HUMANITAS UNIVERSITY

MEDTEC SHOOL

Course: Biocompatibility and Biomaterials

Year (1st-2nd-3rd-4th-5th-6th): 3rd year

Period (1st-2nd semester – annual): 1st semester

Credits: 5

Objectives

The course aims to provide the student with the basic knowledge of materials science and technology, in particular exploring the three main material classes: metals, polymers, and ceramics. In addition, the student will be given skills regarding materials that are used in the biomedical field, highlighting the problems, the advantages, and the main applications. The possible mechanisms of degradation of polymeric and metallic materials will be illustrated to better understand how they can influence the response of the biological environment in the presence of a biomaterial.

The course includes an analysis of the interaction mechanisms that are established between a biomaterial/device with living biological tissues. The course aims to provide the student with basic knowledge of the biological and chemical interaction established at the biomedical device-host organism interface, or of the effects of the host on the implant and vice versa. These interactions, which vary according to the biomaterials used and the anatomical implant site, are based on pathophysiological response mechanisms of the tissues such as inflammation reaction, blood coagulation, and immune response.

The topic of regenerative medicine, with a particular focus on tissue engineering, will also be explored with the aim of providing students with knowledge of the most used biomaterials, the engineering tools that can be considered to design a cell culture system under dynamic conditions. The general design specifications of scaffolds and bioreactors will be identified and aimed at specific biological applications (e.g., bone tissue, muscle tissue, vascular tissue). During the course, examples of scaffolds and bioreactors will be brought into the classroom in order to illustrate more properly all design aspects of the systems.

After passing the examination, the student:

- will be able to define the main properties of the materials used to make biomedical devices;
- will know and be able to explain the fundamental mechanisms of degradation of polymeric and metallic materials;
- will be able to evaluate the possible applications of biomaterials in the biomedical field;
- will be able to apply the knowledge to many biomedical problems;
- will have learned and will know how to conduct the assessment of the biocompatibility of materials and devices;
- will have learned and will be able to explain how to conduct the assessment of the biocompatibility of materials and devices;

- will know and will be able to explain the fundamental concepts and mechanisms of the inflammatory response;
- will know and will be able to explain the fundamental concepts and mechanisms of blood coagulation;
- will know and will be able to explain the fundamental concepts and mechanisms of the immune response;
- will have a critical knowledge of the fundamental concepts of biological tissue engineering, related to the sterility of the process, to the scaffold and to the cellular component;
- will be able to formulate and solve engineering problems related to the design of 2D and 3D scaffolds and dynamic culture devices;
- will possess methods and tools to address the design of scaffolds and bioreactors for regenerative medicine;
- will learn, through innovative teaching actions, transversal skills, and soft skills.

Prerequisites

Basic concepts in Chemistry, Physics, and Biology are required.

Contents

- Polymeric materials: structure, obtainment (natural, synthetic), thermal transitions, and general properties.
- Ceramic materials: structure and properties.
- Metal materials and alloys: structure and properties.
- Composite materials: main properties.
- Mechanical properties of materials, evaluation methods, and parameters obtainable.
- Processing technologies of the various classes of materials, with particular reference to biomedical applications.
- Sterilization methods and related problems.
- Degradation of polymeric and metallic materials with particular reference to the human body environment.
- Main types of biomaterials and their use in the preparation of devices and prostheses.
- Cells and tissues: organization and function. Composition, structure and functions of the extracellular matrix, functions of the main cell types involved in defence and repair mechanisms.
- Defence mechanisms and reparative phenomena of the human body: repair and remodelling of biological tissues, blood coagulation, immune reaction, inflammatory reaction, the complement system.

- Biocompatibility and biomaterial-human body interaction: effects of the implant on the human body, effects of host tissues on the implanted device, bacterial adhesion, and calcification.
- Main analytical techniques for the evaluation of biomaterials in vitro and for diagnostic purposes.
- Approach to regenerative medicine and tissue engineering. The scaffold: requirements, biomaterials, and main preparation methods. Static and dynamic cell culture systems.

Teaching Methods

The course is organized in frontal lessons, interactive activities, journal club and visit to research labs at Politecnico di Milano.

The exercises will focus on deepening the topics covered in class. During the exercises, students will also be asked to answer questions concerning specific topics of the course. These activities will be carried out using innovative teaching tools.

The project activities provide, through the active involvement of students organized in groups, the achievement of an assigned goal. These activities will be carried out using innovative teaching tools.

The activities carried out during the course will contribute to the overall evaluation of the student.

Verification of learning

The exam consists of a written test on the entire teaching program, in which the student is asked to answer closed or multiple-choice questions on fundamental concepts covered during the course, using the appropriate formalism and terminology.

During the final exam, the student must demonstrate to:

- Have acquired concepts regarding the classification and main applications of biomaterials;
- Have acquired concepts concerning processing technologies and the specific properties of materials belonging to the three main classes of materials;
- Know how to discuss the possible applications of biomaterials in the biomedical field;
- Know the functions, mechanisms, and components of haemostasis, the inflammatory response, and immunity;
- Know the biological mechanisms (protein and cellular) that govern the response of tissues to the implantation of a biomaterial;
- Apply methods and tools typical of chemical bioengineering to evaluate biocompatibility;
- Know how to manage resources and times for completing the assigned task.

In evaluating the exam, the determination of the final grade takes into account the following elements:

- problem analysis skills;
- formal and substantial correctness of the procedures identified for solving problems;
- correctness of the results obtained;
- knowledge and understanding of the topics;

- adequacy of the technical-scientific language used;
- autonomy of judgment.

Texts

- Ratner B, Hoffman A, Schoen F, Lemons J. Biomaterials Science. An Introduction to Materials in Medicine, Academic Press, 2012.
- Tanzi MC, Farè S. Characterization of Polymeric Biomaterials, Woodhead Publishing, 2017.
- Tanzi MC, Farè S, Candiani G, Foundations of Biomaterials Engineering, Academic Press, 2019.