COURSE DESCRIPTION
BIOMATERIALS

SSD: BIOINGEGNERIA INDUSTRIALE (ING-IND/34)

DEGREE PROGRAMME: BIOINGEGNERIA INDUSTRIALE (P16)
ACADEMIC YEAR 2024/2025

COURSE DESCRIPTION

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GENERAL INFORMATION ABOUT THE COURSE

INTEGRATED COURSE: U1580 - BIOMATERIALS AND TISSUE ENGINEERING
MODULE: U1589 - BIOMATERIALS
TEACHING LANGUAGE: INGLESE
CHANNEL: FG A-Z
YEAR OF THE DEGREE PROGRAMME: II
PERIOD IN WHICH THE COURSE IS DELIVERED: SEMESTER I
CFU: 6

REQUIRED PRELIMINARY COURSES

There are no required preliminary courses.

PREREQUISITES

There are no required prerequisites.

LEARNING GOALS

This course aims at providing the student with the basic principles to understand the function of biological tissues, highlighting the relationship between their structure and their function in physiological conditions. Furthermore, pathological conditions and/or biological dysfunctions will be introduced as consequences and/or causes of alterations in the composition and structure of the tissues. Once these notions have been achieved, the student will acquire skills related to the design and manufacturing, at both molecular and structural levels, of material scaffolds capable of temporarily replacing the functions of damaged tissue and at the same time promoting the regrowth and regeneration of damaged tissues. In particular, topics concerning both the

mechanical and structural design of scaffolds and the principles for their bioactivation in the guidance and regulation of cellular functions will be covered during the course. Part of the course will deal with some of the technologies and chemical strategies to enhance the cell-material interaction and in particular the biocompatibility with cells, tissues and blood or to modulate some specific aspects of the chemical-physical properties of materials.

EXPECTED LEARNING OUTCOMES (DUBLIN DESCRIPTORS)

Knowledge and understanding

At the end of the course the student will have acquired advanced knowledge to: (i) describe the main components of a biological tissue and the relationship between its structural organization and its functions; (ii) define the most relevant chemical-physical characteristics in the choice of a biomaterial that has the purpose of carrying out a temporary mechanical support action and at the same time promoting and guiding the processes of tissue regeneration; (iii) define the most advanced processing and transformation technologies and (iv) biochemical and biophysical functionalization strategies aimed at controlling the mechanisms of interaction between biomaterials and organism and defining cellular functions and fate.

Applying knowledge and understanding

At the end of the course the student will be able to apply the knowledge acquired to the biomaterial design for specific applications in the biomedical and pharmaceutical fields, through the identification of the most adequate class of materials, transformation technologies and functionalization strategies.

COURSE CONTENT/SYLLABUS

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Part 1: What are biological tissues?

1. Classification of basic biological tissues.
2. Composition of biological tissues at cellular scale.
3. Composition of biological tissues at macromolecular scale: production and assembly of extracellular matrix (ECM).
4. Structure-function relationship of biological tissues:
   4.1. How molecular composition and structural organization control mechanical properties of biological tissues.
   4.2. The special case of tendons/ligaments and skin: hierarchical structure responsible for non-linear and viscoelastic behavior.
5. Mechanical models for biological tissues:
   5.1. Linear-elastic, hyperelastic (Neo-Hookean, Mooney-Rivlin, Ogden, Fung, Holzapfel-Gasser-Ogden) e viscoelastic (Maxwell, Kelvin-Voigt, Standard linear solid) materials.
   5.2. Application to special cases (skin and muscle).
   5.3. Multiphasic theory for biological tissues.
6. ECM role in Physiology and Pathology.

7. Measuring alteration in ECM structure and function during pathology.

Part 2: Cell-material-signal interaction –how to confer structural/morphological and functional features to scaffolds

1. Biomaterials and scaffolds: definitions.
2. Scaffold requirements: biodegradability, biocompatibility, cell guidance and structural support.
3. Classification of polymeric biomaterials (natural and synthetic) for scaffolds.
4. The special case of polyesters (biodegradation: hydrolytic process and autocatalysis; biocompatibility; thermal properties of polysters: amorphous and semy-cristalline polymerns; relationship between crystallinity grade and biodegradation; mechanical properties of polyesters; cell adhesion as consequence of protein absorptions: how surface energy, charge and topography affect protein absorption).
5. Scaffold design: the importance of porosity to define the mechanical properties and the biodegradation of the scaffolds.
6. Scaffold fabrication techniques (Solvent casting/Particulate leaching, Phase separation, Miscrosphere sintering, Electrospinning, Solid free form fabrication techniques: fused deposition modelling, inverse 3D printing, 3D printing and laser sintering, stereolitography, bioplotting).
7. Decellularized matrix: methods and techniques of decellularization and applications (bone regeneration, articular cartilage regeneration, tendon regeneration, etc.).
8. Modifications of chemical and physical properties of material surfaces and interfaces to control biomaterial-tissue interaction:
 8.1. Matricellular signals: role of peptides/proteins in regulating cell adhesion and behavior (RGD, fibronectin, collagen I, etc.); micro-nano topographic features to control cell functions and fate.
 8.2. Mechanical signals: mechanical forces/biomaterial mechanical properties.
 8.3. Soluble signals: growth factors/chemokines/cytokines.
 8.4. Biomolecular gradients.
 8.5. How the chemical-physical signals influence the cell cytoskeleton mechanics and the cell health; experimental techniques and mechanical models for cell mechanics.
9. Regulation of cellular functions: migration and cellular differentiation, wound repair.

READINGS/BIBLIOGRAPHY

Ratner “Biomaterials Science An Introduction to Materials in Medicine”
Williams “Essential Biomaterials Science”
Presentation and notes

TEACHING METHODS OF THE COURSE (OR MODULE)

Lectures

EXAMINATION/EVALUATION CRITERIA

a) Exam type

☐ Written

☑ Oral

- [x] Project discussion
- [ ] Other

In case of a written exam, questions refer to

- [ ] Multiple choice answers
- [ ] Open answers
- [ ] Numerical exercises

b) Evaluation pattern