Univerza v Mariboru

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	**Biofizika**
Course title:	**Biophysics**

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Biomedicinska tehnologija/Biomedical Technology 3. stopnja/3rd Degree		**1**	**1,2**

Vrsta predmeta / Course type

Univerzitetna koda predmeta / University course code:

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
20	**40**	**15**			**225**	**10**

Nosilec predmeta / Lecturer: **Red. prof. dr. Marko Marhl**

Jeziki / Languages:	**Predavanja / Lectures:**	**Slovenščina/Slovene**
	Vaje / Tutorial:	**Slovenščina/Slovene**

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:

Prerequisits:

Vsebina:

Biofizika celice in celične membrane: mehanske lastnosti celične membrane, metabolizem celice, termodinamski potenciali in kemijski potencial, kislinsko-bazno ravnotežje, osmoza, difuzija in elektrodifuzija, membranski potencial, Nernstova enačba, Donnanovo ravnovesje, elektrodifuzijski potencial. Električna vzdražljivost celice in prenos električnega impulza. Biofizika celičnega skeleta in molekularni motorji (delovanje mišice). Izbrani fiziološki sistemi: kri in krvni obtok, čutila, okostje in mišice, živčevje. Regulacija bioloških sistemov (sistemska analiza, regulacija metaboličnih sistemov – kontrolna teorija). Biološki dinamični sistemi (celična signalizacija, razvoj populacije). Samoorganizacija bioloških sistemov. Teorije in modeli evolucije. Interakcija neionizirajočega elektromagnetnega sevanja s tkivom človeka. Interakcija ionizirajočega sevanja s tkivom.

Pri obravnavi vsebin spoznamo nekaj ključnih biofizikalnih teoretičnih in eksperimentalnih raziskovalnih metod, ki so pomembne za znanstveno raziskovalno delo na področju medicine.

Teoretične metode: stabilnostna anliza dinamičnih sistemov, numerične metode in deterministično modeliranje, izračun Lyapunovih eksponentov, analiza kaotičnih atraktorjev, določanje fraktalne dimenzije,

Content (Syllabus outline):

Cell and cell membrane biophysics: mechanical properties of a cell membrane, cellular metabolism, thermodynamic potentials and chemical potential, acid-base equilibrium, osmosis, diffusion and electro-diffusion, the membrane potential; Nernst equation, Donnan equilibrium, electro-diffusion potential. Electrical excitability and propagation of electric pulse. Biophysics of cytoskeleton and molecular motors (muscle contraction). Selected physiological systems: blood and cardiovascular system, senses, skeletal-muscular system, nervous system. Regulation of biological systems (system analysis, control theory of metabolic systems). Biological dynamic systems (cell signalling, growth of population). Self-organisation of biological systems. Theory and models of evolution. Interaction of non-ionising electromagnetic radiation with human tissue. Interaction with ionising radiation with tissues.

In the frame of the proposed content we learn some key theoretical and experimental research methods used in biophysics, which is crucial for the research work in the field of medicine.

Theoretical methods: stability analysis of dynamical systems, numerical methods and deterministic modelling, determination of Lyapunov exponents, analysis of chaotic attractors, determination of fractal dimension, stochastic

stohastično modeliranje in Gillespijev algoritem, metoda Monte Carlo, celični avtomati, teorija iger, teorija mrež, analiza časovnih vrst. *Eksperimentalne metode:* optična mikroskopija, elektronska mikroskopija, analiza nanomaterialov in uporaba nanodelcev, nuklearnma magnetna resonanca, elektronska paramagnetna resonanca.	modelling and Gillespie algorithm, Monte Carlo method, cellular automata, game theory, network theory, time-series analysis. *Experimental methods:* optical (light) microscopy, electron microscopy, analysis of nanomaterials and the use of nanoparticles, nuclear magnetic resonance, electron paramagnetic resonance.

Temeljni literatura in viri / Readings:

- R. Glaser, Biophysics: An Introduction. Springer-Verlag, 2012.
- P. F. Dillon, Biophysics: A Physiological Approach. Cambridge University Press, 2012.
- J. Newman, Physics of the Life Sciences, Springer Science+Bussiness Media. LLC, 2008.
- S. A. Kane, Introduction to Physics in Modern Medicine. CRC Press, 2009.
- R. Heinrich, S. Schuster, The Regulation of Cellular Scystems. Chapman & Hall, 1996.
- W. Greiner, L. Neise. H. Stöcker, Thermodynamics and Statistical Mechanics. Springer, 1997.
- K. A. Dill, S. Bromberg, Molecular Driving Forces: Statistical Thermodynamics in Biology, Chemistry, Physics, and Nanoscience, Second Edition. Garland Science, Taylor & Francis Group, 2011.
- S. H. Strogatz, Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering. Perseus Books Publishing, 1994.
- A.-L- Barabási, Network Science. Cambridge University Press, 2016.
- D. J. Watts, Small Worlds: The Dynamics of Networks between Order and Randomness. Princeton University Press, 2003.
- Fractals in Biology and Medicine, Eds: G.A. Losa, D. Merlini, T.F. Nonnenmacher, E.R. Weibel, Birkhäuser Verlag, 2005.
- S. Camazine, J.-L. Deneubourg, N. R. Franks, J. Sneyd, G. Theraulaz, E. Bonebeau, Self-Organization in Biological Systems. Princeton University Press, 2001.
- M. Broom, J. Rychtàr, Game-Theoretical Models in Biology. CRC Press, Taylor & Francis Group, 2013.

