Advanced Biomaterials, 3D Bioprinting and Micro/nano Biofabrication

Academic Year: (2024 / 2025) **Review date: 16-05-2024**

Department assigned to the subject: Bioengineering Department

Coordinating teacher: MARTINEZ SANTAMARIA, LUCIA

Type: Electives ECTS Credits : 6.0

Year : 4 Semester :

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Chemistry
Physics I
Cell and Molecular Biology
Biochemistry
Materials Science and Engineering
Anatomy and Physiology I and II
Introduction to Biomaterials
Fundamentals of Tissue Engineering and Regenerative Medicine
It is also recommended to have completed Biomechanics of continuum media I (solids) and Biomechanics of continuum media II (fluids)

SKILLS AND LEARNING OUTCOMES

RA3: Be able to carry out conceptual designs for bioengineering applications according to their level of knowledge and understanding, working in a team. Design encompasses devices, processes, protocols, strategies, objects and specifications broader than strictly technical, including social awareness, health and safety, environmental and commercial considerations.
RA4: Be able to use appropriate methods to carry out studies and solve problems in the biomedical field, commensurate with their level of knowledge. Research involves conducting literature searches, designing and carrying out experimental practices, interpreting data, selecting the best approach and communicating knowledge, ideas and solutions within their field of study. May require consultation of databases, safety standards and procedures.
RA5: Acquire intermediate/advanced knowledge of engineering and biomedical sciences and demonstrate an understanding of the theoretical and practical aspects and methodology of work in their field of study.
CB1: Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2: Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3: Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4: Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5: Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG2: Ability to design, draft and develop scientific-technical projects in the field of biomedical engineering.
CG4: Ability to solve problems with initiative, decision-making, creativity, and to communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the biomedical engineer's activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG6: Knowledge of current standards, regulations and legislation and ability to apply them to bioengineering projects. Bioethics applied to biomedical engineering.
CG7: Drafting, representing and interpreting scientific-technical documentation.

CG8: Ability to solve mathematical, physical, chemical and biochemical problems that may arise in biomedical engineering.
CG10: Knowledge of the structure, composition, processing, properties and behaviour in service of the different families of materials and their interrelationships. Being able to select materials according to their applications in biomedicine.
CG15: Ability to apply microfabrication, microfluidics, nanotechnology and 3D printing techniques in the field of biomaterials.
CG17: Ability to apply engineering, micro-engineering, nano and biotechnology techniques to solve complex biomedical problems in regenerative medicine.
CG18: Ability to apply knowledge of human anatomy and physiology to the resolution of problems in medicine from the point of view of bioengineering. Ability to identify medical problems that can be treated by means of techniques encompassed in Biomedical Engineering.
CT1: Ability to communicate knowledge orally and in writing to both specialised and non-specialised audiences.
CT2: Ability to establish good interpersonal communication and to work in multidisciplinary and international teams.
CT3: Ability to organise and plan their work, making the right decisions based on the information available, gathering and interpreting relevant data in order to make judgements within their area of study.

OBJECTIVES

The field of Biomaterials has evolved over approximately the past fifty years from the intersection of multiple viewpoints, including materials science, biology, engineering, and clinical, business, and regulatory perspectives. In addition, the constant evolution of new processes and materials makes the field of Biomaterials very dynamic. In particular, there is an increased need of integrating more complex biological knowledge into the design of improved biomaterials.
Much consideration is given to the design of a biomaterial for a specific application. Certain properties of the biomaterial must be controlled in order to perform the necessary function and to elicit the appropriate response. These properties can be tailored to a specific need by carefully controlling the structural characteristics, modifying the surface properties, and employing biomimetic elements in the biomaterial design. Biomimetic principles are gaining widespread acceptance in the development of biomaterials, especially for drug delivery, regenerative medicine and nanotechnology.
After being introduced to the fundamentals of Biomaterials (Course: Introduction to Biomaterials, 3rd year), students will become familiar with the state of the art technology in biomaterial research in order to solve complex biomedical problems that arise not only at hospitals, but also at universities, research centers and companies.
The student will acquire advanced knowledge to design biomaterials for applications in bioengineering, biotechnology and nanomedicine. Furthermore, the student should acquire a critical ability for the possibilities of these technologies in the near future. Students will be required to acquire understanding and expertise from analysis of primary literature.

