

AL-FARABI KAZAKH NATIONAL UNIVERSITY
Faculty of Medicine and Healthcare
Higher School of Medicine
Department of Fundamental Medicine

Final exam program of
Molecular, Cellular and Genetic Basis of Medicine (7 credits)
Fall semester 2023- 2024 academic year

Expected outcomes:

Students in the final exam must demonstrate the ability to:

1. Demonstrate knowledge of gene biology and mechanisms for implementing genetic information, protein biosynthesis.
2. Apply knowledge of the causes and mechanisms of development of certain changes in the structure and functioning of nucleic acids, especially the expression of genes.
3. Understand the mechanisms of hereditary, variability and their role in the formation of human hereditary pathology and congenital malformations.
4. Understand the molecular-genetic and cellular mechanisms of the body's response to drugs and biologically active compounds.
5. Demonstrate the ability to apply the language and knowledge of each discipline to discuss and solve fundamental scientific and clinical problems.
6. Integrate knowledge of the structural and functional characteristics of the genome to solve clinical problems.
7. Explain the structure, isomerism, and nomenclature of biologically active compounds.
8. Describe the physico-chemical properties, the biological role of compounds involved in the processes of vital activity.
9. Demonstrate the ability to apply the language and knowledge of each discipline to discuss and solve fundamental scientific and clinical problems.
10. Independently find, analyze, and summarize educational and scientific information about situations related to the course content.
11. Apply knowledge of DNA replication and protein biosynthesis processes to solve problems in molecular biology.

MOLECULAR BIOLOGY (4 ECTS)

Approved final exam form - written exam

Topics included in final exam:

1. Introduction to Molecular Biology.
2. The human genome structure and its organization
3. Gene expression: Transcription of genetic information and mRNA processing
4. Gene expression: Translation of genetic information and post-translational modification of proteins
5. Regulation of gene expression
6. Epigenetics
7. Cell signaling
8. Cell differentiation and the development of the multicellular organism.
9. Mutation
10. DNA repair
11. Methods and Techniques in Molecular Biology
12. Methods and Techniques in Molecular Biology

13. Gene engineering and recombinant DNA technology
14. Molecular biomedicine
15. Nanotechnology in medicine

Sample typology of exam questions

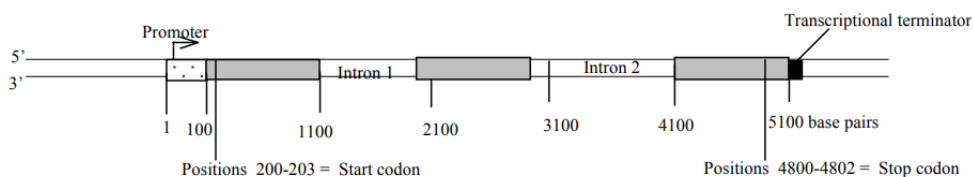
1. Describe the Chargaff, Griffith, Avery-MacLeod-McCarty, Hershey-Chase experiments and explain their significance.
2. Explain informational properties of macromolecules.
3. Explain the central dogma of molecular biology.
4. Briefly discuss the role of molecular biology in medicine.
5. Describe, identify and draw the components of nucleosides and nucleotides.
6. Characterise and describe the chains of nucleic acids in DNA and RNA.
7. Describe the three hypotheses of DNA replication.
8. Describe the Meselson-Stahl experiment and explain its significance.
9. Explain the molecular mechanism of semiconservative DNA replication.
10. Explain the role of main enzymes implicated in the replication process.
11. Explain proofreading mechanisms and error correction during DNA replication.
12. Define the terms: transcription, promoter, enhancer, terminator.
13. Describe prokaryotic and eukaryotic RNA-polymerases' structure and functions.
14. Describe phases of transcription; explain the processes happening at each phase and their importance.
15. Explain the process, importance and difference of Rho-independent and Rho-dependent termination of transcription.
16. Explain the mechanism of polyadenylation, its importance.
17. Describe the structure of the cap fragment, its synthesis and functions.
18. Describe the splicing mechanism and its meaning.
19. Explain the effect of splicing on gene expression.
20. Explain the ribosome cycle and fidelity of translation.
21. Define the genetic code, tRNA, mRNA, codon, anticodon.
22. Describe the structure of tRNA and the mechanism of its charging.
23. Explain the scanning model of translation.
24. Explain the mechanism of translation and its phases.
25. Describe the structure of ribosomes and polysomes.
26. Draw a functional connection between primary structure and higher-order spatial organization of polypeptides.
27. Explain the auxiliary role of chaperones in protein folding.
28. Give detailed examples of human disorders linked with protein misfolding.
29. Define the terms: operon, cistron, promoter.
30. Explain the functioning and regulation of the following operons: lac, ara, trp, gal.
31. Explain positive and negative controls of operons.
32. Differentiate between constitutive and inducible promoters.
33. Explain the mechanism of transcription regulation in eukaryotes.
34. Describe the structure of the promoter: TATA-box, GC-box.
35. Explain the functions of enhancers and silencers.
36. Describe the role of transcription factors and activators in the regulation of transcription
37. Describe the structure and significance of DNA-binding domains and transcription activation domains.
38. Compare translation regulation in pro- and eukaryotes.
39. Explain what a mutation is and its importance for evolution of life.
40. Classify and characterize the main types of mutations.

