DANYLO HALYTSKY LVIV NATIONAL MEDICAL UNIVERSITY

Biophysics Department

APPROVED
First Vice Rector on
Scientific and Pedagogical Work
Assoc. Prof. Iryna SOLONYNKO
"17" 07 2023

DISCIPLINE PROGRAM

MODERN PROBLEMS OF BIOPHYSICS

elective course, ВБ 1.30

Second (master's degree) level of higher education
Field of Knowledge 22 "Healthcare"
specialty 222 "Medicine"

Discussed and approved
at the educational-methodical meeting
of the Biophysics department
Minutes No 9 dated "30" May 2023

Head of the Biophysics department
Prof. Roman FAFULA

Approved
by the Profile Methodical Board
of the Faculty of Foreign Students
Minutes No 4 dated "31" May 2023

Head of the Methodical Board
of the Faculty of Foreing Students
Assoc. Prof. Tetyana YESHCHENKO

AUTHORS OF THE ACADEMIC PROGRAM OF THE DISCIPLINE:

Roman FAFULA	Professor, Doctor of Biological Science, Head of the Biophysics Department of Danylo Halytsky Lviv National Medical University;
Maria VISTAK	Doctor of Technical Science, Professor of the Biophysics Department of Danylo Halytsky Lviv National Medical University;
Zoryana FEDOROVYCH	PhD in Biology, Associate Professor of the Biophysics Department of Danylo Halytsky Lviv National Medical University.

REVIEWERS:

Zinoviy VOROBETS	Professor, Doctor of Biological Science, Head of the Medical Biology, Parasitology and Genetic Department of Danylo Halytsky Lviv National Medical University;
Oksana BOYKO	Professor, Doctor of Technical Science, Head of the Medical Informatics Department of Danylo Halytsky Lviv National Medical University

INTRODUCTION

The academic program of the discipline (elective course) "Modern problems of biophysics"
according to the Higher Education Academic Standard of the second (Master's) level education sector 22 "*Healthcare*"
speciality 222 "*Medicine*"
education program *master of medicine*.

The description of the discipline "Modern problems of biophysics" (annotation)

Academic program of the discipline "Modern problems of biophysics" (elective course) provides knowledge about the structure and physical properties of living systems at the molecular level and application of modern research methods in medical science and practice. The main focus is on the study of the physical foundations of the structural organization and functioning of biomolecules, which determines their biological functions, as well as modern diagnostic methods used in medicine.

According to the curriculum, the discipline "Modern problems of biophysics" (elective course) is studied by the first year students. The academic program of the discipline is divided into 2 chapters:

Chapter 1. Fundamentals of molecular biophysics of cells and tissues.

Chapter 2. Application of biophysical technologies in biomedical research.

The role of the water environment, intramolecular relationships, the physical basis of the structural organization and functioning of proteins, nucleic acids, as well as biophysical methods of studying biopolymers are studied in chapter 1.

The biophysical foundations of X-ray and magnetic resonance diagnostics, as well as the application of laser technologies in biomedical research are studied in chapter 2.

Structure of discipline	**The amount of credits, hours including**				**Year of study, semester**	**Forms of the control**
	In total	Auditorial		Indivi-dual work		
		Lectures	Practical classes			
Discipline "Modern problems of biophysics" ***Chapters – 2***	**3 credits / 90 hours**	**12**	**18**	**60**	**1st year**	**Pass-fail test**
by semesters						
Chapter 1	**2.0 credits / 60 hours**	**6**	**10**	**44**	**1st year**	**Pass-fail test**
Chapter 2	**1.0 credit / 30 hours**	**6**	**8**	**16**		

The subject of study of the discipline "Modern problems of biophysics" (elective course) is the study of the physical properties of macromolecules, biophysical methods of cell research, the physical foundations of methods of biomacromolecule research, modern technologies and systems that use the properties of X-rays, nuclear magnetic resonance and induced radiation used in biomedical practice.

Interdisciplinary links:

Discipline "Modern problems of biophysics" integrates with the following disciplines:

Medical and biological physics
Medical biology, parasitology, genetics;
Medical chemistry.

Discipline "Modern problems of biophysics" (elective course) lays the foundations to study following disciplines:

Biological chemistry;
Bioorganic chemistry;
Physiology;
Pathophysiology;
Medical informatics;
Propaedeutics of internal medicine;
Hygiene and ecology;
Radiology.