DESCRIPTION OF CONTENTS: PROGRAMME

This course is designed to instruct the students in the experimental design of biomaterials for specific applications, including:
Fundamentals of biomaterials science and its application in biomedical engineering design. Selection and functionalization of biomaterials. Biocompatibility of materials. Designing biomaterials to control the transport of drugs and genes. Nanomedicine. Regulatory issues.
Biomaterials are substances that have been designed to direct the course of any therapeutic or diagnostic procedure by controlling interactions with biological systems. A large toolbox of non-biological materials has been engineered to study cell behavior at the cell-material interface. In this course, we will examine how this interface can be leveraged to study cellular systems and generate novel therapeutics. A critical evaluation of the primary research literature will be used to frame discussions about the interactions between cells and biomaterials. In particular, we will discuss how cell behavior can be altered by controlling biochemical and biophysical cues of substrate materials, how new organs and tissues can be produced by the use of structured scaffolds that direct cells into organized forms, and how specific patterning of materials can enable biological processes to be studied and altered at the single-cell level. We will also consider the applications at patterned cell-material interfaces to build artificial systems, such as organs-on-a-chip, which can be used to perform preclinical tests for the activity and toxicity of drug candidates. Also, we will discuss the combination of non-biological materials with genetic material (DNA and RNA), which can be a robust approach to modifying

gene expression at the level of cells, tissues, or organs.
The course includes the following topics:
- Biomaterial selection for tissue engineering
- Nano and biomaterial design: microfabrication, modification and functionalization
- Biosensors
- Biocompatibility of biomaterials: cell-material crosstalk
- Atomic force microscopy for living cells
- Nanotechnology and Targeted drug/protein/gene delivery systems
- Biomaterials for cell, tissue and organ on a chip:lab-on-a-chip devices
-Stem cell niche generation:high thorughput technologies
-3D-Bioprinting technology
-Bioinspired materials for biomedical applications

LEARNING ACTIVITIES AND METHODOLOGY

The program will be divided into:

- Master classes: lectures focused on biomaterial experimental design and biomedical applications of biomaterials. Some lectures will be given by prestigious professionals in the field.

- Discussion classes (seminars): relevant scientific articles and problems will be presented and discussed by the students and the teaching team.

- Practical sessions in the laboratory: three weeks (15 hours/student). The laboratory sessions will give students a practical overview of biomaterials experimental design and they will need to apply the knowledge acquired during the course to perform the corresponding experiments.

ASSESSMENT SYSTEM

% end-of-term-examination:	35
% of continuous assessment (assigments, laboratory, practicals…):	65

Grading will be based on continuous evaluation and a final exam covering the whole subject, including invited lectures and seminars. Help sessions and tutorial classes will be held prior to the final exam upon students´ request.
Attendance to lectures and seminars is not compulsory. However, failure to attend any test will result in a mark of 0 in the corresponding continuous evaluation block (see below). The attendance to 80 % of practical sessions is mandatory.

GRADING:
Total score: 10 points
Continuous evaluation: 6.5 points out of 10
Final exam: 3.5 points out of 10

CONTINUOUS EVALUATION: It accounts for up to 65% of the final score of the subject (6.5 points of the TOTAL SCORE), and includes three components:
1) One test: 2.5 points of THE TOTAL SCORE. The test will be announced at least one week in advance and it will take place mostly during lectures. The topics of the continuous evaluation test will not be included in the final exam.
2) Practical sessions in the laboratory. 2 points of THE TOTAL SCORE. The final exam will include some questions regarding the laboratory sessions.
3) Presentation of a "lab-on-a-chip" project: 2 points of THE TOTAL SCORE

FINAL EXAM: it will account for the 35 % of the final score (3.5 points of the TOTAL SCORE). The minimum score in the final exam to pass the subject is 4 over 10, notwithstanding the mark obtained in continuous evaluation.

EXTRAORDINARY EXAM: there are two possibilities:
a) Examination of all the topics of the course (100% extraordinary exam mark)
b) The same criteria of the continuous evaluation (65% continuous evaluation, 35% final exam)

ACADEMIC CONDUCT: Unless specified, all exams will be closed-book, closed-notes, no PC or mobile phone, or anything else other than a writing implement and the exam itself. Plagiarism, cheating or other acts of academic dishonesty will not be tolerated. Any infractions whatever will result in a failing grade.

% end-of-term-examination: 35

% of continuous assessment (assigments, laboratory, practicals…): 65

BASIC BIBLIOGRAPHY

- Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen and Jack E. Lemons. Biomaterials Science: An Introduction to Materials in Medicine., Academic Press, 2012

- Chee Kai Chua, Wai Yee Yeong Bioprinting:Principles and Applications (Wspc Book Series in 3D Printing), World Scientific Publishing, 2015

- Jason A. Burdick and Robert L. Mauck. Biomaterials for Tissue Engineering Applications: A Review of the Past and Future Trends., Springer Verlag., 2011

- Johnna S. Temenoff and Antonios G. Mikos. Biomaterials: The Intersection of Biology and Materials Science., Prentice Hall, 2009