Univerza v Mariboru

Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Modeliranje in simulacije v medicini in biologiji
Course title:	Modeling and Simulations in Medicine and Biology

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Fizika 2. st.		2	3
Physics 2nd degree			

Vrsta predmeta / Course type izbirni/elective

Univerzitetna koda predmeta / University course code:

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Laboratory work	Teren. vaje Field work	Samost. delo Individ. work	ECTS
15	15	0	15	0	105	5

Nosilec predmeta / Lecturer: Aleš Fajmut, Andraž Stožer

Jeziki / Languages:		
	Predavanja / Lectures:	slovenski/Slovenian
	Vaje / Tutorial:	slovenski/Slovenian

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisits:
Jih ni.	None.

Vsebina:	Content (Syllabus outline):
KONTROLA CELIČNEGA VOLUMNA IN ELEKTRIČNE LASTNOSTI CELIČNE MEMBRANE (modeliranje kontrole celičnega volumna, prehod ionov preko membrane, simulacija širjenja akcijskega potenciala po živčni celici, Davenportov in Darrow-Yannetov diagram) MEHANIKA MIŠIC (relacija med silo in hitrostjo, dinamika prečnih mostičkov, računalniška simulacija pripetja in odpetja prečnih mostičkov, p-V diagram srca, krivulja srčne, žilne in ledvične funkcije) BIOLOŠKI RITMI (razne oscilacije v bioloških sistemih, npr. cikel spanja in budnosti,	CONTROL OF CELL VOLUME AND ELECTRICAL PROPERTIES OF CELL MEMBRANES (modeling of cell volume control, the movement of ions across membrane, computer simulation of the nerve action potential, Davenport diagram, Darrow-Yannet diagram) MUSCLE MECHANICS (the force-velocity relationship, crossbridge dynamics, computer simulation of crossbridge attachment and detachment, p-V relationship of the heart, cardiac, vascular, and renal function curve) BIOLOGICAL RHYTHMS (various oscillations in biological systems, e. g., the sleep-wakefulness

spreminjanje koncentracije hormonov v plazmi) FIZIOLOŠKO BAZIRANI FARMAKOKINETIČNI MODELI (npr. regulacija glukoze v krvi) ANALIZA IN REKONSTRUKCIJA SLIK V MEDICINI IN PRI MIKROSKOPSKIH TEHNIKAH (detekcija objektov na slikah elektronske in konfokalne svetlobne mikroskopije). V okviru seminarja študent izbere eno izmed razpisanih tem za projektno nalogo, ki ima obliko krajšega strokovnega prispevka. Študent po izdelavi in pregledu naloge pripravi predstavitev pred kolegi. *Vsebina laboratorijskih vaj:* - modeliranje izbranih bioloških procesov tudi s stališča medicine - računalniška simulacija in vizualizacija rezultatov z računalniškimi orodji	cycle, changes in plasma hormone concentration) PHYSIOLOGICALLY BASED PHARMAKOKINETIC MODELS (e.g., regulation of blood glucose level) ANALYSIS AND RECONSTRUCTION OF IMAGES IN MEDICINE AND MICROSCOPY TECHNIQUES (object detection in TEM and confocal images) The seminar is intended for the presentations of student projects, which should have the form of a shorter professional paper. After preparing and reviewing the project, the student prepares a presentation in front of colleagues. *Laboratory work outline:* - modeling of selected biological processes also from the medical point of view - computer simulation and visualization of results with computer tools

Temeljni literatura in viri / Readings:

1. Hoppensteadt F. C., Peskin C. S. Modeling and Simulation in Medicine and the Life Sciences, Springer-Verlag, New York 2004.
2. Keener J., Sneyd J. Mathematical Physiology, Springer-Verlag, New York 1998
3. Hobbie R. K. Intermediate Physics for Medicine and Biology, John Wiley & Sons, New York 1988
4. Wood A.W. Physiology, biophysics and biomedical engineering, CRC Press, Boca Raton 2012

Cilji in kompetence:	**Objectives and competences:**
Študent je po uspešno opravljenem izpitu zmožen: - razumeti obravnavane zahtevnejše teoretične biofizikalne koncepte in metode modeliranja živih sistemov predvsem na ravni fizioloških procesov v telesu - identificiranja in obravnave izbranih kompleksnejših problemov v bio-znanostih in medicini ter pristopa k iskanju njihovih rešitev s pomočjo metod teoretičnega biofizikalnega modeliranja in računalniških simulacij	After passing the exam, the student is able: - to understand the discussed complex theoretical biophysical concepts and methods of modeling of living systems especially on the level of physiological processes within the body - to identify and treat the selected complex problems in bio-sciences and medicine, and to find strategies for their solutions with methods of theoretical biophysical modeling and computer simulations - of professional cooperation, communication and transfer of knowledge in the field of interdisciplinary natural sciences and medicine

- strokovnega sodelovanja, komunikacije ter prenosa znanj na področju naravoslovnih interdisciplinarnih ved in medicine	

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Po zaključku predmeta je študent zmožen: - kvalitativno in kvantitativno (s fizikalno-matematičnimi odvisnostmi) opisati obravnavane zahtevnejše teoretične biofizikalne koncepte predvsem na fiziološki ravni - aplicirati te koncepte na konkretnih primerih kompleksnejših modelov bioloških sistemov z aplikacijo v medicini in fiziologiji - rešiti z računalniškimi orodji konkretne kompleksne obstoječe modele bioloških sistemov in z njimi napovedati rezultate, ki so relevantni za medicino in fiziologijo - na podlagi rezultatov matematičnega modeliranja oblikovati in napovedovati enostavnejše hipoteze, ki so relevantne za medicino in fiziologijo Prenesljive/ključne spretnosti in drugi atributi: - sposobnost napredne uporabe računalniških orodij za modeliranje in simulacijo v medicini in fiziologiji - zavedanje o pomenu in koristnosti biofizikalnih teoretičnih pristopov k obravnavi bioloških sistemov za razvoj novih eksperimentov in metod zdravljenja	Knowledge and Understanding: Upon completion of the course, the student is able: - to qualitatively and quantitatively (with physical and mathematical dependencies) describe selected complex theoretical biophysical concepts especially at the physiological level - to apply these concepts on selected examples of complex models of biological systems with applications to medicine and physiology - to solve selected complex existing models of biological systems with help of computer tools and to predict the results that are relevant to medicine and physiology - predict simpler hypotheses that are useful to medicine and physiology on the basis of the results of mathematical modeling Transferable/Key Skills and other attributes: - the ability to use advanced computer tools for modeling and simulations in medicine and physiology - awareness of the importance and usefulness of biophysical theoretical approaches for the treatment of biological systems accounting for the development of new experiments and methods of medical treatment

Metode poučevanja in učenja:	**Learning and teaching methods:**

Predavanja podkrepljena s simulacijami Seminar; pisne in ustne predstavitve projektnih nalog iz izbrane teme Laboratorijske vaje (delo z računalnikom).	Lectures, supported by simulations Seminar; oral and written presentations of projects from selected topics Laboratory work (work with computer)

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Ustni izpit iz vsebin predavanj in vaj	70	Oral exam from the topics of lectures and tutorials
Poročilo o delu na problemu	30	Case study report

Reference nosilca / Lecturer's references:

Andraž Stožer

1. POSTIĆ, Sandra, GOSAK, Marko, TSAI, Wen-Hao, PFABE, Johannes, SARIKAS, Srdjan, STOŽER, Andraž, KOROŠAK, Dean, YANG, Shi-Bing, RUPNIK, Marjan. pH-dependence of glucose- dependent activity of beta cell networks in acute mouse pancreatic tissue slice. Frontiers in endocrinology. Jun. 2022, vol. 13, str. 1-11. ISSN 1664-2392. DOI: 10.3389/fendo.2022.916688. [COBISS.SI-ID 117435907]
2. POHOREC, Viljem, KRIŽANČIĆ BOMBEK, Lidija, SKELIN, Maša, DOLENŠEK, Jurij, STOŽER, Andraž. Glucose-stimulated calcium dynamics in beta cells from male C57BL/6J, C57BL/6N, and NMRI mice: a comparison of activation, activity, and deactivation properties in tissue slices. Frontiers in endocrinology. March 2022, vol. 13, str. 1-16, ilustr. ISSN 1664-2392. https://www.frontiersin.org/articles/10.3389/fendo.2022.867663/full, DOI: 10.3389/fendo.2022.867663. [COBISS.SI-ID 103005187]
3. MAROLT, Urška, PARADIŽ, Eva, POHOREC, Viljem, LIPOVŠEK DELAKORDA, Saška, VENGLOVECZ, Viktória, GÁL, Eleonóra, ÉBERT, Attila, MENYHÁRT, István, POTRČ, Stojan, GOSAK, Marko, DOLENŠEK, Jurij, STOŽER, Andraž. Calcium imaging in intact mouse acinar cells in acute pancreas tissue slices. PloS one. 2022, vol. 17, iss. 6, str. 1-26, ilustr. ISSN 1932-6203. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0268644, DOI: 10.1371/journal.pone.0268644. [COBISS.SI-ID 112261635]
4. STOŽER, Andraž, SKELIN, Maša, GOSAK, Marko, KRIŽANČIĆ BOMBEK, Lidija, POHOREC, Viljem, RUPNIK, Marjan, DOLENŠEK, Jurij. Glucose-dependent activation, activity, and deactivation of beta cell networks in acute mouse pancreas tissue slices. American journal of physiology. endocrinology and metabolism. 2021, vol. 321, iss. 2, str. e305-e323, ilustr. ISSN 0193-1849. https://journals.physiology.org/doi/full/10.1152/ajpendo.00043.2021?rfr_dat=cr_pub++0pubmed&url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org, DOI: 10.1152/ajpendo.00043.2021. [COBISS.SI-ID 75400451]
5. ŠTERK, Marko, DOLENŠEK, Jurij, KRIŽANČIĆ BOMBEK, Lidija, MARKOVIČ, Rene, ZAKELŠEK, Darko, PERC, Matjaž, POHOREC, Viljem, STOŽER, Andraž, GOSAK, Marko. Assessing the origin and velocity of Ca2+ waves in three-dimensional tissue: insights from a mathematical model and confocal imaging in mouse pancreas tissue slices. Communications in Nonlinear Science and Numerical

Simulation. Feb. 2021, vol. 93, art. 105495, str. 1-17. ISSN 1007-5704. DOI: 10.1016/j.cnsns.2020.105495. [COBISS.SI-ID 26793987]

Aleš Fajmut

1. ŠTERK, Marko, MARKOVIČ, Rene, MARHL, Marko, FAJMUT, Aleš, DOBOVIŠEK, Andrej. Flexibility of enzymatic transitions as a hallmark of optimized enzyme steady-state kinetics and thermodynamics. Computational biology and chemistry. [Print ed.]. Apr. 2021, vol. 91, str. 1-10. ISSN 1476-9271. DOI: 10.1016/j.compbiolchem.2021.107449. [COBISS.SI-ID 52543491]
2. FAJMUT, Aleš, PAL, Kaushik, HARKAI, Saša, ČREŠNAR, Dejvid, KUTNJAK, Zdravko, KRALJ, Samo. The core structure of a laboratory-made dust devil-like vortex and its condensed matter analogs. Journal of molecular structure. [Print ed.]. 2021, vol. 1237, str. 30335-1-30335-8. ISSN 0022-2860. DOI: 10.1016/j.molstruc.2021.130335. [COBISS.SI-ID 58279171]
3. DOBOVIŠEK, Andrej, MARKOVIČ, Rene, BRUMEN, Milan, FAJMUT, Aleš. The maximum entropy production and maximum Shannon information entropy in enzyme kinetics. Physica. A, Statistical mechanics and its applications. [Print ed.]. 2018, vol. 496, str. 220-232. ISSN 0378-4371. DOI: 10.1016/j.physa.2017.12.111. [COBISS.SI-ID 23601416]
4. DOBOVIŠEK, Andrej, VITAS, Marko, BRUMEN, Milan, FAJMUT, Aleš. Energy conservation and maximal entropy production in enzyme reactions. Biosystems. [Print ed.]. 2017, vol. 158, str. 47-56. ISSN 0303-2647. DOI: 10.1016/j.biosystems.2017.06.001. [COBISS.SI-ID 23218696]
5. FAJMUT, Aleš. Molecular mechanisms and targets of cyclic guanosine monophosphate (cGMP) in vascular smooth muscles. V: SAKUMA, Kunihiro (ur.). Muscle cell and tissue : novel molecular targets and current advances. London: IntechOpen, cop. 2021. Str. 1-31. ISBN 978-1-83968-651-1, ISBN 978-1-83968-650-4, ISBN 978-1-83968-652-8. https://www.intechopen.com/chapters/76823, DOI: 10.5772/intechopen.97708. [COBISS.SI-ID 79467011]