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je obravnavati strukturo in delovanje bioloških sistemov oziroma njihovih gradnikov na molekularni in makromolekularni ravni, na stopnji supramolekularne organiziranosti, na ravni celice in interakcije med njimi ter na ravni organov človeškega telesa. Pristop temelji na matematični formulaciji konceptov v biofiziki. Obravnavani primeri so izbrani iz biologije človeka in zato posebej zanimivi za medicino. Pri obravnavi primerov so izpostavljene teoretične in eksperimentalne raziskovalne metode.	The main objective of the course is to discuss the structure and function of biological systems at different levels of biological complexity from a molecular, macromolecular and supramolecular level to a cellular level and tissue as well as to organs of the human body. The course is based on mathematical formulation of biophysical concepts. The presented systems are selected from human biology with indicated applications to medicine. In particular, a special attention is given to learn about theoretical and experimental research methods.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Usvojeno pregledno interdisciplinarno znanje o strukturnih lastnosti in delovanju bioloških sistemov na različnih ravneh organiziranosti od molekule do organizma. **Prenesljive/ključne spretnosti in drugi atributi:** Sposobnost vključitve v poglobljeno raziskovalno delo z namenom nadaljevanja doktorskega študija in izdelave doktorata na različnih problemih biofizike in medicine.	**Knowledge and understanding:** Broad interdisciplinary knowledge of structure and function of different biological systems considered at different levels of complexity from molecules to human organs. **Transferable/Key Skills and other attributes:** Ability of a student to be involved deeply in research in order to continue his/her doctoral studies leading to PhD thesis on various problems from biophysics and medicine.

Metode poučevanja in učenja:	Learning and teaching methods:
predavanja seminarji	lectures seminars

Načini ocenjevanja:	Delež (v %) / Weight (in %)	Assessment:
Seminarska naloga	40%	Seminar work
Ustno preverjanje znanja	60%	Oral examination

Reference nosilca / Lecturer's references:

MARKOVIČ, Rene, PELTAN, Julien, GOSAK, Marko, HORVAT, Denis, ŽALIK, Borut, SEGUY, Benjamin, CHAUVEL, Remi, MALANDAIN, Gregoire, COUFFINHAL, Thierry, DUPLÁA, Cécile, **MARHL, Marko**, ROUX, Etienne. Planar cell polarity genes frizzled4 and frizzled6 exert patterning influence on arterial vessel morphogenesis. *PloS one*, ISSN 1932-6203, 2017, vol. 12, iss. 3, str. 1-19, doi: 10.1371/journal.pone.0171033. [COBISS.SI-ID 22990856].

GOSAK, Marko, MARKOVIČ, Rene, FAJMUT, Aleš, **MARHL, Marko**, HAWLINA, Marko, ANDJELIĆ, Sofija. The analysis of intracellular and intercellular calcium signaling in human anterior lens capsule epithelial cells with regard to different types and stages of the cataract. *PloS one*, ISSN 1932-6203, 2015, vol. 10, iss. 12. http://dx.doi.org/10.1371/journal.pone.0143781, doi: 10.1371/journal.pone.0143781. [COBISS.SI-ID 2645676].

GOSAK, Marko, STOŽER, Andraž, MARKOVIČ, Rene, DOLENŠEK, Jurij, **MARHL, Marko**, RUPNIK, Marjan, PERC, Matjaž. The relationship between node degree and dissipation rate in networks of diffusively coupled oscillators and its significance for pancreatic beta cells. *Chaos*, ISSN 1054-1500, July 2015, vol. 25, iss. 7, 073115-1-073115-8, doi: 10.1063/1.4926673. [COBISS.SI-ID 512523576].

STOŽER, Andraž, GOSAK, Marko, DOLENŠEK, Jurij, PERC, Matjaž, **MARHL, Marko**, RUPNIK, Marjan, KOROŠAK, Dean. Functional connectivity in islets of Langerhans from mouse pancreas tissue slices. *PLoS computational biology*, ISSN 1553-734X. [Print ed.], Feb. 2013, vol. 9, iss. 2, str. e100292312-1-e1002923-12, doi: 10.1371/journal.pcbi.1002923. [COBISS.SI-ID 512264760].

BODENSTEIN, Christian, GOSAK, Marko, SCHUSTER, Stefan, **MARHL, Marko**, PERC, Matjaž. Modeling the seasonal adaptation of circadian clocks by changes in the network structure of the suprachiasmatic nucleus. *PLoS computational biology*, ISSN 1553-734X. [Print ed.], Sep. 2012, vol. 8, iss. 9, e1002697-1-e1002697-12, doi: 10.1371/journal.pcbi.1002697. [COBISS.SI-ID 19375368].