1. Objective and tasks of the academic discipline

1.1. The objective of teaching the discipline "Modern problems of biophysics" (elective course) is introducing students to modern problems of molecular biophysics and the latest achievements in the field of medical and biological physics, prospects for its application in biomedical practice.

1.2. The main learning tasks of the discipline "Modern problems of biophysics" (elective course) are:

- ✓ elucidation of the physical mechanisms underlying the biological functions of biomacromolecules;
- ✓ definition of the main methods used to study the structure and activity of biomacromolecules;
- ✓ physical phenomena underlying diagnostic and physiotherapeutic (treatment) methods used in biomedical practice.

1.3. The discipline "Modern problems of biophysics" (elective course) contributes following **competence and learning outcomes** (the relationship with the normative content of higher education graduates training, formulated in terms of learning outcomes of Higher Education Standard).

In accordance with the requirements of Higher Education Standard, discipline ensures students' acquisition of **competences:**

– *integral*:

The ability to solve complex problems, including those of a research and innovation nature in the field of medicine.

Ability to continue learning with a high degree of autonomy.

– *general:*

GC 1 The ability for abstract thinking, analysis and synthesis.

GC 2 Ability to learn and master modern knowledge.

GC 3 The ability to apply knowledge in practical situations.

GC 4 Knowledge and understanding of the subject area and understanding of the professional activities.

GC 5 Ability to adapt and act in a new situation.

GC 6 Ability to make informed decisions.

GC 7 Ability to work in a team.

GC 8 Interpersonal skills.

GC 9 Ability to communicate in a foreign language.

GC 10 Skills in using information and communication technologies.

GC 11 Ability to search, process and analyze information from various sources.

GC 12 Definiteness and perseverance to the tasks and assumed responsibilities.

- *special (professional):*

PC 2 Ability to determine the required list of laboratory and instrumental studies and evaluate their results.

PC 10 Ability to perform medical procedures.

PC 17 Ability to assess the impact of the environment, socio-economic and biological determinants on the health of the individual, family and population.

Details of the competencies are set out below in the competency matrix table.

COMPETENCY MATRIX

No	Competence	Knowledge	Ability	Communication	Autonomy and responsibility
	Integral competence				
	The ability to solve complex problems, including those of a research and innovation nature in the field of medicine. Ability to continue studies with a high degree of autonomy.				
	General competences				
1	Ability for abstract thinking, analysis and synthesis; ability to learn and master modern knowledge.	To know: methods of analysis, synthesis and further modern training.	Be able to: analyze information, make informed decisions, acquire modern knowledge.	Establish appropriate relationships to achieve goals.	To take responsibility for the timely acquisition of modern knowledge.
2	Ability to apply knowledge in practical situations.	To know: specialized conceptual knowledge.	Be able to: solve complex problems and issues that arise in professional activities.	Clear and unambiguous communication of one's own conclusions, knowledge and explanations that substantiate them to specialists and non-specialists.	To take responsibility for making decisions in difficult conditions.
3	Knowledge and understanding of the subject area and understanding of the professional activities.	To know: the structure of professional activity.	Be able to: carry out professional activity that needs updating and integration of knowledge.	Ability to effectively form a communication strategy in professional activities.	To take responsibility for professional development, ability to further professional training with a high level of autonomy.
4	Ability to adapt and act in a new situation.	To know: elements of industrial and social adaptation and factors of successful adaptation to a new environment.	Be able to: to form an effective strategy of personal adaptation to new conditions.	Interact with a wide range of people (colleagues, management, specialists from other fields) when new situations with elements of	To take responsibility for making decisions.

				unpredictability arise.	
5	The ability to make informed decisions; to work in a team; interpersonal skills.	To know: tactics and strategies of communication, laws and methods of communicative behavior.	Be able to: make informed decisions, choose methods and strategies of communication to ensure effective teamwork.	Use communication strategies and skills of interpersonal interaction.	To take responsibility for the choice and tactics of the method of communication.
6	Ability to communicate in a foreign language.	To know: one (several) foreign languages.	Be able to: apply knowledge of a foreign language.	Use a foreign language in professional activities.	To take responsibility for using a foreign language in professional activities.
7	Skills in using information and communication technologies.	To know: information and communication technologies used in professional activities.	Be able to: use information and communication technologies in the professional field that needs updating and integration of knowledge.	Use information and communication technologies in professional activity.	To take responsibility for the development of professional knowledge and skills.
8	Ability to search, process and analyze information from various sources.	To know: ways of searching, processing and analyzing information.	Be able to: search, process and analyze information.	Use different methods of information processing.	To take responsibility for information management.
9	Definiteness and perseverance to the tasks and assumed responsibilities.	To know: responsibilities and ways of performing tasks.	Be able to: to determine the goal and task, be persistent and conscientious in the performance of duties.	Set interpersonal communication for effective implementation of tasks and responsibilities.	To take responsibility for qualitative performance of tasks.
	Special (professional) competences				
1	Ability to determine the required list of laboratory and instrumental studies and evaluate their results.	To know: the influence of physical factors on the human body, standard methods of laboratory and instrumental research.	Be able to: analyze research results.	Reasonably select and evaluate research results.	To take responsibility for making a decision regarding the evaluation of research results.
2	Ability to perform medical	To know:	Be able to:	Reasonably form and	Responsibility,

	procedures.	biophysics of human organs and systems.	analyze the biophysical parameters of human organs and systems.	prove conclusions about the need for medical manipulations to the patient and specialists.	independence.
3	Ability to assess the impact of the environment, socio-economic and biological determinants on the health of the individual, family and population.	To know: environmental factors that negatively affect the health of the population.	Be able to: assess the state of the environment and negative factors affecting health.	Make conclusions about the health of the population on the basis of the relationship with environmental factors.	To take responsibility for the correct conclusions regarding the negative impact of environmental factors.

Learning outcomes:
Integrative final program learning outcomes (PLO) of the discipline "Modern problems of biophysics" (elective course) are:

PLO 1. Have thorough knowledge of the structure of professional activity. To be able to carry out professional activities that require updating and integration of knowledge. To take responsibility for professional development, the ability for further professional training with a high level of autonomy (GC1 – GC12, FC2, FC10, FC17).

PLO 2. Understanding and knowledge of fundamental and clinical biomedical sciences at a level sufficient for solving professional tasks in the field of health care (GC4, GC6, GC10 – GC12, FC2, FC10, FC17).

PLO 3. Specialized conceptual knowledge, which includes scientific achievements in the field of health care and is the basis for research, critical understanding of problems in the field of medicine and related interdisciplinary problems (GC1 – GC3, GC6, GC7, GC9 – CG12, FC2).

PLO 23. Assess the impact of the environment on the state of human health in order to estimate the morbidity pattern of the population (FC17).

PLO 24. Organize the necessary level of individual safety (own and persons cared for) in case of typical dangerous situations in the individual field of activity (CG6).

Learning outcomes for the discipline. As a result of learning of "Modern problems of biophysics" student has to

know:

- ✓ general physical and biophysical regularities underlying the processes occurring in a living organism;
- ✓ physical foundations of research methods of biomacromolecule;
- ✓ the essence of modern achievements, problems and main trends in the field of modern biophysics and the possibilities of using these achievements in biomedical practice.

able to:

- ✓ explain the physical foundations of modern methods of research of biological systems and visualization methods in medical diagnostics;
- ✓ analyze the informativeness of the methods and carry out a comparative analysis of their effectiveness;
- ✓ interpret experimental data of methods of analysis of biological objects, if they are obtained for known compounds;
- ✓ explain the principle of operation of medical equipment.

2. Information content of academic discipline

3 ECTS credits (90 hours) are allocated for discipline. The academic program of the discipline is structured into 2 chapters.

Chapter 1. Fundamentals of molecular biophysics of cells and tissues

Topic 1. Basic physical properties of biomacromolecules

Biological macromolecules in solution. Conformation of macromolecules. Intramolecular interactions in biological macromolecules. Hydrophobic interactions and water structure. Viscosity of solutions of biomacromolecules. Diffusion of macromolecules. Quasi-elastic scattering of light. Interaction between macromolecules in saline solution.

Biophysics of proteins. Kinetics of enzymatic reactions. Activation energy. Biophysics of nucleic acids. Hyperchromic effect.

Topic 2. Biophysical methods of studying biopolymers

Biophysical methods of biopolymer research. Electrophoresis of macromolecules. Sedimentation of macromolecules. Centrifugation. Chromatographic method: gel filtration. Dispersion of optical rotation and circular dichroism. Differential scanning microcalorimetry.