41. Define the terms: deletion, insertion, inversion, duplication, translocation, and explain what type of mutation each term belongs to and why.
42. Give specific examples of hereditary diseases.
43. List and describe the sources of DNA damage in the cell.
44. Explain the significance of DNA repair.
45. Explain the mechanisms of base excision, nucleotide excision, homologous recombination, non-homologous end joining modes of repair.
46. Explain the importance of epigenetic regulation and its role in heritability of cellular traits.
47. Explain the role of DNA methylation in regulation of gene expression.
48. Explain the mechanism of RNAi.
49. Describe chromatin structure at the levels of organization: nucleosome, 30-nm fiber, chromosome.
50. Explain the effects of histones on transcription.
51. Explain how transcription is affected by: nucleosome positioning, histone acetylation and methylation, chromatin remodeling.
52. Describe the mechanisms and major players of above mentioned processes.
53. Give the definition of intracellular signaling (signal transduction).
54. Classify and characterize membrane cell receptors, give specific examples.
55. Describe and provide examples of secondary intermediaries.
56. Predict the signaling pathways when the cell is exposed to insulin and thyroid hormone, steroid hormones.
57. Characterize the cytoplasmic and nuclear receptors.
58. Give examples of signaling pathways when a cell is exposed to steroid hormones.
59. Give the definitions to the following terms: cell differentiation, morphogenesis, embryogenesis, ontogenesis, stem cells, totipotency, pluripotency.
60. Explain how the level of expression of various genes changes during cell differentiation and at different stages of development of a multicellular organism.
61. Describe the use of stem cells in medicine and cosmetology; analyze the advantages and disadvantages of these methods.
62. Analyze the various theories of aging in the body and the possible relationship of the aging process with stem cells and molecular biological processes.
63. Describe the main histocompatibility complex and its role in human immunity.
64. Explain what humoral and cellular immunity is.
65. Classify and characterize proteins involved in humoral and cellular immunity.
66. Describe congenital and acquired disorders of human immunity.
67. Describe the structure of the human genome: protein-coding genes, intergenic regions (spacers), satellites, tandem repeats, single nucleotide polymorphisms (SNPs).
68. Explain the role of non-coding DNA in the human genome.
69. Discuss the prospects for applying knowledge about the human genome in medicine and pharmaceuticals.
70. Describe DNA transposons, retrotransposons, retroviral integration.
71. Provide examples of human diseases triggered by transposable elements.
72. Discuss the usage of transposable elements in medicine.
73. Give the definitions of genomics, proteomics and bioinformatics, describe their research methods.
74. Explain the Sanger, Maxam-Gilbert, NGS (New Generation Sequencing) and other methods of genome sequencing.
75. Characterize and analyze the main methods of protein research: two-dimensional gel electrophoresis, mass spectrometry, chromatography, X-ray structural analysis, nuclear magnetic resonance.
76. Describe EMBL-EBI, DDJB, NCBI, PIR, MIPS, NBRF, SwissProt, UniProt and other bioinformatical databases.

