UAB
Universitat Autònoma de Barcelona

Modelling and Simulation of Biosystems

Code: 100919
ECTS Credits: 6

2024/2025

Degree	Type	Year
2500253 Biotechnology	OT	4

Contact

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Teaching groups languages

You can view this information at the end of this document.

Prerequisites

To have fundamental knowledge of algebra, differential and integral calculus, chemistry and biochemistry, bioreactors.

Be able to read English scientific literature.

Be able to use basic office software (word, Excel,...)

Basic knowledge in computer programming is an advantage

Oral and written basic knowledge of Catalan language is necessary

Objectives and Contextualisation

Computer simulation of real systems is a well-developed field of science especially in engineering areas, in physics or in chemistry. In biotechnology and in generally in biological sciences, its application was initially limited. In this context classical simulation approaches reproduce the behavior of microorganisms and enzymes in bioreactor. But the real impact of computer simulation in biotechnology results as a consequence on one side, due to the accumulation of knowledge about the isolated operation of components of biological systems and on the other side from the experimental observation that the components of a biological entity, such as a cell, operate in an autonomous and coordinated manner as an integrated system. Thus the biological system can be seen as a network of networks (metabolic, genetic, signal transduction,..) operating in a coordinated manner. This way, to understand the operation of even one of the simplest of those systems, is not possible without the perspective of its operation as an integrated system. The operation as a system results in the emergence of key properties, non-existing in any of its isolated parts but fundamental for the successful operation of the system. This new vision has resulted in the emergence of the field of Systems Biology. Biological systems computer simulation has been key in the development of systems biology, together with the increasing accumulation of knowledge on the operation of biological systems in public databases and the wide spread and cheap availability of computing power. By means of computer simulation it is made evident the different behaviors obtained depending on the individual properties of the components, their interconnections as well as the operational conditions.

In this context the course intends to introduce the student in the basic approximations and methodologies to simulate the behavior of a biological system in a computer. From the bioreactor as an experimental system to the examples of simulation of different types of networks (metabolic, genetic, signal transduction,..) in different operational modes (steady state, dynamic,..). As a global objective it is intended that the student has a firsthand experience on the differences and relevance of the behavior of a system as an integrated 'whole' in opposition to the isolated characteristics of its components, as well as the information derived from the different operational modes and therefore the requirements for their study.

As the main goal is to offer the student first hand experience on biological systems simulation, the course has a high practical content. Thus the student will use either a programming environment, such as Matlab, to understand the basic procedures by means of simple examples, as well as using more specific simulation software for biological systems (COPASI, ...) in examples of higher complexity.

The different subjects are introduced gradually, from the basic concepts towards the description of systems of increasing complexity. In a way such that the student can understand the need to study biological systems as integrated entities in the context of the new biotechnology of the XXI century.

Learning Outcomes

1. CM32 (Competence) Plan a process for obtaining biotechnological products.
2. CM32 (Competence) Plan a process for obtaining biotechnological products.
3. KM35 (Knowledge) Explain the bases of design, instrumentation and monitoring of biotechnological processes.
4. KM35 (Knowledge) Identify the bases of design, instrumentation and monitoring of biotechnological processes.
5. SM33 (Skill) Interpret the kinetic parameters of enzymatic reactions, by means of graphical methods and using computer programmes.

Content

Unless the requirements enforced by the health authorities demand a prioritization or reduction of contents, the course will include:

1. Introduction. Models and systems
    1. Model. Definition, advantages, necessity
    2. Approximations to systems modelling
    3. Characteristics of systems
    4. Phases in the modelling process
    5. Components and types of models.
2. Review of fundamental concepts and modelling
    1. Balance equations and structure.
    2. Kinetics and thermodynamics
3. Dynamics of simple systems
    1. Bioreactor and biocatalyst systems
    2. Simple metabolic systems
    3. Basics of systems dynamics
4. Systems in steady state
    1. Bioreactor and biocatalyst systems
    2. Metabolic networks. Elementary modes.
    3. Optimization of systems in steady state.
    4. Systems sensitivity analysis. Metabolic control analysis
6. Simulation examples
    1. Metabolic networks
    2. Gene networks.
    3. Signal transduction networks

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Individual tutor appointments	4	0.16	
Practical computer classes	36	1.44	KM35, KM35, SM33
Theory classes	14	0.56	CM32, KM35, SM33
Type: Autonomous			
Personal computer simulation practice	36	1.44	KM35, KM35, SM33
Simulation (team) work	30	1.2	KM35, KM35, SM33
Study	30	1.2	CM32, KM35, SM33

The proposed teaching methodology may experience some modifications depending on the restrictions to face-to-face activities enforced by health authorities.

