UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Chemistry for Biomedical Nanotechnologies

2627-2-F5402Q025

Aims

Students will acquire the chemical fundamentals (theoretical, conceptual, and methodological) for the synthesis, characterization, and biomedical applications of advanced nanoscale biomaterials. The course includes a section focused on the development of nanoparticles for diagnostic and therapeutic applications, and a section dedicated to the development of nanostructured biomaterials for regenerative and prosthetic medicine. Chemical strategies for the development of innovative materials for use in theranostics and sensors, bio-inks for 3D printing of biological tissues, and devices for the treatment of medical and biological problems will be described. Different chemical approaches for synthesizing and characterizing nanomaterials using synthetic, natural, and hybrid polymers will be covered.

At the end of the course, in line with the Dublin descriptors, students will acquire:

- Knowledge and understanding: evaluate the characteristics of synthetic and natural nanostructured materials useful for biomedical applications.
- Ability to apply knowledge: select appropriate synthetic, formulation, and manufacturing methodologies for the development of nanosystems (nanoparticles or biomaterials) for diagnostic and/or therapeutic purposes.
- Making independent judgments: evaluate the applicability of various polymers and materials for different biomedical purposes. Determine the different performances of biomaterials based on their chemical, structural, and biological properties. Evaluate the use of innovative technologies (e.g., Artificial Intelligence / Machine Learning / Deep Learning) in the predictive and automatic synthesis of innovative biomaterials and their characterization. Evaluate their applicative relevance for the rational design of bio- and nanomaterials.
- Communication skills: ability to orally present and critically analyze an original scientific article, actively participating in cross-examination and open discussion on nanotechnology topics.
- Learning skills: develop analytical autonomy that allows for identifying particularly promising advances in the nanotechnology sector and staying up-to-date on new platforms (e.g., Artificial Intelligence) used in the field.

Contents

The course will cover the chemical methodologies for the development of nanostructured materials for biomedical applications. In particular, chemical approaches to synthesize nanomaterials that employ 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 nanostructured materials for biomedical applications.
- Detect the different performances of biomaterials based on chemical, structural and biological properties.
- Evaluate the applicability of polymers of various nature 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 the applications, useful data and applicability of predictive synthesis systems and robotic automation (AI, ML, DL) in the field of bio and nanomaterials.

Detailed program

The application of conjugation, synthesis and characterization of materials/biomaterials and the use of innovative systems based on Artificial Intelligence for predictive synthesis, synthesis assisted by collaborative robotics and characterization strategies based on artificial intelligence / machine learning/deep learning. In detail, the following objectives will be highlighted:
Specifically, the following will be highlighted:

- methods for preparing nanoparticles, nanostructures, nanofilms, nanopolymers, biopolymers, etc.;
- methods for characterizing nanoscale systems, using both spectroscopic and microscopic techniques;
- nanoparticles for therapeutic and diagnostic use, and the associated biological challenges—specifically, fundamental principles of the immune system, biological barriers, the protein corona, and relevant organs and tissues;
- strategies for controlled drug delivery, including methods for targeting nanoparticles to specific tissues and cells;
- molecular recognition; methods for functionalizing nanomaterials with drugs, diagnostic agents, and molecules designed for molecular recognition; and chemoselective conjugation methods;
- key biomedical applications of nanoparticles;
- applications of nanostructured biomaterials capable of mimicking tissues and organs;
- implantation and application sites for permanent (non-biodegradable) and non-permanent (biodegradable) medical devices, and methods for preparing nanostructured materials for prosthetics and regenerative medicine;
- methods for characterizing the physicochemical properties of advanced materials for tissue engineering applications;
- design and synthesis methods for natural, synthetic, and hybrid materials; chemoselective functionalization methods to obtain tissue- and organ-specific, bio-responsive materials; cross-linking methods for the covalent stabilization of 3D structures; and methods and strategies for bioactivating polymeric materials to impart advanced biological properties;
- development and synthesis strategies for materials in the form of injectable hydrogels, scaffolds, bulk materials, and implantable networks.
- formulation strategies and methodologies (such as solvent casting, freeze-drying, molding, and layer-by-layer assembly) will be covered;
- new formulation methodologies and associated chemical strategies will also be described: 3D printing and

bioprinting, including the characteristics and classification of printable polymers; synthetic and characterization methods for developing printable and bioprintable polymers; and the design of 3D models for prosthetics and tissue engineering;
- new methods and artificial intelligence-based platforms used for the automated prediction, synthesis, and formulation of biomaterials and nanomaterials for biomedical applications.

Prerequisites

Organic Chemistry I

Teaching form

A total of 48 hours, delivered entirely in-person (LEL). The activities are divided as follows:
Expository Teaching (DE): 44 hours held in-person (LEL), structured into 22 frontal lectures of 2 hours each.
Interactive Teaching (DI): 4 hours held in-person (LEL), structured into 2 interactive seminars/modules of 2 hours each, aimed at actively engaging the students.

Textbook and teaching resource

Slides (PPT). Videos and Scientific Articles (Reviews and Original Articles). Software for planning and design, biomaterial synthesis prediction, databanks

Semester

I semester

Assessment method

Students may choose to take the exam in either Italian or English; it consists of: a) a PowerPoint presentation on a specific article selected from topics proposed by the instructor; and b) questions regarding the course syllabus.
The presentation component is defined as follows:

- The assessment consists of an oral presentation supported by PowerPoint slides covering topics addressed during the course, incorporating critical analysis and personal research input. The instructor will propose several open-ended themes.
- Individual oral presentations will focus on an original scientific article selected by the student and will be followed by an open discussion (including questions and critical exchange with the audience) to evaluate the student's acquired knowledge, independent analytical and evaluative skills, presentation abilities, and capacity to identify particularly promising advancements within a specific nanotechnology sector.
- Following the presentation, questions regarding topics covered during the course will be asked.

The final grade, based on the presentation and competencies acquired during the course, is awarded on a scale of 30, with the possibility of distinction (*cum laude*).

Office hours

appointment

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING