IDENTIFYING DATA				
(*)Modelado e simulación sistemas biomédicos				
Subject	(*)Modelado e simulación sistemas biomédicos			
Code	V04M192V01103			
Study programme	Máster Universitario en Ingeniería Biomédica			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	4.5	Mandatory	1st	1st
Teaching language	Galician			
Department				
Coordinator	Fernández Villaverde, Alejandro			
Lecturers	Fernández Villaverde, Alejandro			
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General description	In this subject the students will gain the knowledge and skills required for building dynamic models of biosystems, with a focus on the processes and systems of interest in biomedical engineering. They will get acquainted with the techniques used in identification, simulation, and analysis of mathematical models, and they will learn to apply them to biomedical engineering problems.			

Skills	
Code	
A5	Students must possess the learning skills that enable them to continue studying in a way that will be largely self-directed or autonomous.
B3	Knowledge in basic and technological subjects that will enable students to learn new methods and theories, and provide them the versatility to adapt to new situations.
C3	Ability to select and apply advanced modeling methods to the design and simulation of biomedical systems.

Learning outcomes	
Expected results from this subject	Training and Learning Results
To know the usefulness of mathematical modeling and apply it to biosystems of interest in medicine.	B3 C3
To know model simulation methods and computational tools for modeling.	B3 C3
Learn to build models from experimental data and existing biomedical knowledge.	A5 B3 C3
To apply models to analyze the behavior of biosystems	A5 B3 C3

Contents	
Topic	
1. Introduction to mathematical modelling in biomedicine	1.1. Motivation and history of biomedical modelling 1.2. Dynamic modelling: components and paradigms 1.3. Types of dynamic models 1.3.1. Graphs 1.3.2. Differential equations 1.4. Combinations of models 1.5. Examples

2. Dynamical biomedical systems. Approaches to their modelling	2.1. Types of biosistems of interest 2.2. Biochemical reaction kinetics 2.3. Cellular level 2.3.1. Metabolism 2.3.2. Cellular signalling 2.3.3. Gene expression 2.4. Organ level 2.4.1. Electrophysiology 2.4.2. Glucose regulation 2.4.3. Pharmacokinetics and pharmacodynamics 2.5. Population level 2.5.1. Epidemiology 2.5.2. Microbial communities
3. Numerical simulation methods	3.1. Integration of ordinary differential equations 3.1.1. Fixed step methods 3.1.2. Variable step methods 3.2. Integration of stochastic equations 3.2.1. Gillespie algorithm 3.3. Simulation software 3.3.1. General purpose programming environments 3.3.2. Specialized simulation tools 3.4. Standards, formats, and repositories
4. Model building and system identification	4.0. STEP 0: obtain the equations of the model 4.1. STEP 1: analyse observability and structural identifiability 4.2. STEP 2: define the objective function 4.3. STEP 3: parameter optimization 4.3.1. Local methods 4.3.2. Global methods 4.3.3. Definition of the optimization problem 4.4. STEP 4: analysis of the goodness of fit 4.5. STEP 5: Parameter uncertainty quantification 4.6. STEP 6: Prediction uncertainty quantification 4.7. Experimental design 4.8. Model selection 4.9. Computational resources
5. Dynamic behaviour	5.1. Equilibrium and stability 5.1.1. Mathematical characterization of stability 5.2. Bifurcations 5.3. Oscillations 5.4. Robustness 5.4.1. Redundancy 5.4.2. Parametric insensitivity 5.4.3. Feedback 5.4.4. Feedforward loops 5.5. Model reduction

Planning

	Class hours	Hours outside the classroom	Total hours
Lecturing	16.5	20	36.5
Problem solving	7.5	11.5	19
Practices through ICT	12	24	36
Essay questions exam	3	18	21

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies

	Description
Lecturing	Lectures given by the professor about the contents of the subject.
Problem solving	The professor will solve problems and exercises in the classroom. The students will solve similar exercises in order to purchase the necessary abilities.
Practices through ICT	In the practices the students will apply the theoretical knowledge about model building, calibration, simulation, and analysis, using computational tools (MATLAB).

Personalized assistance

Methodologies	Description
Lecturing	Answering the students' questions and doubts.

Problem solving	Answering the students' questions and doubts.
Practices through ICT	Answering the students' questions and doubts.
Tests	**Description**
Essay questions exam	Answering the students' questions and doubts.

Assessment

	Description	Qualification	Training and Learning Results		
Practices through ICT	The practicals will be evaluated continuously (session to session), each one with a grade of 0 to 10. Evaluation criteria: - Minimum attendance to 80% of the sessions. - Punctuality. - Previous preparation of the practical session. - Attitude and utilisation of the session. - Achievement of the session goals.	30	A5	B3	C3
Essay questions exam	The final examination will consist in a written test (questions and/or problems), graded between 0 and 10 points. It will be carried out individually and in person, and it will be held at the end of the semester, as scheduled by the direction of the school.	70		B3	C3

Other comments on the Evaluation

Both parts (final exam and practicals) must be passed in order to pass the subject, thus obtaining the total grade according to the percentage indicated above. If any one of the parts is not passed, the partial grades will be scaled so that the overall grade does not exceed 4.5.

If a student does not pass the practicals in continuous evaluation throughout the semester, she/he will not be able to pass the subject in the first call of the course. In the second call, she/he will be able to take a single laboratory practical exam that would allow, if passed, to achieve a pass in the practices, and thus to have the possibility to pass the subject (as long as the final exam is also passed).

For the purpose of considering the student as "presented" or "not presented", only the participation in the final exam will be taken into account.

In the second call of the same course (i.e. within the same academic year), students must be examined for the parts not passed in the first call.

Ethical commitment: Students are expected to have an appropriate ethical behavior. In the case of detecting unethical behavior (such as copying, plagiarism, use of unauthorized electronic devices, among others) it will be considered that the student does not meet the necessary requirements to pass the subject. In this case, the overall grade in the current academic year will be a fail (0.0).

Sources of information

Basic Bibliography

Joseph DiStefano III, **Dynamic systems biology modeling and simulation**, 9780124104938, https://vdoc.pub/download/dynamic-systems-biology-modeling-and-simulation-4iqd7mrh3fv0, Elsevier Science, 2015

Complementary Bibliography

Edda Klipp et al, **Systems biology: a textbook**, 978-3527336364, Wiley-Blackwell, 2016

Brian Ingalls, **Mathematical Modelling in Systems Biology: An Introduction**, 978-0262018883, https://www.math.uwaterloo.ca/~bingalls/MMSB/MMSB_w_solutions.pdf, The MIT Press, 2018

D. del Vecchio, R.M. Murray, **Biomolecular feedback systems**, 978-0-691-16153-2, http://www.cds.caltech.edu/~murray/BFSwiki/, Princeton University Press, 2014

Recommendations

Subjects that continue the syllabus

(*)Control e regulación das funcións corporais/V04M192V01202