The methodology is heavily based on the student's work guided by the mentorship of the faculty members. In this context, and according with the objectives of the course, the different activities proposed can be grouped into theoretical classes, practical classes, autonomous work or individual tutor appoinments.

The different class typologies used can be described as follows:

Theory classes: Where all the necessary basic concepts will be provided as necessary to allow a proper autonomous learning step. IT resources (slides, .ppt, .pdf, simulations,…) used in class will be available to the student through the Moodle virtual platform.

Practical computer classes: Most of the learning outcomes of the course will be acquired via the practical classes using a computer. On the one side one objective is learning to use appropriated software for the simulation of biological systems. To this purpose the student will perform practical computer simulation exercises allowing the student to see the model implementation as well as the evolution of its behavior in different conditions. One of the main objectives will be to gain a deeper understanding of the behavior of a biological system and understand that this knowledge cannot be gained knowing the isolated behavior of its parts. The exercises will consist in the programming and simulation of example models corresponding to metabolic, genetic, signal transduction or other complex networks using the proper software for each case. The practical simulation classes will be performed in the computer rooms as scheduled in the course calendar. For each practical class a guide for the practical work will be available at the Moodle virtual campus for the course. While performing the exercises the student will keep the corresponding computer files inhis own virtual portfolio. Once the class will be finished the student will deliver the required files through the Moodle virtual campus as described ineach practical class guide. This will also serve as a register for each student's personal work. Some of the delivered exercises will be graded and given a mark. Which particular exercises are graded will be specified in the corresponding practical class guides. It is mandatory to be present in all practical classes. Should a student no be able to fulfill such requirement without proper documented justification it will be penalized as detailed in the corresponding evaluation section.

Simulation (team) work: Besides the above mentioned activities, the students will present a simulation work alone or in small group (2, 3 or 4 people) based on a computer simulation research paper. The paper can be selected from a list proposed by the teacher or alternatively proposed previously by the group and agreed with the teacher.

Individual tutor appointments: individual tutor appointments can be arranged with the professor to clarify concepts or any other course issues as well as to receive other advice such as available information resources.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Delivery of practical computer class results (activity A)	20	0	0	KM35, SM33
Graded exercises (activity C)	48	0	0	CM32, KM35, SM33
Simulation (team) work (activity B)	32	0	0	CM32, KM35, SM33

Student's assessment may experience some modifications depending on the restrictions to face-to-face activities enforced by health authorities.

Course assessment will be performed in the following way.

Activity A. Delivery of practical computer class results (20%): During the course the student will deliver through the Moodle virtual campus, the computer files resulting from the practical computer work as described in the corresponding practical class guide document. The delivery is compulsory. Failure in the delivery at the proper time will result in a penalty proportional to the number of course deliveries.

Activity B. Simulation (team) work (32%). It will correspond to the grade obtained in the delivered (team) simulation work.

Activity C. Graded exercises (48%): It will be the average of the marks received for the graded exercises. At present time it can be foreseen that the graded exercises will be included in the practical computer class results corresponding to practical classes 3, 6, 9 and 12. Nevertheless the graded practical exercises will be clearly identified in the corresponding practical class guide.

Any evidence part of the continuous evaluation procedure accounting for less or equal the 20% of the final mark will not be reprogrammed and considered non recoverable.

Final grade: It will be calculated as the weighted average of the practical computer class results (20%), Group simulation work (32%) and Graded exercises (48%). To allow for such weighted average it is necessary to have a minimum average grade of 3.8 in the Graded exercises.

Remedial exam (100%). In case the weighted average obtained using the above procedure would not be equal or higher to 5, the student can take a remedial exam. In this case, the final mark obtained will be the one obtained in this exam. To be eligible for the retake process, the student should havebeen previously evaluated in a set of activities equaling at least two thirds of the final score of the course or module. It must be taken into account that if the student takes this option any previous qualification, deriving from the continuous evaluation activities, will be discarded and not considered furthermore.Students passing the course with this exam in the first edition will not be considered for the Excellent with honors qualification.

This exam will also be open to students who failed to pass the course in previous editions of the course.

The minimum grade mark necessary to pass the course is 5.

Unique evaluation (100%): Students approved by the faculty to take this evaluation mode will have to present on the same day all the necessary evidences to pass the course. Those evidences will be:

Synthesis exam (70%): The synthesis exam will consist on two parts:

Part A) Practical simulation work at the computer. Equivalent to the practical graded exercises performed during the continuous evaluation and proposed by the professorship. It will include two parts. One of exercises to be solved using Matlab and a second one with exercises to be solved using COPASI

Part B) Questions including both the theoretical part of the course as well as on the results obtained during the practical exercises.

Scientific publication work (30%): The student will present a work based on a scientific publication where the mathematical simulation is applied to the fields of Molecular Systems Biology or Metabolic Engineering. The work must include practical simulations performed by the student either for verification of the paper results and/or for improvement or complementing the paper. Works based solely on commenting the presented paper will not be accepted. It will follow the same constraints as the teamwork presented in the continuous evaluation but will be individual.

This exam will be taken on the same date as for the last exam of the continuous evaluation and will be subject of the same method of review and recovery as for the continuous evaluation.

Students passing the course with this exam will not be considered for the Excellent with honors qualification.

Other issues:

Not Evaluable: Any student not attending to two thirds (2/3) of the graded activities, will be qualified as 'Not Evaluable'. Also, any student not attending to at least 80% of the practical classes will be qualified as 'Not evaluable'.

Dates: The dates of delivery of practical exercises or simulation (group) work will be informed thorough the Moodle virtual campus and may be changed for adaptation to previously unforeseen events. This communication method will also be used to inform of any change in the schedule or planned activities as it is considered the main communication method between the student and the faculty members.

Plagiarism: Irrespective of any other measure that may be adopted, and according to the actual academic regulations, any irregular action committed by a student resulting in a variation of the result of any evaluation activity, will receive a qualification of zero. Therefore, to copy or let any other one to copy, during a test, an exercise or a practical activity will result in its failure. Should this activity be necessary to pass the course, the complete course will not be passed. Any activity qualified this way cannot be recovered. Therefore, the complete course will be failed without the opportunity to pass it during the same semester.

Grading of the previously enrolled students: Once the student has been enrolled in the course for more than one year, grading of the course will be done in a final exam. Grading using the A, B and C activities is possible but has to be previously agreed with the professor at the beginning of the course (joan.albiol@uab.cat). That is before 8 days after the beginning of the course.

Review of grades: both for the unique or the continuous assessment, the teacher will inform the students of the day/time/place of the review of the tasks subject of assessment.

Honors Grade (MH): it is a personal decision of the faculty team responsible of the course to give a final honors grade. According to UAB regulations it can be given to students with a final mark equal or higher than 9, but the professorship can fix a higher minimum level if there are more candidates than the maximum number of honors available, or request for complementary activities. The maximum number of Honors that can be given is limited to 5% of the students enrolled in the course.

Bibliography

Ingalls, B.P. Mathematical modelling in systems Biology. An Introduction. The MIT press. 2013 (https://bibcercador.uab.cat/permalink/34CSUC_UAB/1c3utr0/cdi_askewsholts_vlebooks_9780262315630)

Covert M.W. Fundamentals of Systems Biology: From Synthetic Circuits to Whole-cell Models CRC Press 2015. (https://www-taylorfrancis-com.are.uab.cat/books/mono/10.4324/9781315222615/fundamentals-systems-biology-

Klipp, E., W. Liebermeister, C. Wierling, A. Kowald; Systems Biology. A textbook 2nd ed. Weinheim: Wiley-VCH, 2016. (https://csuc-uab.primo.exlibrisgroup.com/permalink/34CSUC_UAB/1eqfv2p/alma991006672719706709)

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Kremling, A. Systems Biology. Mathematical Modelling and Model Analysis. Chapman & Hall. 2013

Nielsen, J.; Hohmann, S. Systems Biology. Wiley-Blackwell. 2017 (https://bibcercador.uab.cat/permalink/34CSUC_UAB/15r2rl8/cdi_elibro_books_ELB177228)

Palsson, B.O. Systems Biology. Properties of reconstructed networks. Cambridge: Cambridge University Press, 2006.

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Szallasi, Z., V. Periwal, i J. Stelling, . System Modeling in Cellular Biology: From Concepts to Nuts and Bolts. The MIT Press, 2006.

Software

- COPASI (http://copasi.org/)

- Matlab (https://es.mathworks.com/academia/tah-portal/universitat-autonoma-de-barcelona-40811157.html)

Language list

Name	Group	Language	Semester	Turn
(PLAB) Practical laboratories	441	Catalan	first semester	afternoon
(TE) Theory	44	Catalan	first semester	morning-mixed