77. Give the definition of molecular diagnostics and describe its various methods.
78. Explain the reasons for choosing different methods of molecular diagnostics to detect different types of hereditary diseases (gene, chromosomal and genomic), infectious diseases and metabolic diseases, give specific examples.
79. Discuss the ethics of conducting genetic and molecular biological experiments on humans.
80. Describe recombinant DNA technology.
81. Discuss about perspectives and dangers of creating the genetically modified organisms.
82. Describe the use of genetic engineering in the production of vaccines and drugs.
83. Explain the principles of CRISPR-Cas9 technology.
84. Explain what gene therapy is *ex vivo* and *in vivo*, analyze the problems and prospects of genomic technologies in medicine.
85. Give definitions of nanotechnology and bionanotechnology.
86. Describe and provide examples of various bionanotechnologies for targeted delivery of drugs and gene therapy vectors into the cells of the human body.
87. Analyze bionanotechnological methods for the diagnosis and treatment of cancer: quantum dots, magnetic and radioactive nanoparticles, etc.
88. Analyze the prospects for the use of nanorobots in biomedicine.
89. Give definitions and explain the difference between the terms "pharmacogenomics", "pharmacogenetics", "personalized medicine".
90. Explain how a hereditary predisposition can affect the individual reactions of the human body to drugs and dietary supplements, give specific examples.
91. You are studying a very short protein-encoding region whose sequence is shown below. The region of sequence shown is from the transcriptional start site to the transcriptional stop site. This region encodes two different polypeptides. The region's one small intron is shown for you in bold.

5'-CTACGTA**CTATGTATTCCGATCTATA**CTCGATCTAGTCGCATTCCGATAAGATCGTAC-3'
 3'-GATGCATGATACATAAGGCTAGATATGAGCTAGATCAGCGTAAGGCTATTCTAGCATG-5'

- a) What are the sizes of the two polypeptides?
 - b) Which strand is used as a template in transcription for the smaller polypeptide, the upper strand or the lower strand?
92. Below is a schematic of gene Y, which encodes protein Y. The promoter region is indicated by the dotted box. Transcription begins immediately following the promoter.



- a) The transcript first produced by this gene would be approximately how many nucleotides long?
 - b) The transcript from this gene that is used for translation would be approximately how many nucleotides long?
93. DNA isolated from the bacterial virus M13 contains 25% A, 33% T, 22% C, and 20% G. Do these results strike you as peculiar? Why or why not? How might you explain these values?
94. A single-stranded fragment of a DNA molecule has the nucleotide sequence CGTGATTTTGGTTGTA. What structure will the DNA molecule have after replication? Calculate the length of DNA molecule, if the length of single nucleotide is 0.34 nm.
95. What is the length of a fragment of a DNA molecule if it contains 3600 adenyl nucleotides, which is 18% of the total number of nucleotides, and the length of one nucleotide is 0.34 nm?
96. The DNA molecule stores information about a protein, which includes 150 amino acids. There are 1.5 times more thymidyl nucleotides in the DNA fragment than guanyl nucleotides. Determine the number of nucleotides (by content) in DNA and what its length is.

BIOORGANIC CHEMISTRY (3 ECTS)

Approved final exam form - written exam

Topics included in final exam:

1. Introduction: Fundamentals of the structure and reactivity of organic compounds
2. Saturated and unsaturated organic compounds: alkanes, cycloalkanes, alkenes, alkadienes, alkynes
3. Aromatic compounds
4. Mono- and polyhydric alcohols, phenols, ethers
5. Aldehydes, ketones, carboxylic acids
6. Heterofunctional compounds
7. Heterocyclic compounds
8. Carbohydrates: monosaccharides
9. Carbohydrates: di-, oligo- and polysaccharides
10. Amino acids. Biologically important properties of α -amino acids. Peptides
11. Nucleic acids (nucleotides, polynucleotides) and enzymes
12. Lipids
13. Lipids: fatty acids
14. Solutions of macromolecular compounds

Sample typology of exam questions

1. Describe the general structural characteristics of organic molecules the tetravalent nature of carbon and the various ways in which it manifests.
2. Define the functional groups of atoms in organic molecules and give examples.
3. Describe the differences between structural (constitutional) isomers and isomers of functional groups.
4. Write the structures of organic molecules in various ways.
5. Classify organic compounds.
6. Name the organic compounds in accordance with the IUPAC nomenclature system, and derive their structures from the given names.
7. Make structural, condensed, and linear formulas for simple organic compounds.
8. Convert any structural, condensed, or linear formula into its corresponding alternative.
9. Name the hydrocarbons according to the IUPAC nomenclature system.
10. Name and write the structural isomers of alkanes, alkenes, and alkynes.
11. Describe the differences in the physical and chemical properties of alkanes, alkenes, alkynes and aromatic hydrocarbons.
12. Describe the physical properties and basic reactions of alkanes.
13. Draw the isomeric products formed by the halogenation of simple alkanes.
14. Name the cycloalkane by its structure and draw the cycloalkane by its name.
15. Name the functional groups present in the alkenes and alkynes.
16. Explain the differences between saturated and unsaturated molecules.
17. Name a simple alkene or alkyne, given its condensed or linear structure.
18. Draw a condensed or linear structure of an alkene or alkyne by name.
19. Draw and name the cis-trans isomers of alkenes.
20. Predict the products of addition to the alkenes H_2 , Cl_2 , HCl and H_2O .
21. Define "unsymmetrically substituted" and "symmetrically substituted" alkenes.
22. Apply the Markovnikov rule, describing the addition reactions to unsymmetrically substituted alkenes.
23. Predict what polymer forms the alkene monomer gives.

24. Explain the preliminary laboratory techniques of organic chemistry.
25. Be able to apply practical chemical methods.
26. Develop experimental skills and research potential.
27. Give the name according to the IUPAC system and the rational nomenclature of alkanes.
28. Describe the reactions and properties of halogen compounds.
29. Define the alkyl- and aryl halides.
30. Identify the different types of organic reactions.
31. Describe the structural differences between alcohols, phenols, and esters.
32. Explain why alcohols have higher boiling points than compounds of similar molecular weight.
33. Write systematic names for simple alcohols.
34. Draw the alcohol structure by name in condensed and linear format.
35. Classify alcohols as primary, secondary, and tertiary.
36. Define and give examples of glycols.
37. Describe the chemical properties of alcohols.
38. Describe the hydrophobic and hydrophilic alcohols.
39. Predict the products obtained by dehydration of alcohol.
40. Predict the oxidation products of primary, secondary and tertiary alcohol.
41. Explain why alcohols and phenols are weak acids.
42. Define and explain the differences between esters and alcohols.
43. Describe the carbonyl group, its polarity, shape, and chemical properties.
44. Name and draw simple aldehydes and ketones.
45. Describe the polarity, hydrogen bonds, and water solubility of aldehydes and ketones.
46. Describe the reactions and reduction products of aldehydes and ketones.
47. Explain the differences between hemiacetals and hemiketals, acetals and ketals.
48. Name and draw hemiacetals, hemiketals, acetals, and ketals and predict their hydrolysis products.
49. Compare and contrast the structures, reactions, hydrogen bonds, water solubility, boiling points, and acidity or basicity of carboxylic acids, esters, and amides.
50. Name simple carboxylic acids, esters, and amides by their structure, and vice versa, write the structure by the name of these substances.
51. Describe the acidity of various carboxylic acids and predict the products of their reactions with strong bases.
52. Describe how esters and amides are formed from carboxylic acids.
53. Name and write the structures of the aromatic compounds.
54. Explain the importance and function of resonance in aromatic compounds.
55. Name simple monosubstituted or disubstituted aromatic compounds.
56. Predict the products of the interaction of aromatic compounds with concentrated acids and halogens: HNO_3 , Cl_2 , Br_2 and H_2SO_4 .
57. Define and name the aromatic compounds by their structure, explain the value of resonance and aromaticity.
58. Explain the Hückel rule.
59. Describe the chemical properties of heterocyclic compounds.
60. Predict the possible products of chemical reactions of heterocyclic compounds.
61. Describe the nomenclature, structure, and properties of heterocyclic compounds.
62. Give the definition of a chiral carbon atom.
63. Describe the differences between chiral and achiral molecules.
64. Find the stereocenters in the structure of organic molecules and label their configuration as R or S.
65. Explain the differences between enantiomers and their specific rotations.
66. Describe the principles of determining the structure of organic molecules using ultraviolet spectroscopy, infrared spectroscopy, nuclear magnetic resonance, and mass spectrometry.

67. Explain the basics of IR, NMR, UV, and mass spectrometric methods for determining the structure of organic compounds.
68. Draw the structures of twenty protein α -amino acids and their side chains.
69. Define and classify amines as primary, secondary, or tertiary.
70. Name simple amines by their structure or draw amines by their name.
71. Describe the properties of amines, such as hydrogen bonding, solubility, boiling point, and basicity.
72. Define the quaternary ammonium ion and describe its physical and chemical properties.
73. Explain what is meant by α -amino acids, isoelectric point for amino acids, L-configuration for natural amino acids, and the "zwitter-ionic" nature of amino acids.
74. Describe the different functions of proteins and give an example for each function.
75. Define the peptide bond and explain how it is formed.
76. Draw and name the oligopeptide by its amino acid sequence.
77. Find the amide and carboxyl end of the amino acid sequence by its chemical structure.
78. Define the primary structure of the protein and explain how the primary structures are written and depicted.
79. Describe the flat sections of the primary sequence, their effect on the shape of the protein backbone, and find these sections using the drawing of the primary sequence.
80. Give an example of how changing the primary sequence can change the function of a protein.
81. Define the secondary structure, the α -helix and β -sheet, give an example of a protein that consists of α -helices, and a protein that contains β -sheets.
82. Describe the specific hydrogen bond responsible for the formation of the secondary structure of the protein.
83. Explain the differences and functions of fibrous and globular proteins.
84. Classify carbohydrates by functional group and number of carbon atoms, give examples.
85. Draw the D- and L-enantiomers and any diastereomers of the monosaccharides in the Fischer projection.
86. Draw the Fischer projection for the given monosaccharide.
87. Convert the five- and six-carbon monosaccharides from the Fischer projection to the Haworth projection.
88. Find the anomeric carbon atom and the α - or β -form of the monosaccharide and describe the role of mutarotation in the cyclic structure.
89. Give the names and structures of the most common monosaccharides, describe their sources and use.
90. Predict the products of the oxidation and reduction reactions of monosaccharides.
91. Predict the reaction products between monosaccharides and alcohols.
92. Predict the products of polysaccharide hydrolysis reactions and monosaccharide phosphorylation reactions.
93. Predict the results of some common reactions of simple carbohydrates, such as oxidation, reduction, osazone formation, etc.
94. Describe the formation of a glycosidic bond as a type of dehydration reaction.
95. Give the names and structures of the most common disaccharides, their components, and the relationship between them, describe the sources of these disaccharides and their use.
96. Name and describe common polysaccharides, their natural sources, and functions.
97. Describe the monomers of these polysaccharides and the type of chemical bond between them in each polysaccharide.
98. Name and describe the modified monosaccharides found in natural polysaccharides and determine the functions of these polysaccharides.
99. Describe the chemical structure and general properties of fatty acids, waxes, sterols, fats, and oils.
100. Describe the characteristics of fatty acids and fatty acid esters.

101. List the physical properties of fats and oils and explain how they differ.
102. Describe the reactions of hydrogenation and hydrolysis of triacylglycerols, give the reagents and reaction products.
103. Define phospholipids and glycolipids, describe their chemical structure and functions.
104. Define sterols and their derivatives and describe their structure and functions.

Sample exam ticket

Ticket №

| № | Question text | Grades |
|----------------|---|--------|
| BLOCK 1 | | |
| | Explain the role of DNA methylation in regulation of gene expression. | 30 |
| BLOCK 2 | | |
| | DNA isolated from the bacterial virus M13 contains 25% A, 33% T, 22% C, and 20% G. Do these results strike you as peculiar? Why or why not? How might you explain these values? | 30 |
| BLOCK 3 | | |
| | Name and describe the modified monosaccharides found in natural polysaccharides and determine the functions of these polysaccharides. | 40 |

Response Quality Scale

| The mark | Criteria | The scale, points |
|---------------------|--|-------------------|
| Excellent | 1. all key aspects included and presented logically; 2. high accuracy (relevance, without redundancy) and consistent focus on question; 3. excellent integration of theoretical issues; 4. provision of relevant examples; 5. in-depth analysis and theoretical justification of given problem (if applicable), all key aspects identified and interpreted; 6. fluency in use of professional terminology | 90 - 100 |
| Good | 1. all key aspects included and presented logically; 2. consistent focus on question with satisfactory accuracy, and relevance, and/or some redundancy; 3. satisfactory integration of theoretical issues; 4. lack of examples; 5. satisfactory analysis and theoretical justification of given problem (if applicable), most key aspects identified and interpreted; 6. correct use of professional terminology | 70 - 89 |
| Satisfactory | 1. most key aspects included; 2. satisfactory focus on question - some lapses of relevance and/or noticeably redundancy; 3. theoretical issues presented without noticeably integration; 4. provision of unsuccessful examples or no examples; 5. some analysis and theoretical justification of given problem (if applicable), most key aspects identified and interpreted; 6. correct use of professional terminology | 50 - 69 |
| Unsatisfactory (FX) | 1. most key aspects missed; 2. lack of focus on question - no relevance and notable redundancy; 3. some theoretical issues presented in some way; 4. no or irrelevant examples; 5. some analysis and theoretical justification of a given problem (if applicable), most key aspects missed; 6. lapses in use of professional terminology | 25 - 49 |
| Failed | 1. most or all key aspects missed; 2. no focus on question, irrelevant information; 3. theoretical issues missed or superficial; 4. no or irrelevant examples; 5. no analysis and no theoretical justification of a given problem (if applicable), most key aspects missed; 6. lapses in use of professional terminology | 0-24 |

The system of marks

| Alphabetic Grading System | Numeric Equivalent | Score (percentage) | Traditional Grading System |
|---------------------------|--------------------|--------------------|--|
| A | 4,0 | 95-100 | Excellent |
| A- | 3,67 | 90-94 | |
| B+ | 3,33 | 85-89 | Good |
| B | 3,0 | 80-84 | |
| B- | 2,67 | 75-79 | |
| C+ | 2,33 | 70-74 | |
| C | 2,0 | 65-69 | Satisfactory |
| C- | 1,67 | 60-64 | |
| D+ | 1,33 | 55-59 | |
| D- | 1,0 | 50-54 | |
| FX | 0,5 | 25-49 | Unsatisfactory |
| F | 0 | 0-24 | |
| I (Incomplete) | - | - | “The discipline has not been completed” <i>(is not taken into account during the GPA calculation)</i> |

Guidelines for exam conducted offline in the classroom.

WRITTEN EXAM:

TRADITIONAL - ANSWERS TO QUESTIONS.

The process of taking a written exam by the student involves the automatic creation of an exam ticket for the student, to which you must form a written answer by direct handwriting.

Exam Technology Instructions

1. The duration of the exam is exactly 2 hours.
2. Written exams are administered according to the approved schedule.
3. Students may enter the auditorium where the written exam is administered only with an ID card (Passport or student ID card). The presence of persons not participating in the examination procedure is prohibited.
4. The proctor reconciles the identification document with the admission permission slip. A student who has a discipline clearance rating of less than 50% is not allowed to take the written exam.
5. The proctor (calls the names from the list and sits them down according to the list) starts them in the auditorium.
6. Late students are not allowed to take the exam.
7. Proctor gives each student an answer sheet (if necessary, the student may take an additional answer sheet) and gives the student a ticket for the discipline being passed.
8. Students present at the exam must sign the admission form.
9. The start and end times of the written exam are recorded on the blackboard.
10. During the written exam, students' questions on the content of the examination tickets are not considered.

11. If the student does not comply with the established requirements at the exam: uses crib notes, mobile and other devices, allows disciplinary violations, disturbs other students with their actions, the proctor has the right to remove student from the audience. In this case, an act of violation of the examination procedure is drawn up, the answer sheet is annulled by crossing out diagonally, the mark "Removed for violation" is made in the admission sheet, "0" points will be given in the sheet.

12. It is allowed for a student to visit the restroom no more than 1 time per hour, lasting no more than 5 minutes. If frequent visits to the restroom are required (for example, due to health conditions), the student must undergo a medical examination, and the exam is counted as the student's absence from the exam.

13. At the end of the exam, the student must turn in his/her ticket and answer sheet.

Basic literature:

1. Alberts B. et al. Molecular biology of the cell. 6th ed. 2015. Garland Science.
2. Lodish H. et al. Molecular cell biology. 8th ed. 2016. WH Freeman.
3. John McMurry, et al. Fundamentals of General, Organic, and Biological Chemistry, 8th Edition. 2018. Pearson Education Limited.
4. Soderberg T. Organic Chemistry with a Biological Emphasis. 2016. Chemistry Publications.
5. Azimbayeva, Gulnur Toleugaziyevna. Organic Chemistry [Text]: textbook / Gulnur Toleugaziyevna Azimbayeva; Ministry of Education and Science of the Republic of Kazakhstan. - Almaty: Association of Higher Educational Institutions of Kazakhstan, 2016. - 313 p.: tab. - Bibliogr.: p. 313. - ISBN 978-601-7529-86-4

Additional literature

1. Jenis, J. Study Guide and Practice Tests for Organic Chemistry (Organic Compounds of Aliphatic Series) / Al-Farabi KazNU. Almaty: Qazaq university, 2017.
2. Russell P.J. iGenetics. A molecular approach. 3rd ed. 2009. Pearson.
3. Karp G. Cell and molecular biology. Concepts and experiments. 7th ed. 2013. Wiley.
4. Hartwell L. et al. Genetics. From genes to genomes. 4th ed. 2011. McGraw Hill.
5. Zhussupova A.I. Molecular Biology (Interdisciplinary Approaches in Teaching and Research) / Al-Farabi KazNU. Almaty: Qazaq university, 2016.
6. Kroschwitz J.I. Chemistry: general, organic, biological. New York, 1990.
7. Rastogi V.B. Zubay's principles of biochemistry. New Dehli, 2017.
8. Alagarsamy, V. Textbook of Medicinal Chemistry. New Dehli, 2016.
9. Zhussupova A.I. Modern issues in molecular diagnostics / Al-Farabi. Kazakh National University - Almaty: Qazaq university, 2015.
10. Nazarbekova S.P. Chemistry. - Almaty: Association of Higher Educational Institutions of Kazakhstan, 2016.
11. Jenis J. Chemistry of Natural Compounds / Al-Farabi Kazakh National University. - Almaty: Qazaq university, 2016.
12. Zhussupova A.I. PCR-diagnostics / Al-Farabi Kazakh National University. - Almaty: Qazaq university, 2015.

Internet resources

1. Lecturio.com
<https://www.lecturio.com>
2. "Human Genome" Project
https://web.ornl.gov/sci/techresources/Human_Genome/project/info.shtml
3. NCBI - The National Center for Biotechnology Information, USA
<https://www.ncbi.nlm.nih.gov/>
4. NDB - a portal for three-dimensional structural information about nucleic acids
<http://ndbserver.rutgers.edu/>
5. OMIM - compendium of human genes and genetic phenotypes
<https://www.ncbi.nlm.nih.gov/omim?db=OMIM>
6. Ensembl - Genome browser for vertebrate genomes
<http://asia.ensembl.org/index.html>
7. EMBL-EBI - European Bioinformatics Institute
<https://www.ebi.ac.uk/>
8. Video lectures by Molecular Biology:
<https://www.khanacademy.org/>