

**Federal State Autonomous Educational Institution of Higher Education "Moscow
Institute of Physics and Technology
(National Research University)"**

APPROVED
**Head of the Phystech School of
Biological and Medical Physics**
D.V. Kuzmin

Work program of the course (training module)

course: Medicinal Chemistry: fundamental concepts and modern approaches/Медицинская химия: фундаментальные концепции и современные подходы

major: Biotechnology

specialization: Medical Biotechnology/Медицинская биотехнология
Phystech School of Biological and Medical Physics
Center for educational programs in bioinformatics

term: 2

qualification: Master

Semester, form of interim assessment: 3 (fall) - Exam

Academic hours: 30 AH in total, including:

lectures: 30 AH.

seminars: 0 AH.

laboratory practical: 0 AH.

Independent work: 30 AH.

Exam preparation: 30 AH.

In total: 90 AH, credits in total: 2

Authors of the program:

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O.Y. Belogurova-Ovchinnikova, phd (candidate of biological sciences)

The program was discussed at the Center for educational programs in bioinformatics 30.08.2021

Annotation

The purpose of the discipline is the formation of basic knowledge in medicinal chemistry, the ability to apply the knowledge gained in practice; understanding the basic principles of developing physiologically active compounds based on synthetic and natural molecules; theoretical mastery of modern methods of computer design of physiologically active substances.

1. Study objective

Purpose of the course

- formation of basic knowledge in medicinal chemistry, the ability to apply the knowledge gained in practice;
- understanding the basic principles of the development of physiologically active compounds based on synthetic and natural molecules;
- theoretical mastery of modern methods of computer design of physiologically active substances.

Tasks of the course

- study of basic concepts, terminology and methods of medicinal chemistry;
- study of the basic principles of drug design;
- theoretical mastering of key technologies for drug development;
- familiarization with current examples of drug development.

2. List of the planned results of the course (training module), correlated with the planned results of the mastering the educational program

Mastering the discipline is aimed at the formation of the following competencies:

Code and the name of the competence	Competency indicators
UC-1 Use a systematic approach to critically analyze a problem and develop an action plan	UC-1.1 Systematically analyze the problem situation, identify its components and the relations between them
	UC-1.2 Search for solutions by using available sources
	UC-1.3 Develop a step-by-step strategy for achieving a goal, foresee the result of each step, evaluate the overall impact on the planned activity and its participants
UC-2 Manage all stages of a research project	UC-2.1 Set an objective within a defined scientific problem; formulate the agenda, relevance, significance (scientific, practical, methodological, or other, depending on the project type), forecast the expected results and possible areas of their application
	UC-2.2 Forecast the project outcomes, plan necessary steps to achieve the outcomes, chart the project schedule and monitoring plan
	UC-2.3 Organize and coordinate the work of project stakeholders, provide the team with necessary resources
	UC-2.4 Publicly present the project results (or results of its stages) via reports, articles, presentations at scientific conferences, seminars, and similar events
Gen.Pro.C-1 Gain fundamental scientific knowledge in the field of biological, physical, mathematical sciences	Gen.Pro.C-1.1 Apply fundamental scientific knowledge in the field of biological, physical, mathematical sciences
	Gen.Pro.C-1.2 Consolidate and critically assess professional experience and research findings
	Gen.Pro.C-1.3 Understand interdisciplinary relations in applied biological, physical, mathematical sciences and apply them in professional tasks
	Gen.Pro.C-1.4 Able to plan, organise and carry out research work in biotechnology, correctly process the results of experiments and draw valid opinions and conclusions
	Gen.Pro.C-4.1 Apply ICT knowledge and skills to search for and study scientific literature, using software products

Gen.Pro.C-4 Successfully perform a task, analyze the results, and present conclusions, apply knowledge and skills in the field of physical and mathematical sciences and ICTs	Gen.Pro.C-4.2 Apply knowledge in the field of physical and mathematical sciences to solve problems, make conclusions, and evaluate the obtained results
	Gen.Pro.C-4.3 Justify the chosen method of scientific research
	Gen.Pro.C-4.4 Evaluate, analyze, and interpret the results of biotechnological processes
	Gen.Pro.C-4.5 Set scientific and technical objectives, using biotechnological processes and the proper equipment

3. List of the planned results of the course (training module)

As a result of studying the course the student should:

know:

