UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Chemistry for Biomedical Nanotechnologies

2425-2-F5401Q073

Aims

The student will have to acquire the chemical foundations (theoretical, conceptual and methodological) on the synthesis, characterization and biomedical applications of advanced biomaterials on the nanometric scale. The course includes a part aimed at the development of nanoparticles for diagnostic and therapeutic applications, and a part dedicated to the development of nanostructured biomaterials for regenerative and prosthetic medicine. Chemical strategies for the development of bio-inks for 3D printing of biological tissues will be described.
The different chemical approaches to synthesize nanomaterials through the use of synthetic, natural and hybrid polymers will be covered
At the end of the course, the student will be able to:

- Master the characteristics of synthetic and natural nanostructured materials useful for biomedical applications.
- Detect the different performances of biomaterials based on their chemical, structural and biological properties.
- Evaluate the applicability of various types of polymers for different biomedical purposes; choose the appropriate synthetic methodologies useful for the development of nanosystems (nanoparticles or biomaterials) for diagnostic and/or therapeutic purposes.
- Evaluate the use of innovative technologies (e.g. Artificial Intelligence) in the predictive and automatic synthesis of innovative biomaterials and in their characterization.

Contents

The course will focus on chemical methodologies for the development of nanostructured materials for biomedical applications. In particular, chemical approaches to synthesize nanomaterials using synthetic, natural and hybrid polymers will be presented. A particular focus will be dedicated to the translational potential of bio- and nano-materials in the development of nanostructured diagnostic and therapeutic tools, implantable medical devices and systems based on 3D printed and 3D bioprintable materials.

At the end of the course the student is able to:

- Determine the characteristics of synthetic and natural nanostructural materials for biomedical applications.
- Detect the different performances of biomaterials based on their chemical, structural and biological properties.
- Evaluate the applicability of various types of polymers for different biomedical purposes; choose the appropriate synthetic methodologies useful for the development of nanosystems (nanoparticles or biomaterials) for diagnostic and/or therapeutic purposes.
- Identify the most suitable formulation methodologies based on the target biological system, the pathologies of interest and the use of the "medical device" / nanoformulation (including 3D printing and bioprinting)
- Identify applications, useful data and applicability of predictive synthesis and robotic systems (AI, ML, DL) in the field of bio and nanomaterials.

Detailed program

The course will provide an extensive overview relating to biomaterials and nanomaterials for biomedical applications. Devices currently used in clinical practice for diagnostic and therapeutic applications will also be considered. The applications of conjugation, synthesis and characterization of the main materials and the use of innovative systems based on Artificial Intelligence aimed at predictive synthesis, collaborative robotics-assisted synthesis and machine learning-based characterization strategies. In detail the following will be highlighted:

- methods for preparing nanoparticles, nanostructures, nanofilms, nanopolymers, biopolymers, etc.;
- methods for characterizing nanosized systems, both spectroscopically and with microscopies;
- nanoparticles for therapeutic and diagnostic use and the biological problems to be addressed: the fundamental principles of the immune system, biological barriers and corona proteins, reference organs and tissues.
- strategies for the controlled release of drugs, such as directing nanoparticles to specific tissues and cells. Molecular recognition.
- methods of functionalization of nanomaterials with drugs, diagnostics and molecules responsible for molecular recognition. Chemoselective conjugation methods.
- the main applications of nanoparticles for biomedical use.
- the applications of nanostructured biomaterials capable of mimicking tissues and organs.
- The implantation and application sites of permanent (non-biodegradable) and non-permanent (biodegradable) medical devices
- methods for preparing nanostructured materials in the prosthetic sector and in regenerative medicine
- methods to characterize the chemical-physical properties of advanced materials for tissue engineering applications.
- the design and methods for synthesizing natural, synthetic and hybrid materials
- chemoselective functionalization methods to obtain tissue- and organ-specific bio-responsive materials
- crosslinking methods for the covalent stabilization of 3D structures
- methods and strategies for the bioactivation of polymeric materials with advanced biological properties.
- development and synthesis strategies of materials in the form of injectable hydrogels, scaffolds, bulks and implantable networks.
- formulation strategies and methodologies using solvent casting, freeze dry, molding and layer-by-layer etc.…
- new formulation methodologies and associated chemical strategies: 3D printing and bioprinting, characteristics and classification of printable polymers
- 3D printing and bioprinting: synthetic and characterization methodologies for the development of printable and bioprintable polymers.
- 3D printing and bioprinting: design of 3D prosthetic and tissue models
- Artificial intelligence-based methods and platforms used in the prediction, synthesis and formulation of bio- and nanomaterials for biomedical applications.

Prerequisites

Organic Chemistry I

Teaching form

44 h two-hour lectures, in person, Delivered Didactics

20 h Seminars
2 seminars/hour for 2 h modules, Seminars

Textbook and teaching resource

Recording of lessons
Slides (PPT)
Video
Scientific Articles (Reviews and Original Articles)

Semester

I Semester

Assessment method

The exam can be taken at the student's choice in Italian or English and consists of a test defined below:

The test consists of an oral presentation on the topics covered by the course, with critical analysis and personal research contribution.

Individual oral presentations are the subject of open discussion, with questions and cross-examination by those present, and allow us to verify the level of knowledge acquired, the autonomy of analysis and judgement, the student's presentation skills, the ability to identify particularly promising advances in a given nanotechnology sector. The final grade is expressed in thirtieths with possible honors.

Office hours

Any working day by appointment and availability of the teacher.

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING