinetics of enzymatic reactions: dependence of reaction rate on temperature and pH of medium. Show graphically and explain.
56. Regulation of enzyme activity. Activators (positive effectors), direction of action, examples.
57. Regulation of enzyme activity. Reversible and irreversible inhibition. Competitive and uncompetitive inhibition, examples.
58. Enzymopathology, enzymodiagnostics, enzymotherapy.
59. Medical application of enzymes, diagnostics of enzymes, therapy by enzymes. Explain such directions in study and application of enzymes. Examples.
60. Vitamins: definition, classification, occurrence, importance for humans, causes of hypo- and avitaminoses.
61. Vitamin A: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
62. Vitamin D: nomenclature, sources, chemical structure, biological role, hypo- and hypervitaminosis, pharmpreparations.
63. Vitamin E: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
64. Vitamin K: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
65. Vitamin B1: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
66. Vitamin B2: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
67. Vitamin B3: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
68. Vitamin B5: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
69. Vitamin B6: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
70. Vitamin Bc (B9, Folic acid): nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
71. Vitamin B12: nomenclature, sources, chemical nature, biological role, hypovitaminosis, pharmpreparations.
72. Vitamin C: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
73. Biotin: nomenclature, sources, chemical structure, biological role, hypovitaminosis.
74. Water-soluble compounds – vitamin P (Bioflavonoids); biological role, occurrence, chemical nature, mechanism of action.
75. Metabolism: definition, characteristics of two principal directions – catabolism and anabolism. Significance of free energy for metabolic processes.
76. Phases of energy liberation from food substances. Phenomenon of “fuel” universalization in the human organism.
77. High energy compounds: definition, biological role, examples. Write the structural formula of ATP (Adenosine triphosphate).
78. Biological oxidation, its species. Tissue respiration as a special kind of biological oxidation. Write the structural formula of NAD⁺ (Nicotinamide adenine dinucleotide).

79. Name the structural complexes of the mitochondrial respiratory chain (4). Write the structural formula of FMN (Flavin mononucleotide).
80. Point cytochromes of the mitochondrial respiratory chain, give short descriptions to them. Write the structural formula of FAD (Flavin adenine dinucleotide).
81. Ubiquinone (coenzyme Q): its chemical structure, reaction of reduction, biological role.
82. Oxidative phosphorylation: definition, mechanism of the ATP biosynthesis according to the Mitchell's chemi-osmotic theory.
83. Give short descriptions to microsomal and free radical oxidations. Prooxidants and antioxidants: definition, examples.
84. Inhibitors and uncouplers of the tissue respiration and oxidative phosphorylation: definition, examples. Write the structural formula of 2,4-dinitrophenol.
85. The Citric Acid Cycle (Krebs cycle) reactions. Localization and biological significance of the Krebs cycle for the human organism.
86. Xenobiotics: definition, characteristics, possible danger for the human organism.
87. Name the main possible consequences of biochemical transformation of drugs in tissues.
88. Point principal phases in metabolism (biotransformation) of xenobiotics and briefly characterize their essence.
89. Describe the process of microsomal oxidation, name its key participants, and explain importance of such metabolic transformations for the human organism.
90. Name the main reactions of xenobiotic biotransformation phase II; give examples of sulfate conjugation and methylation of drug metabolites.
91. Point the main endocrine glands in the human organism and the hormones they produce.
92. Thyroid gland hormones: chemical nature, biological role, hypo- and hyperfunction of thyroid, pharmaceuticals
93. Hormones, regulating Ca/P metabolism: chemical nature, biological role, hypo- and hypersecretion, pharmaceuticals.
94. Pancreatic hormones: chemical nature, biological role. Abnormalities in functioning of the pancreas; pharmaceuticals.
95. Adrenal medulla hormones: chemical structure, biological role, pharmaceuticals.
96. Glucocorticoids: chemical structure, biological role; hypo- and hyperfunction of the adrenal cortex. Use of glucocorticoids in practice. Pharmaceuticals.
97. Hormones, regulating metabolism of minerals – mineralocorticoids: chemical structure of aldosterone, biological role, hypo- and hypersecretion, pharmaceuticals.
98. Male sex hormones: chemical structure of testosterone, biological role; hyposecretion; pharmaceuticals.
99. Female sex hormones: chemical structure of estradiol and progesterone, biological role; hyposecretion; pharmaceuticals.
100. Anterior pituitary hormones: chemical nature, biological role; abnormalities in secretion; pharmaceuticals.
101. Posterior pituitary hormones: chemical nature, biological role; hyposecretion; pharmaceuticals.
102. Hypothalamic hormones: chemical nature, biological role; pharmaceuticals.
103. Metabolism: definition, characteristics of two principal directions – catabolism and anabolism. Significance of free energy for metabolic processes.

104. Phases of energy liberation from food substances. Phenomenon of “fuel” universalization in the human organism.
105. High energy compounds: definition, biological role, examples. Write the structural formula of ATP (Adenosine triphosphate).
106. Biological oxidation, its species. Tissue respiration as a special kind of biological oxidation. Write the structural formula of NAD⁺ (Nicotinamide adenine dinucleotide).
107. Name the structural complexes of the mitochondrial respiratory chain (4). Write the structural formula of FMN (Flavin mononucleotide).
108. Point cytochromes of the mitochondrial respiratory chain, give short descriptions to them. Write the structural formula of FAD (Flavin adenine dinucleotide).
109. Ubiquinone (coenzyme Q): its chemical structure, reaction of reduction, biological role.
110. Oxidative phosphorylation: definition, mechanism of the ATP biosynthesis according to the Mitchell’s chemi-osmotic theory.
111. Give short descriptions to microsomal and free radical oxidations. Prooxidants and antioxidants: definition, examples.
112. Inhibitors and uncouplers of the tissue respiration and oxidative phosphorylation: definition, examples. Write the structural formula of 2,4-dinitrophenol.
113. The Citric Acid Cycle (Krebs cycle) reactions. Localization and biological significance of the Krebs cycle for the human organism.
114. Digestion of carbohydrates in the human gastro-intestinal tract. Enzymes. Write the structural formulae of sucrose and lactose.
115. Parietal digestion of carbohydrates. Mechanism of monosaccharide absorption.
116. Glycolysis. Chemical reactions. Energy output. Biological significance.
117. Alcohol fermentation, chemical reactions. Similarity and distinction between alcohol fermentation and glycolysis.
118. Glycogenolysis. Chemical reactions. Energy output. Biological significance of the process.
119. Mechanism and enzyme system of the oxidative decarboxylation of pyruvate.
120. Gluconeogenesis: definition of the process, description in short, occurrence in tissues, biological significance.
121. Regulation of carbohydrate metabolism. Hormones of hypo- and hyperglycemic effects.
122. Diabetes mellitus and other pathologies of carbohydrate metabolism. Hypoglycemic pharmaceutical preparations.
123. Glycogen storage diseases (glycogenoses) and other carbohydrate metabolism abnormalities. Give short characteristics.
124. Lipids: definition, properties, biological functions, classification.
125. Chemical structure of triacylglycerols, their biological role.
126. Steroids: chemical structure of cholesterol, biological role.
127. Phospholipids: chemical structure of lecithin, biological role.
128. Emulsification of fats in the intestine. Bile acids, chemical nature, biological role.

129. Lipid digestion in the human GIT. Enzymes. Resynthesis of lipids in the intestinal wall.
130. Reactions of the conversion of glycerol to pyruvate.
131. β -Oxidation of fatty acids by the example of stearic acid. Role of carnitine. Fate of acetyl-CoA. Energy output.
132. β -Oxidation of fatty acids by the example of palmitic acid. Role of carnitine. Energy output.
133. Ketogenesis. Write the formulae of the ketone bodies; their biological role.
134. Regulation and pathologies of lipid metabolism.
135. Hyperlipidemias and atherosclerosis as the most widespread lipid metabolism abnormalities.
136. Define essential and nonessential amino acids for humans. Give structural examples. Significance of amino acids for protein and other syntheses.
137. Digestion of proteins in the stomach. Enzymes. Role of HCl. Mechanism of the pepsinogen activation.
138. Digestion of proteins in the intestine. Enzymes. Mechanism of activation of the pancreatic proteolytic enzymes. Autocatalysis.
139. Reactions of transamination by the examples of pyruvic acid and aspartic acid, alanine and α -ketoglutaric acid. Enzymes. Biological role.
140. Deamination of aminoacids. Definition of the process, examples and its biological significance.
141. Decarboxylation of amino acids. Formation of serotonin, histamin and GABA. Their biological role.
142. The urea cycle: chemical reactions, localization, biological role.
143. Hyperammonemia as a dangerous condition for humans; its causes and consequences.
144. Disorders of amino acid metabolism.
145. Degradation of hemoglobin. Formation of the bile pigments. Characteristics of free and conjugated bilirubin.
146. Pathologies of pigment metabolism. Types of jaundice, their characteristics.
147. Digestion of nucleoproteins in the human GIT.
148. Tissue metabolism of the nucleic acids. Degradation of the purine nucleotides, reactions.
149. Hyperuricemia as a pathological condition in the blood. Gout. Use of allopurinol for treatment.
150. The central dogma of molecular biology which refers to the principal ways of the genetic information transfer.
151. Mechanism of DNA replication. Definition, main stages. Characteristics of the enzymes that take part in the replication process.
152. Reparation of a damaged DNA. Enzymes, catalyzing this process.
153. Transcription of DNA: definition, main stages of the process.
154. The genetic code: definition. Properties of the genetic code.
155. Recognition; its definition. The role of t-RNAs. Formation of aminoacyl-t-RNAs. Characteristics of the enzymes – ARSases.
156. Translation: definition, main stages. Scheme of the translation process.
157. Post-translational covalent modifications of polypeptides synthesized.
158. Preparations that enhance the protein biosynthesis process and its inhibitors.

159. Mutations: main types, characteristics. Molecular diseases.
160. Xenobiotics: definition, characteristics, possible danger for the human organism.
161. Name the main possible consequences of biochemical transformation of drugs in tissues.
162. Point principal phases in metabolism (biotransformation) of xenobiotics and briefly characterize their essence.
163. Describe the process of microsomal oxidation, name its key participants, and explain importance of such metabolic transformations for the human organism.
164. Name the main reactions of xenobiotic biotransformation phase II; give examples of sulfate conjugation and methylation of drug metabolites.

ESTIMATION OF THE FINAL MODULE CONTROL OF THE DISCIPLINE "BIOLOGICAL CHEMISTRY"

Final module control (FMC) is carried out after the completion of the study of module 1 in the final control sessions. Only those higher education graduates who are recruited for the current activity at the end of the vitamin module, at least 36 points (the amount of points for each current class and the control of content modules, see the schedule) are admitted to the FMC. The total amount for the FMC is maximum 40 points. The FMC is considered to be enrolled if a higher education student has scored at least 25 points.

Means for diagnosing the level of training for higher education:

1. Written theoretical survey, the ticket consists of 5 theoretical issues.
2. SUNRAW test (100 tests each).

The structure of the evaluation of tasks for FMC:

- For one theoretical question to a higher education student is exposed from 4 points (see table), generally from 0 to 20 points.

- The score for the answers to the multiple choice questions starts with the 81st test and is scored at 1 point for the test, thus the maximum number of points is: 20.

- The total number of points for the FMC is the arithmetic sum of these two tasks.

When developing the evaluation criteria, the completeness and correctness of the answer to the question are taken as a basis. In addition, the ability of higher education graduates to differentiate, integrate and unify knowledge is taken into account.

ESTIMATION CRITERIA

(for one theoretical question is exposed from 0 to 4 points)

Rating score, points	Criteria for evaluation
3-4	is exhibited by a higher education student who, upon answering the questions, has shown comprehensive, systematic, deep knowledge of the program material, demonstrates the knowledge of the information sources provided by the program and creatively uses this knowledge when answering the problematic issues.
2-3	is exhibited by a higher education student who, upon answering a question, showed full knowledge of the program material, provided at the level of similar reproduction, but suggested some minor failures
1-2	is exhibited by a higher education student who, when answering a question, revealed insufficient knowledge of the main software material to the extent necessary for further study and work provided by the program at the reproductive level
0-1	if, upon answering the question, the applicant of higher education revealed serious gaps in the knowledge of the main material, committed fundamental errors

Rating system of estimation

Module I. Structure of biological macromolecules. Principles of metabolism				Module II. Metabolism and its regulation			
Current control			Module control	Current control			Module control
CM1 Structure, occurrence and biological role of proteins	CM2 Structure and functions of biomolecules	CM3 Introduction into metabolism		CM4 Metabolism of carbohydrates and lipids	CM5 Metabolism of proteins	CM6 Integration and regulation of metabolism	
20	20	20	40	20	20	20	40
100				100			
200/2							

Total rating on the discipline equals to sum of points for current control and final module control (points for *Module I* + *Module II*) : 2.

Quantity of points on the discipline, which is counted for each student, corresponds to certain rating on ECTS scale and is converted into national scale in such a way:

Control of student's progress in study

National Scale	ECTS Scale	Rating estimate, points
5 - excellent	A - excellent	90 - 100
4 - very good	B - very good	84 – 89
4- - good	C - good	75 - 83
3 - satisfactory	D - satisfactory	68 – 74
3- - enough	E - enough (satisfies minimal criteria)	60 – 67
2 - unsatisfactory	FX - unsatisfactory	35 – 59
Not admitted	F - unsatisfactory (additional work is needed)	1 - 34

EXAMPLE OF EXAMINATION PAPER

**MINISTRY OF HEALTH OF UKRAINE
NATIONAL UNIVERSITY OF PHARMACY**

Educational background Master
program subject area 1201 Pharmacy
Specialty 8.12020101 Pharmacy Semester 5th
Educational program Biological chemistry

**FINAL MODULAR CONTROL
MODULE NO. 1 «GENERAL PRINCIPLES OF CELLULAR METABOLISM
ORGANIZATION»**

EXAMINATION PAPER No. 1

1. Proteinogenous amino acids: definition, chemical classification. Write formulas and give the names for aromatic amino acids.
2. Heparin: place in the system of classification, biological functions. Write a fragment of the heparin structure.
3. Active site of enzyme. How is it composed? What amino acids are more frequently included in its structure? Allosteric site of enzyme.
4. Vitamin B2: nomenclature, sources, chemical structure, biological role, hypovitaminosis, pharmpreparations.
5. Give short descriptions to microsomal and free radical oxidations. Prooxidants and antioxidants: definition, examples.

Approved at the Biological Chemistry Department Meeting _
Examination Record No. 2 from 13th of October 2017

Department Chairman, Prof. _____

Zagayko A. L.

Examiner, Prof. _____

Zagayko A. L.

LIST OF METHODOICAL AND SCIENTIFIC LITERATURE

Main:

1. Biological Chemistry: Textbook for the self-study of students / A.L. Zagayko, L.M. Voronina, G.B. Kravchenko, K.V. Strel'chenko.– Kharkiv: NUPh; Original, 2011. - 264p.
2. Clinical biochemistry: An illustrated colour text / A. Gaw, M.J. Murphy, R.A. Cowan and oth. – ELSEVIER Ltd., 2008.- 179p.
3. Textbook of biochemistry: with clinical correlations / edited by Thomas M. Devlin.- John Wiley & Sons, Inc., 2011. - 1204p.

Additional:

1. Lieberman M., Marks A. Marks' basic medical biochemistry: a clinical approach. – Lippincott Williams & Wilkins, a Wolters Kluwer business., 2009. – 1011p.
2. Bhagavan N.V., Chung-Eun H. Essentials of medical biochemistry: with clinical cases. – ELSEVIER Inc., 2011. – 581p.

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BIOLOGICAL CHEMISTRY
*Methodical recommendations
for the final module control to
higher education applicants
in specialties / educational program
«Pharmacy»*