- the place of medicinal chemistry in the modern paradigm of drug development;
- communication of medicinal chemistry, combinatorial synthesis and computer screening;
- approaches to optimization of pharmacokinetic and physicochemical parameters of molecules;
- the main biological targets and cascades for the action of drugs;
- principles for the development of target-specific compounds;
- principles for the rational design of libraries of chemical compounds;
- methods for the transformation of active compounds (bioisosteric approach, similarity of shape, similarity of small structural fragments, etc.) for the purpose of optimization;
- typical synthetic methods for obtaining physiologically active substances;
- key computer methods in medicinal chemistry;
- basic bases of chemical and biological information;
- communication of medicinal chemistry with modern technologies in genomics and proteomics.

be able to:

- use key methods of medical and chemical design of chemical compounds;
- use modern databases of chemical and biological data;
- select and apply suitable research tools and methods to solve the assigned tasks;
- critically evaluate the applicability of the recommended techniques and methods.

master:

- basic concepts, concepts and methods of medical and chemical design of compounds;
- basic concepts of molecular biotargets;
- basic concepts of the pharmacological properties of chemical compounds.

4. Content of the course (training module), structured by topics (sections), indicating the number of allocated academic hours and types of training sessions

4.1. The sections of the course (training module) and the complexity of the types of training sessions

№	Topic (section) of the course	Types of training sessions, including independent work			
		Lectures	Seminars	Laboratory practical	Independent work
1	Medical chemistry, introduction	3			3
2	Biological targets	3			3
3	Computer screening	2			2
4	Database	3			3
5	Methods for Designing Chemical Structures and Compound Libraries	3			3
6	Molecular modeling techniques	2			2
7	Optimization of pharmacological parameters	3			3
8	Synthetic and analytical methods	3			3
9	Medicines based on natural molecules	3			3

10	Drug development in topical pharmacological areas	2			2
11	Philosophy of discipline, problems, perspectives	3			3
AH in total		30			30
Exam preparation		30 AH.			
Total complexity		90 AH., credits in total 2			

4.2. Content of the course (training module), structured by topics (sections)

Semester: 3 (Fall)

1. Medical chemistry, introduction

History of origin, subject of discipline. The tasks of medicinal chemistry. Connection with modern drug development technologies.

2. Biological targets

Lipid membranes. Nucleic acids. Proteins. Protein biological targets. Enzymes. Types of inhibition. The principles of creating drugs - enzyme inhibitors. Receptors. The structure and function of receptors. Neurotransmitters. Types of receptor modulation. Receptor agonists and antagonists. Ion channel receptors.

G-protein coupled receptors. Structure, functions, mechanisms of functioning. Lipid membranes and receptors. GPCR as a drug target. Kinase and nuclear receptors. Structure, functions, mechanisms of functioning.

3. Computer screening

Computer screening as a key technology in medicinal chemistry and drug development. Key approaches.

The main tasks of computer screening. Data analysis methods. Molecular descriptors.

Methods for the selection of molecular descriptors. Key approaches and algorithms for QSAR analysis. Regressions. Classification analysis. Evaluation of "drug-like". Projection (mapping) methods. Key approaches. Examples of tasks to be solved.

4. Database

Databases of chemical and biological information. Types of bases. Application in medicinal chemistry. Typical problems.

5. Methods for Designing Chemical Structures and Compound Libraries

Methods for the design and morphing of chemical structures. Combinatorial library design.

Bioisosteric similarity.

6. Molecular modeling techniques

Pharmacophore modeling methods. 2D / 3D pharmacophores.

Molecular docking. Theoretical foundations of the approaches. Basic software tools. Examples of drug design.

7. Optimization of pharmacological parameters

Pharmacokinetics and metabolism (ADME properties) of medicinal substances. Forecasting and design methods.

Optimization of physicochemical and pharmacological properties of drugs. Prodrugs. Delivery systems, including targeted ones. Increasing the solubility of substances. Penetrators.

Toxicity of medicinal substances. Forecasting and design methods.

Clinical side effects of medications. Database. Assessment and forecasting methods.

8. Synthetic and analytical methods

Synthetic methods for obtaining physiologically active substances. Analytical methods in medicinal chemistry. Isolation of active substances and their purification.

9. Medicines based on natural molecules

Medicines based on natural molecules. Significance for health care. Research methods, analysis, modification.

Medicines based on natural molecules (continued). Actual examples.

10. Drug development in topical pharmacological areas

Development of anticancer drugs, anti-infectious, cardiovascular drugs, drugs for the treatment of diseases of the nervous system, drugs in other topical pharmacological areas. The main types of drugs. Design methods. Actual examples.

11. Philosophy of discipline, problems, perspectives

Philosophy of discipline. Actual problems. Advanced technologies. New Horizons.

5. Description of the material and technical facilities that are necessary for the implementation of the educational process of the course (training module)

Equipment needed for lectures and seminars: computer and multimedia equipment (projector, sound system)

6. List of the main and additional literature, that is necessary for the course (training module) mastering

Main literature

Provided at the base department

1. Orlov V.D., Lipson V.V., Ivanov V.V. Medical chemistry. - Kharkov .: Folio, 2005 .-- 461 p.
2. Granik V.G. Fundamentals of medicinal chemistry. Moscow: University book, 2001 .-- 384 p.
3. Patrick G.L. Introduction to Medicinal Chemistry. - London, 1995 .-- 336 p.

Additional literature

Provided at the base department

1. Nogrady T. Medicinal chemistry: a biochemical approach. (2nd ed.), 1988.
2. Hermann E., Franke R., Computer Aided Drug Design in Industrial research., 1995.
3. Kubinyi H. QSAR: Hansch Analysis and Related Approaches (Methods and Principles in Medicinal Chemistry, Vol.1), VCH, 1993.

7. List of web resources that are necessary for the course (training module) mastering

<http://chemistry-chemists.com/Uchebniki.html>

<http://www.freebookcentre.net/Chemistry/Medicinal-Chemistry-Books.html>

8. List of information technologies used for implementation of the educational process, including a list of software and information reference systems (if necessary)

For some of the lessons, you will need Zoom. Google Drive to access course materials. The presence of smartphones / laptops during classes is encouraged to participate in interactive exercises.

9. Guidelines for students to master the course

A student who studies discipline must, on the one hand, master a general conceptual apparatus, and on the other hand, must learn to apply theoretical knowledge in practice.

As a result of studying the discipline, the student should know the basic definitions of the discipline, be able to apply this knowledge to solve various problems.

Successful learning requires:

- visits to all classes provided by the curriculum for the discipline;
- conducting the abstract of occupations;
- intense independent work of the student.

Independent work includes:

- reading recommended literature;
- study of educational material, preparation of answers to questions intended for self-study;
- solving problems offered to students in the classroom;
- preparation for performance of tasks of the current and intermediate certification.

An indicator of possession of the material is the ability to answer questions on discipline topics without an outline.

It is important to achieve an understanding of the material being studied, and not its mechanical memorization. If it is difficult to study individual topics, questions, you should seek advice from the teacher.

Intermediate control of students' knowledge in the form of problem solving in accordance with the subject of classes is possible

Assessment funds for course (training module)

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Semester, form of interim assessment: 3 (fall) - Exam

Authors:

A.S. Dukh
O.Y. Belogurova-Ovchinnikova, phd (candidate of biological sciences)

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
UC-1 Use a systematic approach to critically analyze a problem and develop an action plan	UC-1.1 Systematically analyze the problem situation, identify its components and the relations between them
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UC-2 Manage all stages of a research project	UC-2.1 Set an objective within a defined scientific problem; formulate the agenda, relevance, significance (scientific, practical, methodological, or other, depending on the project type), forecast the expected results and possible areas of their application
	UC-2.2 Forecast the project outcomes, plan necessary steps to achieve the outcomes, chart the project schedule and monitoring plan
	UC-2.3 Organize and coordinate the work of project stakeholders, provide the team with necessary resources
	UC-2.4 Publicly present the project results (or results of its stages) via reports, articles, presentations at scientific conferences, seminars, and similar events
Gen.Pro.C-1 Gain fundamental scientific knowledge in the field of biological, physical, mathematical sciences	Gen.Pro.C-1.1 Apply fundamental scientific knowledge in the field of biological, physical, mathematical sciences
	Gen.Pro.C-1.2 Consolidate and critically assess professional experience and research findings
	Gen.Pro.C-1.3 Understand interdisciplinary relations in applied biological, physical, mathematical sciences and apply them in professional tasks
	Gen.Pro.C-1.4 Able to plan, organise and carry out research work in biotechnology, correctly process the results of experiments and draw valid opinions and conclusions
Gen.Pro.C-4 Successfully perform a task, analyze the results, and present conclusions, apply knowledge and skills in the field of physical and mathematical sciences and ICTs	Gen.Pro.C-4.1 Apply ICT knowledge and skills to search for and study scientific literature, using software products
	Gen.Pro.C-4.2 Apply knowledge in the field of physical and mathematical sciences to solve problems, make conclusions, and evaluate the obtained results
	Gen.Pro.C-4.3 Justify the chosen method of scientific research
	Gen.Pro.C-4.4 Evaluate, analyze, and interpret the results of biotechnological processes
	Gen.Pro.C-4.5 Set scientific and technical objectives, using biotechnological processes and the proper equipment

2. Competency assessment indicators

As a result of studying the course the student should:

know:

- the place of medicinal chemistry in the modern paradigm of drug development;
- communication of medicinal chemistry, combinatorial synthesis and computer screening;
- approaches to optimization of pharmacokinetic and physicochemical parameters of molecules;
- the main biological targets and cascades for the action of drugs;
- principles for the development of target-specific compounds;
- principles for the rational design of libraries of chemical compounds;
- methods for the transformation of active compounds (bioisosteric approach, similarity of shape, similarity of small structural fragments, etc.) for the purpose of optimization;
- typical synthetic methods for obtaining physiologically active substances;
- key computer methods in medicinal chemistry;
- basic bases of chemical and biological information;
- communication of medicinal chemistry with modern technologies in genomics and proteomics.

be able to:

- use key methods of medical and chemical design of chemical compounds;
- use modern databases of chemical and biological data;
- select and apply suitable research tools and methods to solve the assigned tasks;
- critically evaluate the applicability of the recommended techniques and methods.

master:

- basic concepts, concepts and methods of medical and chemical design of compounds;
- basic concepts of molecular biotargets;
- basic concepts of the pharmacological properties of chemical compounds.

3. List of typical control tasks used to evaluate knowledge and skills

During the current control, the student should be able to answer the following questions:

1. Medical chemistry: history of origin, subject of discipline. The tasks of medicinal chemistry.
2. Types of biological targets. Features and basic mechanisms of drugs depending on the type of target.
3. Enzymes. Types of inhibition. The principles of creating drugs - enzyme inhibitors.
4. Receptors. The structure and function of receptors. Neurotransmitters. Types of receptor modulation.
5. Agonists and antagonists of receptors. Ion channel receptors.
6. Receptors coupled with G-proteins. Structure, functions, mechanisms of functioning.
7. Kinase receptors. Structure, functions, mechanisms of functioning.
8. Nuclear receptors. Structure, functions, mechanisms of functioning.
9. Computer screening as a key technology in medicinal chemistry and drug development. Key approaches.
10. Methods of data analysis.
11. Molecular descriptors.
12. Methods for the selection of molecular descriptors.
13. Key approaches and algorithms for QSAR analysis. Regressions.
14. Classification analysis. Key approaches and algorithms.
15. Evaluation of "drug-similarity".
16. Methods of projection (mapping). Key approaches and features of the methods. Examples of tasks to be solved.

During the class, interactive discussions can take place in the course chats, which will be homework. It is possible to perform patent search as an independent task. Successful completion of all tasks in the course and the completion of control slices of knowledge gives an advantage in the exam.

4. Evaluation criteria

1. Medical chemistry: history of origin, subject of discipline. The tasks of medicinal chemistry.
2. Types of biological targets. Features and basic mechanisms of drugs depending on the type of target.
3. Enzymes. Types of inhibition. The principles of creating drugs - enzyme inhibitors.
4. Receptors. The structure and function of receptors. Neurotransmitters. Types of receptor modulation.
5. Agonists and antagonists of receptors. Ion channel receptors.
6. Receptors coupled with G-proteins. Structure, functions, mechanisms of functioning.

7. Kinase receptors. Structure, functions, mechanisms of functioning.
8. Nuclear receptors. Structure, functions, mechanisms of functioning.
9. Computer screening as a key technology in medicinal chemistry and drug development. Key approaches.
10. Methods of data analysis.
11. Molecular descriptors.
12. Methods for the selection of molecular descriptors.
13. Key approaches and algorithms for QSAR analysis. Regressions.
14. Classification analysis. Key approaches and algorithms.
15. Evaluation of "drug-similarity".
16. Methods of projection (mapping). Key approaches and features of the methods. Examples of tasks to be solved.
17. Databases of chemical and biological information. Types of bases. Application in medicinal chemistry. Typical problems.
18. Methods for the design and morphing of chemical structures.
19. Design of combinatorial libraries.
20. Bioisosteric similarity. Application in drug design.
21. Methods of pharmacophore modeling. 2D / 3D pharmacophores.
22. Molecular docking. Theoretical foundations of the approaches. Basic software tools.
23. Pharmacokinetics and metabolism (ADME properties) of medicinal substances. Forecasting and design methods.
24. Optimization of physicochemical and pharmacological properties of drugs. Prodrugs.
25. Delivery systems, including targeted delivery systems. Penetrators.
26. Increasing the solubility of substances.
27. Toxicity of medicinal substances. Forecasting and design methods.
28. Clinical side effects of drugs. Database. Assessment and forecasting methods.
29. The main synthetic methods of obtaining physiologically active substances. Methods of C-C connection formation.
30. The main synthetic methods of obtaining physiologically active substances, not associated with the formation of C-C bonds.
31. Combinatorial synthesis as a basic technology in drug development.
32. Analytical methods in medicinal chemistry.
33. Isolation of active substances and their purification.
34. Medicines based on natural molecules. Examples. Significance for health care.
35. Methods of research, analysis, modification of drugs based on natural molecules.

Sample tickets.

1. Development of anticancer drugs. The main classes of drugs by the mechanism of targeted action. Design methods. Examples.
2. Development of anti-infectious drugs. The main classes of drugs by the mechanism of action. Design methods. Examples.

1. Development of cardiovascular drugs. The main classes of drugs by the mechanism of action. Design methods. Examples.
2. Development of drugs for the treatment of diseases of the nervous system. The main classes of drugs by the mechanism of action. Design methods. Examples.

The mark is excellent (10 points) - it is given to a student who has shown comprehensive, systematic, deep knowledge of the curriculum of the discipline, who has an interest in this subject area, has demonstrated the ability to confidently and creatively put them into practice in solving specific problems, and a free and proper substantiation of decisions.

The mark is excellent (9 points) - it is given to a student who has shown comprehensive, systematic, in-depth knowledge of the curriculum of the discipline and the ability to confidently put them into practice in solving specific problems, free and proper substantiation of the decisions made.

The mark is excellent (8 points) - given to a student who has shown comprehensive, systematic, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice in solving specific problems, correct justification of decisions made, with some shortcomings.

A mark is good (7 points) - it is put up for a student, if he knows the material firmly, sets it up competently and in essence, knows how to apply the knowledge gained in practice, but does not competently substantiate the results obtained.

Evaluation is good (6 points) - it is put up to a student, if he knows the material firmly, sets it up correctly and in essence, knows how to apply this knowledge in practice, but admits some inaccuracies in the answer or in solving problems.

A mark is good (5 points) - it is given to a student, if he basically knows the material, correctly and essentially sets it out, knows how to apply this knowledge in practice, but allows a sufficiently large number of inaccuracies to answer or solve problems.

Grade satisfactorily (4 points) is given to a student who has shown the fragmented, fragmented nature of knowledge, insufficiently correct formulations of basic concepts, violations of the logical sequence in the presentation of program material, but at the same time he has mastered the main sections of the curriculum necessary for further education and can apply knowledge is modeled in a standard situation.

Grade satisfactorily (3 points) - given to a student who showed the fragmented, scattered nature of knowledge, making mistakes in formulating basic concepts, disrupting the logical sequence in presenting program material, poorly masters the main sections of the curriculum required for further education and even applies the knowledge gained in a standard situation.

The rating is unsatisfactory (2 points) - is given to a student who does not know most of the main content of the curriculum of the discipline, makes gross mistakes in the wording of the basic principles and does not know how to use this knowledge when solving typical tasks.

Unsatisfactory mark (1 point) - is given to a student who does not know the main content of the discipline's curriculum, makes gross errors in the wording of the basic concepts of the discipline and does not have any skills to solve typical practical problems.

5. Methodological materials defining the procedures for the assessment of knowledge, skills, abilities and/or experience

During the oral exam, the student is given 30 minutes to prepare. The interview for a student in an oral exam must not exceed one astronomical hour.