Biophysical methods of studying the structure of macroparticles. X-ray structural analysis. Molecular spectroscopy of macromolecules. Fluorescence spectroscopy. Rheometry of nucleic acids and proteins.

Electron microscopy. The working principle of the electron microscope. The main types of electron microscopes. Methods of preparing samples and obtaining contrast images. Application of modern electron microscopes in medicine. Study of the surface of isolated cells. Electron microscopy of viruses and bacteria.

Chapter 2. Application of biophysical technologies in biomedical research

Topic 3. Visualization methods in diagnostics and research of substances and biological tissues

Biophysical bases of X-ray diagnostics. X-ray computed tomography (CT). Image reproduction in CT. Spatial resolution of CT. Three-dimensional image. A side effect of a CT scan.

Biophysical bases of magnetic resonance diagnostics. The phenomenon of nuclear magnetic resonance (NMR). Relaxation. Biophysical bases of magnetic resonance diagnostics. The concept of NMR spectroscopy. Magnetic resonance imaging: scanning and image reconstruction; image parameters. Diagnostic capabilities of NMR tomography. Biophysical principles of positron emission tomography.

Biophysical bases of laser diagnostics and therapy. Basic properties of laser radiation. High power lasers and their interaction with biological tissues. Interaction of powerful lasers with biological tissues. The thermal effect of laser radiation on biological tissues. Low power lasers. Cellular mechanisms of photobiomodulation. Cell reaction to radiation. Classification of lasers and safety requirements. Types of damage to biological tissues. Laser technologies in biomedical practice: laser-induced fluorescence; laser profilometry.

3. Structure of the discipline

TOPIC	Lectures	Practical classes	Individual work	Personal tasks
Chapter 1. Fundamentals of molecular biophysics of cells and tissues				
Topic 1 Basic physical properties of biomacromolecules.	4	4	14	–
Topic 2. Biophysical methods of studying biopolymers.	2	6	30	
In total for chapter 1	***6***	***10***	***44***	
Chapter 2. Application of biophysical technologies in biomedical research				
Topic 3. Visualization methods in diagnostics and research of substances and biological tissues.	6	8	16	–
In total for chapter 2	***6***	***8***	***16***	
Total hours 90 / 3 credits ECTS	**12**	**18**	**60**	
Final control				**pass-fail test**

4. Thematic plan of lectures

No	TOPIC	Hours
1	Biological macromolecules in solutions.	2
2	Biophysics of proteins and nucleic acids.	2
3	Modern research methods for determining the structure of biomacromolecules.	2
4	Biophysical principles of X-ray diagnostics.	2
5	Biophysical principles of magnetic resonance imaging and positron emission tomography.	2
6	Biophysical basis of application of laser technologies in medicine.	2
	In total	**12**

5. Plan of laboratory and practical classes

No	TOPIC	Hours
1.	Fundamentals of molecular biophysics.	2
2.	Biophysics of proteins and nucleic acids.	2
3.	Sedimentation and electrophoresis of biological macromolecules.	2
4.	X-ray structural analysis of biological macromolecules.	2
5.	Molecular spectroscopy of macromolecules. Fluorescence spectroscopy.	2
6.	Modern methods of electron microscopy	2
7.	Biophysical principles of X-ray diagnostics.	2
8.	Biophysical principles of magnetic resonance diagnostics.	2
9.	Biophysical principles of laser diagnostics and therapy.	2
	In total	**18**

6. Self-study plan

No	TOPIC	Hours	Type of control
1.	Objects of research in molecular biophysics.	4	Current control during practical classes
2.	Intermolecular interactions and forces stabilizing the structure of biomacromolecules.	5	
3.	The main types of interactions that form biological membranes.	5	
4.	Rheometry of biomacromolecules.	4	
5.	Dispersion of optical rotation and circular dichroism.	6	
6.	Chromatographic method in the study of biomacropolymers.	7	
7.	Application of modern methods of electron microscopy in medicine.	7	
8.	Study of biopolymers by differential scanning microcalorimetry.	6	
9.	Physical principles of X-ray transmission computed tomography.	8	
10.	Laser microspectral analysis in research.	8	
	In total	**60**	

7. Individual tasks are not provided in the curriculum.

8. Teaching methods:

- ✓ verbal methods (lecture, discussion);
- ✓ visual methods (illustration, demonstration, frontal experiment);
- ✓ practical methods (laboratory work and solving of problems with professional content);
- ✓ individual work of students with comprehension and learning of material;
- ✓ use of control and training computer software;
- ✓ use of project method for interdisciplinary integration.

9. Control methods:

Types of control:

- ✓ Current control is realized on the basis of control of theoretical knowledge, skills and abilities in practical classes. The student's individual work is evaluated during practical classes and is a component of the student's final grade.
- ✓ Final control is realized in the form of a pass-fail test which consists in assessing the student's assimilation of the educational material solely on the basis of the results of his performance of certain types of work in practical, seminar or laboratory classes

Assessment of students' current performance is realized at each practical (laboratory) class by a 4-point scale and is recorded in the student progress journal. Students' knowledge is assessed on both theoretical and practical training according to the following **criteria**:

- ✓ grade 5/"excellent" – the student has mastered the theory flawlessly, demonstrates deep and comprehensive knowledge of the certain topic or academic discipline, the main theses of scientific papers and recommended literature, thinks logically and gives an answer, freely uses the acquired theoretical knowledge when analyzing practical material, expresses his attitude to certain problems, demonstrates a high level of mastery of practical skills;
- ✓ grade 4/"good" – the student has mastered the theoretical material well, knows the main aspects from primary sources and recommended literature, presents it in a reasoned way; has practical skills, expresses his thoughts on certain issues, but certain inaccuracies and errors are assumed in the logic of the presentation of theoretical content or in the performance of practical skills;
- ✓ grade 3/"satisfactory" – the student has basically mastered the theoretical knowledge of the topic or discipline, orients himself in primary sources and recommended literature, but answers unconvincingly, confuses concepts, additional questions cause the student uncertainty or lack of stable knowledge; when answering questions of a practical nature, reveals inaccuracies in knowledge, does not know how to evaluate facts and phenomena, relate them with future activities, makes mistakes when performing practical skills;

- ✓ grade 2/"unsatisfactory" – the student has not mastered the material of the topic (discipline), does not know scientific facts, definitions, hardly orients himself in primary sources and recommended literature, lacks scientific thinking, practical skills are not formed.

10. Current control is realized during classes and aims to examine the students' mastery of learning material.
Forms of current control:
1) oral examination (frontal, individual, combined examination);
2) practical verification of the formed professional skills;
3) test control (open and closed tests).
10.1. Evaluation of current educational activity. In evaluating the mastering of each topic for current educational activity the students get grades in the 4-point scale (traditional scale). All types of work provided by the academic program are taken into account. The student's individual work is evaluated during practical classes. The student gets a grade on each topic for further conversion of grades into points by multipoint (200-point) scale.

11. Form of the final control is pass-fail test according to the curriculum.

The pass-fail test is carried out after the end of studying of discipline, before the beginning of the examination session. The pass-fail test is set by lecturers/instructors who has practical and other classes in the academic group. Semester assessment does not require students to be present.

12. The scheme of calculation and distribution of points

Maximum score points which a student can obtain for the current educational activity for admission to the exam is 200 points.

Minimum score points which a student must obtain for the current educational activity for admission to the exam is 120 points.

Calculation of score points is based on grades received by student in the 4-point scale (traditional scale) (by calculation of the arithmetic mean (*AM*) rounded to two decimal places). The resulting value is converted into points by multi-points scale as follows:

$$x = \frac{CA \times 200}{5}$$

For convenience, a table of conversion into 200-point scale is given:

Conversion of the average grade for current educational activity to the point scale for discipline which is finished with pass-fail test

4-бальна шкала	200-бальна шкала	4-бальна шкала	200-бальна шкала	4-бальна шкала	200-бальна шкала	4-бальна шкала	200-бальна шкала
5	200	4.45	178	3.92	157	3.37	135
4.97	199	4.42	177	3.89	156	3.35	134
4.95	198	4.4	176	3.87	155	3.32	133
4.92	197	4.37	175	3.84	154	3.3	132
4.9	196	4.35	174	3.82	153	3.27	131
4.87	195	4.32	173	3.79	152	3.25	130
4.85	194	4.3	172	3.77	151	3.22	129
4.82	193	4.27	171	3.74	150	3.2	128
4.8	192	4.24	170	3.72	149	3.17	127
4.77	191	4.22	169	3.7	148	3.15	126
4.75	190	4.19	168	3.67	147	3.12	125
4.72	189	4.17	167	3.65	146	3.1	124
4.7	188	4.14	166	3.62	145	3.07	123
4.67	187	4.12	165	3.57	143	3.02	121
4.65	186	4.09	164	3.55	142	3	120
4.62	185	4.07	163	3.52	141	Less than 3	Insuffi-ciently
4.6	184	4.04	162	3.5	140		
4.57	183	4.02	161	3.47	139		
4.52	181	3.99	160	3.45	138		
4.5	180	3.97	159	3.42	137		
4.47	179	3.94	158	3.4	136		

Individual work of students is evaluated during the current control of topic on the appropriate class. Mastering topics submitted only for the individual work is controlled at the final control.

Students receive a pass-fail test if the average grade for the current educational activity during the semester is at least "3" (120 points on a 200-point scale).

Points on discipline are converted regardless both in ECTS scale and a 4-point scale (traditional scale). Scores of ECTS scale can not be converted into 4-point scale and vice versa. Score points of students studying in one specialty are ranked on the ECTS scale as follows

Grade in ECTS	Statistical index
A	Top 10% of students
B	The next 25% of students
C	The next 30% of students

D	The next 25% of students
E	The last 10% of students

Ranking with assigning grades of “A”, “B”, “C”, “D”, “E” is held for the students of one course, studying one specialty and successfully completed the academic discipline. Students who have received grades FX, F (“2”) are not recorded to the list of students for ranking. Students who have received grade FX after repassing get grade “E” automatically.

For students who completed the program successfully the points on discipline are converted into a traditional 4-point scale by absolute criteria, which are listed in the table below:

Points on discipline	Grade in 4-point scale
From 170 to 200 points	5
From 140 to 169 points	4
From 139 to minimum score points	3
Lower than to minimum score points	2

The ECTS score is not converted to the traditional scale, as the ECTS scale and the 4-point scale are independent. The objectivity of the assessment of students' learning activities is checked by statistical methods (correlation coefficient between grade in ECTS scale and grade in national scale).

13. Methodical providing:

- ✓ academic program of the discipline;
- ✓ lecture notes on discipline (thesis);
- ✓ lecture presentations;
- ✓ guidelines for lecturers/instructors;
- ✓ guidelines for practical classes for students;
- ✓ guidelines for individual students' work;
- ✓ test and control tasks for practical classes.

14. List of recommended literature

Main sources:

1. Chalyi A.V., Tsekhmister Ya.V., Agapov B.T. Medical and Biological Physics: textbook for the students of higher medical institutions of the IV accreditation level. – Vinnytsia, Nova Knyha, 2010. – 480 p.
2. Davidovits P. Physics in biology and medicine. 5th ed. – Amsterdam: Elsevier Academic Press, 2019. – 377 p.
3. Herman I.P. Physics of the Human Body. Springer, 2008. – 860 p.
4. Hobie R.K., Roth B.J. Intermediate Physics for Medicine and Biology. Springer, 2007. – 616 p.
5. Medical and Biological Physics: Laboratory Manual for students of higher medical institutions of the IV accreditation level // Lychkovsky E.,

Fafula R., Fedorovych Z., Makar N., Odnorih L. – Lviv, Danylo Halytsky Lviv National Medical University, 2014. – 300 p.
6. Newman J. Physics of the Life Sciences. Springer, 2008. – 718 p.

Additional sources:

1. Cotterill R. Biophysics. An introduction. J. Wiley & Sons, 2002. – 396 p.
2. Glaser R., Biophysics, Springer, 2004.
3. Hendee W., Ritenour R. Medical imaging physics. J.Wiley&Sons, 2002.

15. Information resources

1. http://misa.meduniv.lviv.ua/(Distance learning platform of Danylo Halytsky Lviv National Medical University)
2. https://pubmed.ncbi.nlm.nih.gov/ (Electronic database of medical and biological publications)
3. https://www.biophysics.org/ (Biophysical Society)
4. http://iomp.org/ (International Organization of Medical Physics)
5. http://aapm.org/default.asp (Website of the American Association of Physicists in Medicine)
6. http://scitation.aip.org/content/aapm/journal/medphys (Medical Physics Journal)
7. https://physicsworld.com/c/biophysics-bioengineering/ (Information resources on biophysics and bioengineering)
8. https://physicsworld.com/c/medical-physics (Information resources on medical and bioengineering)