UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Nanobiotechnologies

2425-1-F0802Q050

Aims

The term nanobiotechnology refers to the bio-industrial and medical applications of highly structured materials on a nanometric scale, taking advantage of innovative technologies capable of allowing a high control over the chemical-physical properties of materials at the atomic level or of molecular assemblies. Nanobiotechnology is a rapidly evolving young research field, at the crossroads of biotechnology and nanoscience, two very interdisciplinary areas, each of which combines innovative aspects at both the scientific and engineering levels. Molecular architectures with at least one dimension in the range between 1 and 100 nm have tremendous application in biomedicine thanks to the combination of chemical and physical properties dependent on the small size, which do not manifest at the molecular or “bulk” level, and effective interactions with molecular and biological systems. These properties have a particularly interesting potential in the study of tumor. In this context, the synthesis of high-quality organic/inorganic hybrid nanoparticles, endowed with peculiar optical and magnetic properties, is emerging as a new and promising new frontier that is generating a new discipline, the so-called "nano-oncology", whose aim is the creation of therapeutic and diagnostic agents that can be used both as biosensors and for preclinical and clinical research. For this reason, multifunctional nanoparticles have been designed as markers for in vivo tumor imaging and as active drug delivery systems. In the drug delivery area, also polymeric and lipidic nanoparticles are widely used and recent efforts are devoted in the development novel nanocarriers that closely mimics the biological systems. Besides the oncology, the nanotechnology find application in other pathologies (e.g. inflammatory, degenerative and other chronic diseases) as well as in the development of alternative strategies for vaccination.

Knowledge and understanding
At the end of the course, the student will have appropriated the fundamental knowledge for facing the modern problems related to the use of nanotechnology in order to face the new challenges in the industrial field of biomaterials and potential fallouts in the health system.

Applying knowledge and understanding
At the end of the course, the student should be able to apply the knowledge acquired in the field of nanobiotechnology, with particular emphasis on potential outcome in biomedicine.

Making judgments

The student should be able to process what he/she has learned and be able to recognize the situations and problems in which nanotechnology learned can be used for facing and solving the current problems related to human health.

Communication skills
At the end of the course the student will be able to express himself appropriately in the description of the topics addressed with language properties and exposure safety.

Learning skills
At the end of the course the student will be able to read the literature and will be able to analyze, apply, integrate and connect the knowledge acquired with what will be learned in lessons related to the use of new technologies in biotechnology-pharmacology.

Contents

The fundamental items of the course will focus on the following topics:

1. Introduction to nanotechnology: brief history of nanotechnology, basic definitions and basic tools.
2. synthesis and functionalization of colloidal nanoparticles;
3. Interactions among nanoparticles and biological systems;
4. multifunctional nanoparticles for biomedical application;
5. biologic and biomimetic nanoparticles;
6. drug delivery systems based on nanoparticles;
7. methods for biological investigation at the nanoscale.

Detailed program

1. Introduction to Nanotechnology
   Considered by many people as the "key technology" of the 21st century, nanobiotechnology is still in a phase of rapidly expanding embryonic development and, therefore, it is still not easy to univocally identify the field of action and focus the aims of this new discipline. Currently, we tend to indicate with this term the use of biological systems optimized through evolution, including cells, cellular components, proteins and nucleic acids, in order to realize nanostructured functional architectures by combining organic and inorganic materials with high morpho-structural control. Furthermore, nanobiotechnology concerns the optimization of the use of advanced technologies, originally designed to generate and manipulate nanostructured materials, for speculative studies or applications concerning fundamental biological processes.
   Some products deriving from nanotechnology applied to biomedicine are already available on the market such as, for example, some contrast agents for magnetic resonance imaging, vectors for anticancer drugs and the first diagnostic devices based on microarray conjugated with nanostructured detectors. Numerous nanotechnological approaches have been employed to improve the transport of chemotherapeutic agents to tumor cells with the aim of minimizing the toxic effects on healthy tissues while maintaining antitumor efficacy. One of these transport systems, the PEGylated liposomal doxorubicin, has shown a better tumor location of the drug by reducing the cardiotoxic side effects, and has therefore been approved in the treatment of refractory ovarian cancer and Kaposi’s sarcoma in the United States. Paclitaxel bound to albumin nanoparticles shows greater efficacy than traditional injections of Paclitaxel with emulsifying additives ensuring a superior safety profile that has allowed approval in the United States for the treatment of metastatic breast cancer. In addition, there are several other products in development/already available on the market: diagnostics based on lab-on-chip technology, advanced systems for drug delivery (e.g., the recent nanotechnology approved for mRNA delivery in SARS-CoV-2 vaccination), more resistant medical

prostheses with improved biocompatibility, and nanosystems for tissue regeneration are expected.
On a wider perspective, the global spending on nanotechnology is constantly growing and the budget estimated for 2023, including the energy, optoelectronic, textile and telecommunications areas, is close to 15 billion dollars. There are already more than 15,000 companies active in the sector in the world and there are already several thousands products on the market in various sectors.

2. Synthesis and functionalization of colloidal nanoparticles
   The methodologies in use for the preparation, characterization and functionalization of nanoparticles with molecules of biological interest will be presented. Classical approaches and innovative techniques will be presented to obtain a morphological-dimensional control and of the fundamental parameters for a correct arrangement of the molecular ligands.

3. Interactions between nanoparticles and biological systems
   Interactions of colloidal nanoparticles with proteins, cells and the circulatory system and interaction with biological barriers in higher organisms will be presented. In addition, the basic concepts of nanotoxicology will be introduced.

4. Multifunctional nanoparticles for biomedical applications
   Various examples of the application of hybrid colloidal, polymeric and lipidic nanoparticles to complex problems in the field of health will be shown, particularly in oncology.

5. Biologic and biomimetic nanoparticles
   Various examples of applications of recombinant protein nanocages (i.e., ferritin and virus-like particles), cell membrane-derived nanoparticles and extracellular vesicles will be presented.

6. Drug delivery systems based on nanoparticles
   Problems related to the use of nanoparticles for the delivery of small molecules and biological drugs as well as approaches for controlled drug release will be addressed. An in-depth lesion will be dedicated to the use of nanotechnology for nucleic acid delivery with a focus on the lipid nanoparticles technology recently approved for mRNA delivery.

7. Biological investigation techniques on the nanoscale
   The main technologies used for the characterization of nanotechnological systems and the fundamental theoretical aspects underlying them will be presented.

Prerequisites

Background. The strongly interdisciplinary approach requires basic knowledge of chemistry, biochemistry, molecular and cellular biology as well as the fundamentals of physics.
Prerequisites. None

Teaching form

42 h, 21 lessons, 2 h each: a section of delivered didactics (Didattica erogativa, DE) focused on the presentation-illustration of contents by the lecturer; a section of interactive teaching (Didattica Interattiva, DI) including teaching interventions supplementary to delivered didactic activities and discussion of case studies.

Didactic activities are conveyed by means of face-to-face lectures

Teaching language: Italian

Textbook and teaching resource

Bibliography provided by the lecturer

Semester

Second semester

Assessment method

Written test. The examination consists in 15 questions, including some of them as True or False and other ones as open discussion. Optionally, a discussion about the course content.

Office hours

Contact: on demand upon email request to the lecturer.

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING