Національний технічний університет України «КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ імені ІГОРЯ СІКОРСЬКОГО»

Bioinformatics department

MODERN ADVANCES IN BIOENGINEERING AND BIOINFORMATICS

Work program of the discipline (Syllabus)

Details of the discipline

Level of higher education: *Third (educational and scientific)*

Branch of knowledge	16 – Chemical and bioengineering
Specialty	162 Biotechnology and Bioengineering
Educational program	*Biotechnology*
Discipline status	Normative (basic)
Form of study	part-time
Year of preparation, semester	2nd year, spring
Scope of discipline	4 credits
Semester control / types of control	Exam/Test
Lessons schedule	***Lecture: 6 hour ; seminars: 2 hour***
Language	English
Information about professor	Lecturer: Professor, Doctor of Technical Sciences Svitlana Gorobets, pitbm@ukr.net, Professor, Doctor of Technical Sciences Tetyana Todosiychuk, todosiychuk@bigmir.net . Seminars: Professor, Doctor of Technical Sciences Svitlana Gorobets, pitbm@ukr.net, Professor, Doctor of Technical Sciences Tetyana Todosiychuk, todosiychuk@bigmir.net.
Course placement	https://do.ipo.kpi.ua/course/view.php?id=4673

Curriculum of the Discipline

1. Description of the discipline, its purpose, subject of study and learning outcomes

An important task of doctoral training, along with research and dissertation writing is to increase the intellectual potential of doctors of philosophy to the level of understanding the processes of formation and development of new branches of science and improving existing, starting, and developing new industries. The discipline “Modern advances in bioengineering and bioinformatics” is assigned for acquirement of the competencies, knowledge, skills and experience in understanding and forecasting these processes in modern science and including in the field of biotechnology as a scientific and practical activity.

The discipline "Modern advances in bioengineering and bioinformatics" forms a system of competencies, skills and activities for postgraduate students to analyze and predict the development of the biotechnology industry based on the knowledge of the molecular basis of gene therapy and the latest tools and methods of bioinformatics. The objectives of the discipline are the formation of graduate students with the necessary competencies, knowledge, skills and abilities for successful postgraduate activities.

The purpose of discipline is to develop the students' ability to:

- search, analysis and processing of information,
- work in the international scientific space, conducting scientific research at the current level,
- regenerating new ideas for the creation of new drugs using the knowledge of modern development of bioinformatics and bioengineering,
- developing new and improve existing biotechnologies based on new bioengineering methods,
- critical understanding of modern methods of bioengineering and bioinformatics to generate new hypotheses for the adaptation of new methods in technological processes,
- performing original research in the field of bioengineering to create new knowledge in the field of biotechnology,
- critical evaluation of the obtained results, making decisions and recommendations of alternative strategies for solving problems related to the creation and regulation of biological objects, research methods and technologies with their participation.

The subject of the discipline is the patterns of processes of origin and further development of theoretical and experimental principles of gene therapy, methods and approaches of natural and engineering sciences for their applications in the development of drugs for hereditary and acquired diseases**.**

As a result of studying the discipline "Modern achievements of bioengineering and bioinformatics" the PhD students acquire the following program results:

- Knowledge and understanding of problematic issues of modern bioengineering (including interdisciplinary (gene therapy)) to create the latest biotechnologies in the development of drugs.

- Knowledge and use of modern genetic approaches to improve biological agents and regulation of biotechnological processes.

- Knowledge of modern methods of research at the level of world achievements in bioengineering and bioinformatics to gain new knowledge and innovation, organization and planning of the experiment, the practice of publishing results.

- Apply modern tools and technologies for searching, processing and analyzing information, in particular, statistical methods of data analysis of large volumes and / or complex structures, specialized databases and information systems.

- Plan and perform experimental and theoretical research using modern knowledge in the field of bioinformatics, bioengineering and instrumental methods, critically analyze research results.

- Develop and implement scientific and innovative projects.

- Develop new and improve existing biotechnologies based on modern advances in bioinformatics and bioengineering.

- Choose the most effective methods of bioinformatics for research on gene therapy.

The main experience gained by the PhD student at the end of the course is the application of acquired knowledge to the analysis of the latest tools and methods of bioinformatics in drug development and gene therapy, as well as the application of acquired knowledge in research, discussion of results and dissertation content.

1. Prerequisites and postrequisites of the discipline (place in the structural and logical scheme of education according to the relevant educational program)

The place in the structural and logical scheme of education is provided by disciplines such as general chemical and biological disciplines: "Biochemistry", "Biophysics", "Microbiology and Virology", "General Biotechnology", as well as a basic level of English not less than A2. In the structural and logical plane of the program of training PhD in biotechnology, the discipline is based on previously studied disciplines of the master's program, which create a foundation for further research and practical activities of doctoral graduates as senior managers.

The content of the discipline

Postgenomic era in the development of bioengineering and bioinformatics. Gene therapy.

Topic 1.1. Molecular basis of gene therapy.

Development of gene therapy. Problems and prospects of gene therapy in the treatment of diseases. Use of modern bioinformatics databases (DB) for drug development. Mendelian Inheritance in Man (OMIM) database, ClinVar genome mutations database and their relationship to human health.

Topic 1.2. Methods of introducing genetic material into eukaryotic cells.

Viral gene and drug delivery systems. Non-viral gene delivery and drug delivery systems. Chemical methods. Physical methods. Non-viral delivery systems for gene delivery and drug delivery. Bacterial vectors. Application of magnetic nanoparticles (MNPs) for physicochemical methods of gene delivery and drug delivery. Materials used to modify the MNP surface. Methods of magnetically controlled delivery of genes and drugs. Magnetofection. New biological methods of gene and drug delivery. Advantages and disadvantages of existing methods of magnetic labeling of the bacterial vector for the delivery of genes and drugs.

Topic 1.3. Application of modern methods of therapy and bioinformatics in gene therapy.

In vivo study of CRISPR-based human gene editing therapy, where editing takes place inside the human body. Achievements of bioinformatics in the development and improvement of new methods for targeted delivery of genes and drugs.

Training materials and resources

Basic literature

1. An Introduction to Molecular Medicine and Gene Therapy, 2000. https://doi.org/10.1002/0471223875.
2. A. Shahryari, M. Saghaeian Jazi, S. Mohammadi, H. Razavi Nikoo, Z. Nazari, E.S. Hosseini, I. Burtscher, S.J. Mowla, H. Lickert, Development and Clinical Translation of Approved Gene Therapy Products for Genetic Disorders, Front. Genet. 10 (2019). https://doi.org/10.3389/fgene.2019.00868.
3. O. Valenzuela, F. Rojas, I. Rojas, P. Glosekotter, Main findings and advances in bioinformatics and biomedical engineering- IWBBIO 2018., BMC Bioinformatics. 21 (2020) 153. https://doi.org/10.1186/s12859-020-3467-0 .

4. P.T. Harrison, S. Hart, A beginner's guide to gene editing., Exp. Physiol. 103 (2018) 439–448. https://doi.org/10.1113/EP086047.
5. C.K. Baban, M. Cronin, D. O'Hanlon, G.C. O'Sullivan, M. Tangney, Bacteria as vectors for gene therapy of cancer, Bioeng. Bugs. (2010). https://doi.org/10.4161/bbug.1.6.13146.

Additional literature

[1] M. Collins, A. Thrasher, Gene therapy: progress and predictions, Proc. R. Soc. B Biol. Sci. 282 (2015) 20143003. https://doi.org/10.1098/rspb.2014.3003 .

[2] M.F. Dias, K. Joo, J.A. Kemp, S.L. Fialho, A. da Silva Cunha, S.J. Woo, Y.J. Kwon, Molecular genetics and emerging therapies for retinitis pigmentosa: Basic research and clinical perspectives, Prog. Retin. Eye Res. 63 (2018) 107–131. https://doi.org/10.1016/j.preteyeres.2017.10.004 .

[3] P.M. Visscher, N.R. Wray, Q. Zhang, P. Sklar, M.I. McCarthy, M.A. Brown, J. Yang, 10 Years of GWAS Discovery: Biology, Function, and Translation, Am. J. Hum. Genet. (2017). https://doi.org/10.1016/j.ajhg.2017.06.005 .

[4] C.E. Dunbar, K.A. High, J.K. Joung, D.B. Kohn, K. Ozawa, M. Sadelain, Gene therapy comes of age, Science (80-.). (2018). https://doi.org/10.1126/science.aan4672 .

[5] N. Nayerossadat, P. Ali, T. Maedeh, Viral and nonviral delivery systems for gene delivery, Adv. Biomed. Res. (2012). https://doi.org/10.4103/2277-9175.98152 .

[6] M.A. Pule, B. Savoldo, G.D. Myers, C. Rossig, H. V. Russell, G. Dotti, M.H. Huls, E. Liu, A.P. Gee, Z. Mei, E. Yvon, H.L. Weiss, H. Liu, C.M. Rooney, H.E. Heslop, M.K. Brenner, Virus-specific T cells engineered to coexpress tumor-specific receptors: persistence and antitumor activity in individuals with neuroblastoma, Nat. Med. 14 (2008) 1264–1270. https://doi.org/10.1038/nm.1882 .

[7] M. Hudecek, Z. Izsvák, S. Johnen, M. Renner, G. Thumann, Z. Ivics, Going non-viral: the Sleeping Beauty transposon system breaks on through to the clinical side, Crit. Rev. Biochem. Mol. Biol. (2017). https://doi.org/10.1080/10409238.2017.1304354 .

[8] M. Ramamoorth, Non Viral Vectors in Gene Therapy- An Overview, J. Clin. DIAGNOSTIC Res. (2015). https://doi.org/10.7860/JCDR/2015/10443.5394 .

[9] H.D. Liang, Q.L. Lu, S.A. Xue, M. Halliwell, T. Kodama, D.O. Cosgrove, H.J.

Stauss, T.A. Partridge, M.J.K. Blomley, Optimisation of ultrasound-mediated gene transfer (sonoporation) in skeletal muscle cells, Ultrasound Med. Biol. (2004). https://doi.org/10.1016/j.ultrasmedbio.2004.08.021 .

[10] D.A. Dean, D. Machado-Aranda, K. Blair-Parks, A. V. Yeldandi, J.L. Young, Electroporation as a method for high-level nonviral gene transfer to the lung, Gene Ther. 10 (2003) 1608–1615. https://doi.org/10.1038/sj.gt.3302053 .

[11] C.K. Baban, M. Cronin, D. O'Hanlon, G.C. O'Sullivan, M. Tangney, Bacteria as vectors for gene therapy of cancer, Bioeng. Bugs. (2010). https://doi.org/10.4161/bbug.1.6.13146 .

[12] O. Felfoul, M. Mohammadi, S. Taherkhani, D. De Lanauze, Y. Zhong Xu, D. Loghin, S. Essa, S. Jancik, D. Houle, M. Lafleur, L. Gaboury, M. Tabrizian, N. Kaou, M. Atkin, T. Vuong, G. Batist, N. Beauchemin, D. Radzioch, S. Martel, Magneto-aerotactic bacteria deliver drug-containing nanoliposomes to tumour hypoxic regions, Nat. Nanotechnol. (2016). https://doi.org/10.1038/nnano.2016.137 .

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[14] C. Monzel, C. Vicario, J. Piehler, M. Coppey, M. Dahan, Magnetic control of cellular processes using biofunctional nanoparticles, Chem. Sci. 8 (2017) 7330–7338. https://doi.org/10.1039/C7SC01462G .

[15] V. V. Mody, A. Cox, S. Shah, A. Singh, W. Bevins, H. Parihar, Magnetic nanoparticle drug delivery systems for targeting tumor, Appl. Nanosci. (2014). https://doi.org/10.1007/s13204-013-0216-y .

[16] D. Kami, S. Takeda, Y. Itakura, S. Gojo, M. Watanabe, M. Toyoda, Application of Magnetic Nanoparticles to Gene Delivery, Int. J. Mol. Sci. 12 (2011) 3705–3722. https://doi.org/10.3390/ijms12063705 .

[17] J. Estelrich, E. Escribano, J. Queralt, M.A. Busquets, Iron oxide nanoparticles for magnetically-guided and magnetically-responsive drug delivery, Int. J. Mol. Sci. (2015). https://doi.org/10.3390/ijms16048070 .

[18] H. Li, Y. Yang, W. Hong, M. Huang, M. Wu, X. Zhao, Applications of genome editing technology in the targeted therapy of human diseases: mechanisms, advances

and prospects, Signal Transduct. Target. Ther. 5 (2020) 1. https://doi.org/10.1038/s41392-019-0089-y .

[19] S.V. Gorobets, O.V. Medviediev, O.Y. Gorobets, A. Ivanchenko, Biogenic magnetic nanoparticles in human organs and tissues, Prog. Biophys. Mol. Biol. 135 (2018). https://doi.org/10.1016/j.pbiomolbio.2018.01.010 .

[20] H.I. Mikeshyna, Y.A. Darmenko, O.Y. Gorobets, S.V. Gorobets, I.V. Sharay, O.M. Lazarenko, Influence of Biogenic Magnetic Nanoparticles on the Vesicular Transport, Acta Phys. Pol. A. 133 (2018) 731–733 . https://doi.org/10.12693/APhysPolA.133.731 .

[21] S. V. Gorobets, O.Y. Gorobets, I. V. Sharau, Y. V. Milenko, Magnetically controlled vector based on E coli Nissle 1917, ArXiv. (2020), https://arxiv.org/abs/2002.01958 .

Information resources

1. http://www.ncbi.nlm.nih.gov
2. https://en.wikipedia.org/wiki/Single-nucleotide_polymorphism gwascentral.org
3. https://en.wikipedia.org/wiki/DbSNP
4. https://www.ncbi.nlm.nih.gov/clinvar/)
5. https://en.wikipedia.org/wiki/The_Cancer_Genome_Atlas
6. https://en.wikipedia.org/wiki/CRISPR
7. https://en.wikipedia.org/wiki/Human_Metabolome_Database
8. https://en.wikipedia.org/wiki/Human_Protein_Atlas

Educational contest

1. Methods of mastering the discipline (educational component)

№ з/п	Topic lectures and a list of major issues (List of teaching tools, references and tasks independent work of students (IWoS)
	Topic 1. Postgenomic era in the development of bioengineering and bioinformatics. Gene therapy. Molecular basis of gene therapy.
1	Lecture 1. Development of gene therapy. Problems and prospects of gene therapy in the treatment of diseases.

	Literature: basic [1,2], additional [1] IWoS – The first human gene therapy drugs approved by the FDA (Food and Drug Administration). Literature: basic [1], additional [2]
	Topic 3. Application of modern methods of therapy and bioinformatics in gene therapy.
2	Lecture 2. Achievements of bioinformatics in the development and improvement of new methods for targeted delivery of genes and drugs. Literature: basic [3], additional: [19,20]
3	Lecture 3. Examples of the use of bacteria with natural magnetically controlled properties as vectors for targeted delivery of genes and drugs. Literature: basic [5], additional: [21]

Practical training

The main tasks of the cycle of practical classes:

- work with software packages used in Biotechnology;
- practical work with modern databases of molecular biology.

№ з/п	Topic sessions
1	Seminar 1 Search and determination of functions of homologous proteins responsible for biomineralization of biogenic magnetic nanoparticles (BMN) in humans with BMN biomineralization proteins in magnetotactic bacteria in NCBI. Alignment, determination of statistical numbers. Literature: basic [3], information resources: [1]

Independent work of a student / graduate student

The postgraduate student's independent work in the discipline includes preparation for classroom classes (6 hours), modular test (40 hours), preparation for the exam (50 hours) and independent preparation for classroom classes on the following topics, listed below (72 hours).

№ з/п	**The name of the topic submitted for self-study**	**Hours**
1.	Purpose and main characteristics of the database of Single Nucleotide Polymorphisms (SNP), the database of the Genome-wide association study (GWAS). Literature: additional: [3], information resources: [2, 3]	12
2.	Viral systems of delivery of genes and drugs in cancer. Literature: basic [3], additional: [5]	12

№ з/п	The name of the topic submitted for self-study	Hours
3.	Non-viral gene and drug delivery systems. Literature: additional: [5-8]	12
4.	Examples of the use of magnetotactic bacteria in the treatment of cancer. Literature: additional: [11,12]	12
5.	The use of magnetic nanoparticles for the delivery of genes and drugs. Literature: additional: [13-16]	12
6.	A study of CRISPR-based human gene editing therapy. Literature: basic [4], information resources: [6] IWoS – Application of genome editing technology in targeted therapy of human diseases. Literature: basic [4], additional: [18]	12

Policy and Control

1. The policy of the discipline (educational component)

The study of the discipline "Modern achievements of bioengineering and bioinformatics" takes place in lectures and practical classes. Visibility of training sessions is provided by the use of a significant amount of illustrative material (diagrams, tables, slides). During the teaching of this discipline, the teacher conducts a survey of graduate students in order to determine the level of assimilation of the material presented, it is important activity of graduate students, their preparation during the semester of short reports or texts on lectures. Practical classes are conducted using computer equipment and software. The discipline is taught in accordance with the rating system. The student's rating in the discipline consists of points that he receives in the process of working on practical classes and writing a modular test. The student's knowledge obtained during the semester is assessed on a 52-point grading system. In the process of learning, students can receive additional points for performing additional tasks proposed by the teacher.

Provisions on the rating system of assessment in the discipline "Modern advances in bioengineering and bioinformatics" to this working curriculum are presented in Appendix 2.

Types of control and rating system for assessing learning outcomes

Modular control work is carried out in order to control the quality of the material mastered by students and make appropriate adjustments to the educational process based on the results of writing the test. The test is a list of theoretical questions and one task on the topics "Using modern bioinformatics databases (DB) for drug development" and "Methods of introducing genetic material into eukaryotic cells." In the process of writing a modular test, the student must show all the acquired and mastered knowledge and be able to answer

both specific theoretical questions and solve more creative problems. Variants of questions of control work on discipline "Modern achievements of bioengineering and bioinformatics" are presented in Appendix 1.

The rating system for assessing the learning outcomes of students in the credit module "Modern advances in bioengineering and bioinformatics" corresponds to the distribution of study time by type of classes and tasks in the discipline in accordance with the working curriculum.

During the semester, the student has the opportunity to receive a maximum of 50 points.

Writing a modular test and work on practical classes of the graduate student is estimated at 50 points.

50 points are taken for the exam.

Detailed characteristics of Rating System of Evaluation are given in Appendix 2.

2. Additional information on the discipline (educational component)

Appendix 1

1. Questions to the modular test from the course "Modern achievements of bioengineering and bioinformatics"
2. Purpose and classification of databases (Archival databases, supervised databases, derived databases and integrated databases).
3. Formats for presenting information in the database GenBank NCBI.
4. Basic requirements for database software
5. Purpose of the database Mendelian Inheritance in Man (OMIM).
6. Purpose and main characteristics of the ClinVar database.
7. Purpose and main characteristics of the database of Single Nucleotide Polymorphisms (SNP),
8. The main features of the database Genome-wide association study (GWAS).
9. Database of protein sequences (UniProt, PROSITE).
10. Software resources used in bioinformatics DB and their functions.
11. Human Metabolome Database (HMDB). Basic search tools in HMDB database.
12. Purpose and main characteristics of the database Human protein atlas.
13. Online Mendelian Inheritance in Man (OMIM) database.
14. Single Nucleotide Polymorphism (SNP) database.
15. Genome-wide association study (GWAS) database.
16. Purpose and main characteristics of the database Atlas of tumor cells The Cancer Genome Atlas.
17. Features of the postgenomic era in the development of bioinformatics.
18. Gene therapy, definition, development strategy.
19. Viral delivery systems of genes and drugs.
20. Non-viral gene and drug delivery systems.
21. Methods of electroporation for the introduction of genes and drugs.
22. Methods of sonoporation for the introduction of genes and drugs.
23. Methods of magnetically controlled delivery of genes and drugs. Magnetofection.
24. New bacterial magnetically controlled methods of gene and drug delivery.
25. CRISPR technology for human gene editing therapy.
26. The main achievements of CRISPR technology of human gene editing therapy.
27. Examples of achievements of personalized medicine.

28.Examples of foreign and Ukrainian companies offering human genome analysis.

Appendix 2

Rating system for evaluation the learning outcomes of students in the credit module of the course "Modern advances in bioengineering and bioinformatics"

A student's credit module rating consists of the points he receives for:

• execution and defense of 1 practical works;

• writing a modular test.

Scoring criteria.

1. Practical works. Weight score - 10.

flawless work - 10 points;

there are certain shortcomings in the preparation or execution of work - 8 points;

there are shortcomings in the preparation and execution of work - 6 points;

Work not performed or not protected - 0 points.

2. Writing a modular test. Weight score - 40. The maximum number of points for a modular test is 40 points.

Modular test consists of 4 theoretical questions

The maximum number of points for one theoretical question is 10 points:

the student receives a complete correct answer - 10 points;

for the correct answer with minor inaccuracies the student receives - 8 points; for the correct answer, but there are some inaccuracies the student receives - 6 points;

for the answer, in which there are significant inaccuracies, the student receives - 4 points; for incorrect answer the student receives 0 points.

Penalty and incentive points for:

• non-admission to practical work due to unsatisfactory entrance control - 2 point;

• participation in the modernization of practical work; performance of tasks on improvement of didactic materials on discipline is given from 2 to 10 encouraging points.

The exam is rated at 50 points. The control task of this work consists of five questions from the list provided in the appendix to the work program.

Each question is evaluated in 10 points according to the following criteria:

"Excellent" - a complete answer (at least 90% of the required information), provided appropriate justifications and personal opinion - 9-10 points;

"Good" - a fairly complete answer (at least 75% of the required information), performed in accordance with the requirements for the level of "skills", or minor inaccuracies) - 7-8 points;

"Satisfactory" - incomplete answer (not less than 60% of the required information. Made in accordance with the requirements for the "stereotypical" level and some errors) - 5-6 points;

"Unsatisfactory" - unsatisfactory answer - 0 points.

Table of correspondence of rating points to grades on the university scale:

Scores	*Marks*
100-95	Excellent
94-85	Exceptionally good
84-75	Good
74-65	Satisfactorily

64-60	Enough
Less than 60	Unsatisfactorily
Admission conditions are not met	Not allowed

Work program of the discipline (syllabus):

Compose Professor Doctor of Technical Sciences Svetlana Gorobets

Approved by the Department of Bioinformatics (protocol № _16__ from _22/07/2020p.)

Approved by the Methodical Commission of the faculty (protocol № 10 from 26/06/2020p.)